A BIOANTHROPOLOGICAL PERSPECTIVE ON THE PUNIC PERIOD IN IBIZA (SPAIN) AS EVIDENCED BY HUMAN SKELETAL REMAINS

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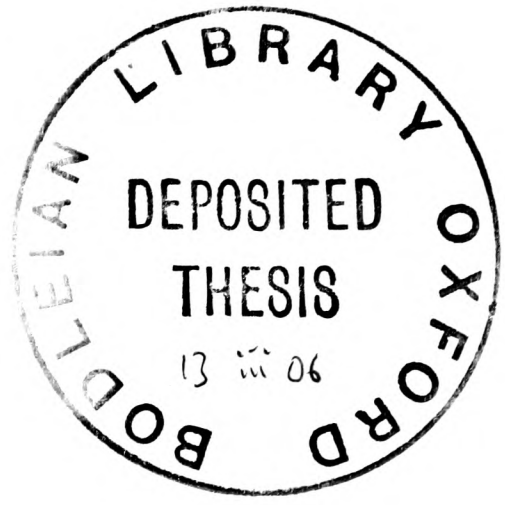

I dedicate this work to all my family, British and Spanish.
Thank you for all your immense help.

ABSTRACT

The Punic period (6th – 2nd century BC) in the island of Ibiza (Spain) has been regarded by historians and archaeologists as a time of flourishing economic wealth and prosperity, as evidenced by its coin production, demographic growth, agricultural exploitation, intensive product manufacturing and its overall importance to Punic trading routes.

From a bioanthropological perspective, this apparent prosperity raises a number of interesting questions. Did such prosperity manifest itself in the biological well-being of the population? What were the morbidity rates like for the inhabitants of Ibiza? Were there differences between urban and rural populations? How might this period compare with a less prosperous era?

These questions led to the following hypothesis being established -

General prosperity in the Punic period in Ibiza should be reflected in the general well-being of the population, as evidenced by human skeletal remains.

To test this hypothesis, morbidity rates in the general population in the Punic period were assessed including an analysis of rural and urban populations. In addition the Punic period was compared to the Late Antiquity – Early Byzantine (4th – 7th century AD) period.

To assess these issues, anthropological data on stature, oral health, infections, trauma, mortality, osteoarthritis and diet was analysed, amongst other indicators. Allied to this, the research attempted to place the analysis in a broader biocultural context.

Whether the above questions could be definitively answered depended on the sample size of material available. A larger sample would certainly have allowed these issues to be explored in even more depth than was possible in this study. Nevertheless, the samples studied have produced a range of interesting results that will aid future research.

This research provides a wider understanding of the Punic period in Ibiza and of the Punic world in the Western Mediterranean; highlights the importance of combining anthropological work with other archaeological data; contributes to the osteological and palaeopathological record for Ibiza; and finally, provides a framework for further research.

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variety of professions and they all had different personalities. I now thank them for having been my teachers.



Facial reconstruction of a Punic male skull (PM01/UE59) –left- and of a Late Antiquity-Early Byzantine female skull (HLL819) –below-. Artist: Simon Lygo.



I have learnt a great deal from your bones and if I could pay you back in any way, let me do so by transmitting your memory to your descendants, the present day people of Ibiza, by telling them something about their past, about how you lived.

1 CHAPTER ONE – INTRODUCTION AND BACKGROUND

'The study of human remains from archaeological sites facilitates the interpretation of lifetime events such as disease, physiological stress, injury and violent death, physical activities, tooth use and diet, and the demographic history of once living populations.'

C. S. Larsen (1997:1)

1.1 Introduction

This thesis is based on the study of human remains from the island of Ibiza with particular reference to the Punic period (6th – 2nd century BC). Using material from various necropoli in the island, an extensive analysis was undertaken of a wide variety of human skeletal remains. This provided the key material to test out the overall hypothesis of the research.

Although the focus of this thesis is primarily based on the human skeletal remains studied, it is important to place the study in a broader context. Accordingly, within this introduction background information is provided on Ibiza including its etymology, geography and history. In addition, details of relevant anthropological work carried out on the island are provided. Comments and considerations on evaluating morbidity in general are also included, as is an examination of some of the issues associated with a biocultural approach. Particular emphasis is placed on the historical background as the movement of peoples, colonisation, shifting trade patterns and the establishment of settlements have had an influence on the skeletal remains studied.

Beyond the introduction lie the main analysis and findings of the research. Chapter 2 contains detailed information on the materials and samples used. The following chapters present the findings in relation to the key areas studied. The conclusion presents a summary of key findings with associated discussion points and suggestions for further research.

The terms 'bioanthropology' and 'biocultural' cover the main themes of this thesis. For the purposes of the current research these terms are taken to assume the following:

- bioanthropology: covers a wide spectrum of research including in human populations past and present, the effect of the environment on growth, human evolution and human adaptation. Some of these themes can be explored via fossil hominids, dermatoglyphics, genetics and human skeletal remains. It is here that a bioanthropological perspective can help in providing a picture of the health, diseases and lifestyles of the people in a given period.

- biocultural: takes into account information from a number of disciplines (e.g. climatology, zooarchaeology) and from a number of sources (e.g. documentary, faunal remains, pollen analysis, artefacts). The kind of information studied can vary from one period to another depending on available evidence.

1.2 Overall hypothesis and research objectives

From the archaeological evidence, the following hypothesis was established:

General prosperity in the Punic period in Ibiza should be reflected in the general well-being of the population, as evidenced by the human skeletal remains.

In order to test the hypothesis this study has two main objectives. Firstly, to undertake an evaluation of morbidity rates in the general population, including an analysis of the differences between populations from rural and urban settlement areas. Secondly, morbidity rates in the Punic period will be compared to the Late Antiquity – Early Byzantine period (4th – 7th century AD)[1]. In parts of this thesis, the Punic period will be referred to as Period 1 and the Late Antiquity – Early Byzantine will be referred to as Period 2.

In order to achieve these objectives, a number of different methods were employed, as outlined in the following chapters. Primarily, research was undertaken using human skeletal remains from a variety of sites on the island of Ibiza.

Compared to mainland studies, research on islands has its advantages (Evans, 1973). The reduced biodiversity and perhaps reduced resources provide a 'controlled' environment in which human biocultural adaptation may be better understood

[1] By convention, archaeologists regard the Byzantine period in Ibiza as lasting only until the seventh century, after which the Muslim influence starts to replace the Byzantine era.

(Pietrusewski *et al.*, 1997; Rodríguez and González, 2003). Furthermore, islands are open to cultural stimuli and the limited range of locally available resources means that the inhabitants may need resources from outside. By importing either raw materials or finished products, or by exporting certain materials not available elsewhere, evidence for trading networks may be identified (Evans, 1973: 518-519). In addition, the relative isolation of some islands may provide an appropriate environment in which to study investment in some cultural aspect, for instance ceremonial, ritual or religious complexes (Evans, 1973: 519). Finally, a small island study may mean that '*a higher degree of confidence may be arrived at than would be possible using mainland evidence, which is generally more open ended'* (Evans, 1973: 520).

Whether the questions raised by this study could be definitively answered depended on the sample size of the skeletal material available for study. Although larger samples would have been more desirable, nevertheless the material available for study was sufficient to show a degree of patterning which allowed some preliminary answers. Furthermore, the analysis itself will help to promote awareness amongst excavators of the enormous potential of skeletal material and the value of detailed recording, which is helpful to anthropological analysis. Future excavations will undoubtedly produce much more material in the coming years, and it is essential that the right questions are asked and an appropriate research protocol is established. If for no other reason, the systematic analysis of what is available today is a worthwhile contribution to the resolution of issues addressed in this thesis.

1.3 Rationale behind the hypothesis

In order to explain the rationale behind the hypothesis, it is worth reviewing in more detail the general picture for the Punic and Late Antiquity – Early Byzantine periods in Ibiza as inferred from the various archaeological and historical sources available. It is also necessary to tackle the question of Punic rural – Punic urban contexts and evaluate the different skeletal indicators that have been used in past studies in order to reconstruct health in the past.

1.3.1 Comparison: Punic and Late Antiquity – Early Byzantine period

This section reviews the basis for the hypothesis of general well-being in the Punic period in view of the archaeological and historical data. While the interplay between environment, biology and culture is complex and must be considered, these are dealt with in later sections. However, two major concerns need to be highlighted before proceeding. Firstly, with regard to the periods studied, there is more archaeological knowledge available on the Punic period than on the Late Antiquity – Early Byzantine periods. Most of the archaeology in Ibiza has focused on the Phoenician and Punic periods, while the evidence for the later period is scarcer. Secondly much of the information gathered below on the Late Antiquity–Early Byzantine periods does not come directly from Ibiza. Extrapolation had to be made from other Mediterranean regions. Additionally, with regard to this later period, reconstructing economic history has been problematic. Although there is a lot of

Byzantine documentary material available, most is only monastic in nature and does not cover all regions (Mango, 1980: 6-7).

1.3.2 The Punic period

The Punic colonisation of Ibiza between 530 BC and 425 BC brought several changes to the island (e.g. see Costa and Fernández, 1995). These included demographic growth, agricultural exploitation, manufacture and export of goods, intense pottery production, coin minting, the creation of sanctuaries, the introduction of a new type of tomb, the hypogeum, with new associated grave-goods and the practice of inhumation, (Kaufman, 2000).

Almagro (1967: 8) has commented that Punic Ibiza enjoyed prosperity in all aspects[2]. Under Carthage's influence, the town *Eivissa* was an important urban centre (Tarradell and Font, 1975: 77). The island experienced a period of economic development that was to increase constantly until the Roman period. An active exportation of local amphorae and their contents was present since 500 BC and increased at a large scale until 150 BC (after Ramon, 1981: 35-36). There is evidence for a number of pottery workshops outside the city walls and dated especially to the fourth and third centuries BC (Ramon, 1995: 66, 69-70; Ramon, 1990-1991, 1998). A peak in commercial activity in the third century BC saw an intensification of the trade in the western Mediterranean associated with agricultural products (wine, olives, oil,

[2] *"...pues la Antigua Ebusus púnica gozó de una prosperidad e independencia grandes en todos los aspectos de su vida, tanto material como artística y cultural."* (Almagro, 1967:8).

figs, vegetables, cereals) and stockbreeding (wool) in the rural areas (Gómez, 1986: 187-188, 191; Gómez, 1995b; Ramon, 1995a). At this time, commercial links were intensified and the Ibizan Punic coin achieved its maximum expansion in the Mediterranean (Costa and Fernández, 2000). Ibiza's material culture even reached the Atlantic coasts of the Iberian Peninsula (see González, 2004). Moreover, Ibizan amphorae were imitated in north eastern Spain from the fourth century BC (see López and Fierro, 1994; Asensio, 2000). Ibizan merchants also set establishments elsewhere, such as *s'Illot de na Guardis* in Majorca, which would have provided control and exploitation of the salt resources, especially important for the fish industry (Guerrero, 1997: 249-250).

During the second half of the second century BC, however, there seems to have been an economic crisis resulting in the abandonment of some establishments, decreased pottery production, the interruption of the local mint, and a general decadence in the level of life of the Ibizan Punic population (Costa and Fernández, 2000). This decline also took part in cities in the south of Spain but apparently only lasted for a short while before a slight recovery at the end of the second century BC (Costa and Fernández, 2000).

In summary, the economic data indicate that the period was a time of wealth and economic prosperity. What effect these economic developments had on the well-being of the inhabitants has been the fundamental basis for this project. Some authors have indicated that this economic development would have required further exploitation of

the land and more specialisation. This in turn would have resulted in an almost slave-like production system, in which the workforce would always be getting poorer (Costa and Fernández, 2000). The skeletal data would be valuable in clarifying this issue.

1.3.3 Late Antiquity – Early Byzantine period[3]

Part of this study has involved a comparison between the Punic and the Late Antiquity – Early Byzantine period. The economy of this later period was less stable with attendant problems for the islanders. This should be reflected in biological (skeletal) differences in terms of health and disease.

Although during the period studied there does seems to be a steady demographic growth in the Mediterranean in general, during the sixth and seventh centuries there seems to have been a population decline associated with droughts, bad harvests, famines, urban violence, natural catastrophes, plagues and foreign invasions (Mango, 1980: 66-68; Salvador, 1990: 165; Cappel, 1991: 607-608). Rising temperatures resulted in droughts in the fourth century AD in Europe (Lamb, 1982). In addition, seismic activity was very high between the fourth and sixth centuries AD, although these were rather restricted to the eastern Mediterranean (Stiros, 2001; Gasparini, 1989: 518-521). The sixth century AD saw the 'Justinianic plague'. Rats spread through the commercial routes and carried the bubonic plague affecting mostly

[3] As will be observed in Chapter 2, the cemetery samples employed range primarily from the fourth century AD to the seventh century AD. This covers the period of Late Antiquity as well as the Early Byzantine period. Due to difficulties ascribing a skeleton to a particular century, the sample is combined and referred as a whole as belonging to the Late Antiquity-Early Byzantine period.

urban areas (Audoin-Rouzeau and Vigne, 1997; Panagiotakopulu, 2004). In 542 it had devastated Constantinople with an estimated toll of 10,000 deaths per day, killing up to one quarter of the people in the Eastern Mediterranean and then spreading to the rest of the Mediterranean, appearing intermittently until 750 AD (McNeill, 1976; Biraben, 1980; Kiple, 1997; Porter, 1997). The plague in addition to Arab raids influenced the dramatic decline in population numbers (Moffatt, 1986: 713).

This dramatic reduction in population was reflected in worsening habitat conditions, reduction of fortified spaces, widespread intramural burials and abandonment of some settlements (Mango, 1980: 8; Hitchner, 1991c: 38-185; Ramallo and Vizcaíno, 2002). The social problems were so severe that even free men were selling themselves and their children as slaves (Salvador, 1990: 164-165). In Ibiza, at the rural site of *Ses Païsses de Cala d'Hort*, for example, although decadence and destruction in the fourth and fifth centuries AD was apparent there was, however, some rehabilitation during the sixth and seventh centuries, although the important economic role the establishment played in previous periods had been lost (Ramon, 1995a: 24-25).

Although the fourth and fifth centuries AD saw the continuation of long distance trade of commodities such as fish sauce, honey, oil, wine and the creation of new centres of production of *Terra Sigillata Hispanica Tardía* in some parts of Spain (Keay, 2003: 209-210; Mango, 2002: 163), the scale of the trade was very much reduced. The evidence from settlement archaeology on declining civic life and population levels, as well as the lack of shipwreck evidence compared to earlier

periods, suggests a reduction in the Mediterranean marine economy at this time (Horden and Purcell, 2000: 153).

1.3.4 Summary of the economic situation in each period

The following table summarises key differences in the economic development of the two periods.

Table 1.1. Summary of aspects related to economic developments in each period.

PUNIC PERIOD (6th BC – 2nd BC)	LATE ANTIQUITY-BYZANTINE PERIOD (4th AD – 7th AD)
Ibiza was a prosperous, dynamic and important urban centre as well as a stopover point in the trade routes.	Evidence is scarce but seems to suggest a state of decline and oblivion after Vandal incursions.
Punic immigration, demographic growth and establishment of agricultural settlements.	Population decline, some abandonment of rural settlements. Plagues.
Coin minting, intensive pottery production and exportation of goods.	Slight revival of the economy after the Vandal presence, small scale foreign imports.
Agricultural exploitation and surplus.	No apparent agricultural surplus.

From the above observations, it was therefore logical to expect that the differences in each period should also result in differences in the quality of life, and therefore the health status of the populations. Therefore useful comparative data on morbidity rates can be gathered, thus helping to test the general hypothesis.

1.3.5 Differences in living conditions between rural and urban settlements in the Punic era

Although rural and urban settings interacted with each other in many aspects such as food and artefacts, lifestyles were likely to be different. For instance, a market economy in the town opposed to a subsistence economy in the countryside (Groenman, 1994). The environments in both settings also differ in that they have their own particular 'micro-climate', with some differences in temperature, air, wind and water pollution (Schofield and Vince, 2003). Animals were likely to be present in both contexts. The difference however may be that while in the rural areas animals were reared and fed, in the urban areas they would be slaughtered and skinned (Schofield and Vince, 2003). Were there therefore any differences between the health of the Punic rural and urban inhabitants?

Biological differences between rural and urban environments may be present with regard to demographic variation, morbidity, stature and weight, which are influenced by growth, nutrition, mating patterns and migration (Brothwell, 1994). Eveleth and Tanner (1990) observed how children were generally larger in the urban rather than the rural environment. In Medieval and post-Medieval Britain, differences in prevalence of maxillary sinusitis have been found between rural and urban populations. This contrast may have been influenced by differences in dental disease, fungal spores and pollen in the environment, dust from processing crops, zoonitic disease, parasitic infection, smoke, hygiene, diet, water supply, indoor pollution,

climate, housing conditions, socio-economic status, population density and occupations (Roberts *et al.*, 1998).

It has been possible to infer some of the factors that could have been affecting, either positively or negatively, the health of the Punic populations from Ibiza (Table 1.2). Only those inferences that are most clear for each period and more applicable to Ibiza have been included. It must be recognised that all of these factors were very likely present in both rural and urban settings and interacted with each other. Infectious disease may have been present in both contexts either influenced by similar or different causative agents. For instance, infection in rural areas may be related to the presence of animals although human immunological adaptation in later centuries may be considered, while in urban areas it may be associated with population density and faecal contamination. With regard to food shortages in the rural areas, this would likely affect the urban areas too. Table 1.2, therefore, merely indicates in which context a particular influential factor was more likely to occur in a particular context. It is open to changes and work on Ibiza from a wide variety of disciplines may add or omit some of these inferences in the future.

Table 1.2. Negative factors affecting health and likely to be present in the Punic period.

Factors	Punic settings
	RURAL *versus* URBAN
Transmission of disease through animals (excluding population immunity and plague from rats coming in through the harbour)	RURAL > Urban
Emergence of disease through landscape changes	RURAL > Urban
Subsistence dependent on climate	RURAL > Urban
Malnutrition (less variety of food, possible food shortages)	RURAL > Urban
Exposure to raids (no military protection such as city walls)	RURAL > Urban
Infectious diseases facilitated by immigrations, high population density and cramped living conditions	URBAN > Rural
Air pollution from industries	URBAN > Rural
Indoor pollution (working indoors)	URBAN > Rural
Problem of waste disposal (associated with overcrowding and population density)	URBAN > Rural
Water pollution (associated with population density and industries)	URBAN > Rural
Occupational related diseases	Urban = Rural

An analysis of urban and rural differences and similarities does shed some light on morbidity issues and this again will help to illuminate the overall hypothesis.

1.4 Ibiza: Etymology

> *The island is broken up at intervals by notable plains and highlands and has a city named Eresus, a colony of Carthaginians. And it also possesses excellent harbours, huge walls, and a multitude of well-constructed houses.*
> Diodorus of Sicily, 1st century BC (Book V:16)

In Antiquity, the Greeks named Ibiza 'Pityussae', which meant 'island of pine trees' (Tarradell and Font, 1975: 232). To the Punic people, the island was known as ''*YBŠM*', translated as 'inhabitants of the island of Bes' (Tarradell and Font, 1975: 232-

233), 'island of Bes' or 'islands of Bes'[4] (Padró, 1978). The present day Spanish name 'Ibiza', or 'Eivissa' as preferred in the local dialect, seems to have its origins in the Phoenician-Punic name (Solá, 1956: 325). The philology of ''*YBŠM*' is linked with the god Bes (Solá, 1956)[5]. This secondary god, adopted by the Phoenicians from the Egyptian pantheon (Padró, 1978), can be identified in archaeological material such as terracotta figurines and amulets found in Ibiza. In addition, the image of the god can be seen represented in coins from Ibiza dating to Punic and early Roman times (Planas *et al.*, 1989).

The god Bes has been found represented in the Valley of the Kings, Egypt, since at least the second millennium BC (Planas *et al.*, 1989: 12). This deity probably originated from Equatorial Africa as interpreted from his physical appearance, his association with dance, and the wearing of a leopard's skin (Padró, 1978; Planas *et al.*, 1989: 11; Kaufman, 2000: 75). From a medical point of view, he has been described as an achondroplastic dwarf (Reverte, 1986a).

In ancient Egypt, Bes was associated with the goddess of love and beauty, Hatho, and representations of women show his image tattooed on their thighs, probably to seek his protection (Planas *et al.*, 1989: 12). He served and protected the main gods and, with regard to mortals, he was the protector during birth, sleep, love, marriage,

[4] 'Islands' is plural here as it refers to both Ibiza and the neighbouring island of Formentera.
[5] See also Sanmartín (1994: 232-233) for a view into some of the problems with the concept and for a more recent discussion of this issue. Other associations to the etymology of Ibiza have included the words 'cypress' or 'pine' but these have not been well supported (Solá, 1956; Aubet, 1993: 273).

childbirth, sexuality and even from poisonous animals (Solá, 1956: 333-334; Fernández, 1996; Fulghum, 2003b: 281).

1.5 Ibiza: Geography

The earliest geological formation involving Ibiza dates back to 223 million years ago (MYA). The current landmass is about 155 million years old and it last re-emerged from the sea around 15 MYA (Fornós, 1992; Giffhorn, 1992). The Mediterranean Sea, itself, was created around 25 MYA when the African and Asian continental blocks collided (Schüle, 1993: 400). Between 5.7 and 5.35 MYA the Mediterranean was closed and the total area dried (Alcover and Bover, 2002: 103). This was a consequence of the movement between the African and European plates. At this time, fauna might have colonised the Balearic Islands (Alcover and Bover, 2002: 103). During the Last Glaciation about 20,000 years ago the Mediterranean Sea level was 100 m lower than it is today (Rackham, 2003: 40). Finally, apart from minor coastline changes, the present sea level and geographical configuration was adopted about 7,400 or 7,000 years ago (Shackleton *et al.*, 1984; Rackham, 2003: 40).

Accounts of Ibiza's location can be found in classical works such as in *Geography of Strabo* (III.5.1.) written by Strabo (c. 64/63 BC – c. 25 AD). Pliny the Elder also mentions Ibiza in the 1st century AD (*Natural History*, III, 5: 76-79):

> *'The first of all the islands scattered over these seas are called with the Greeks the Pityussae, from the pine trees that grow on them; each of these islands is now named Ebusus (...). Their area is 46 miles, and their distance from Denia 87 ½ miles (...), while at the same distance from the Pityussae out to sea are the two Balearic islands (...). The soil of Iviza drives away snakes (...). Iviza does not breed rabbits either, which ravage the crops of the Balearics. The sea is full of shoals, and there are about twenty other small islands (...).'*

In ancient times, the islands of Ibiza and Formentera, together with their surrounding islets, were grouped as the 'Pityussae', while the 'Balearic Islands' would only refer to Majorca and Minorca.

Today, Ibiza forms part of the Balearic Islands, an archipelago belonging to Spain. The Balearic Islands themselves can be divided into the Gymnesic islands (mainly Majorca and Minorca) and the Pitiusic islands (mainly Ibiza and Formentera). This division is due to a submarine channel about 50 miles wide that separates Ibiza from Majorca (Naval Intelligence, 1941: 46). This separation is also associated with historical and ecological differences between the two groups (Palmer *et al.*, 1999: 818-819).

Ibiza is located in the western Mediterranean at latitudes 38°50'40'' and 39°6'22'' North and longitudes 1°22'50'' and 1°43'15'' East (Ill. 1.1)[6]. The island is approximately 92 km from the Iberian Peninsula and 82 km from Majorca (Vallès, 2000a), and about 240 km from the North African coast (Gómez, 1989: 38). The Greek historian Diodorus of Sicily in the first century BC describes (Book V. 16), in terms of

[6] All illustrations (abbreviated 'Ill.') are included in the Appendix.

ancient navigation, the location of Ibiza as being three days and three nights' sail from the Straits of Gibraltar, one day and one night from the North African coast (Libya), and one day's sail from the Iberian Peninsula.

Ibiza's land surface with its surrounding islets is estimated between 541 and 570 km^2, with a maximum length and width of 41 km and 21 km respectively (Vallès, 2000a). There is a capital city of the same name, 'Ibiza' or *Eivissa*[7], and two other smaller towns present: *Sant Antoni* and *Santa Eulària* (Ill. 1.2). *Eivissa* is located at latitude 38.54N and longitude 01.26E. The rest of the nucleated settlements are mainly small villages (*pobles*) but increasingly growing. In 1999, Ibiza had 85,535 inhabitants (Cirer, 2000). By January of 2003 the population had risen to 105.103 inhabitants (INE, 2003).

The island is composed of secondary limestone, with a landscape of lower slopes and an indented coastline with cliffs but with some sandy beaches too (Naval Intelligence, 1941). Ibiza's interior is rugged with the highest peak, *Sa Talaiassa* or *Sa Talaia*, reaching 475 m above sea level (Vallès, 2000b). The coastline reaches a stretch of 210 km and has many small bays. These bays, such as *Sa Caleta* and *Portinatx*, were probably used for anchorage and shelter in ancient times (Almagro, 1969: 351).

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[7] Ibiza has two official languages: Spanish or Spanish Castilian (*español* or *castellano*) and Catalan (*català*). Many natives have *eivissenc* as their first language, officially considered a dialect of Catalan. Some of the words in the text, especially those in italics and mainly referring to geographical locations in Ibiza, will be in Catalan or *eivissenc*. In order to avoid confusion, the word 'Ibiza' is used here as the English translation to indicate the whole island, while the word *Eivissa* will be used to refer to the capital city.

Ibiza's water supply flows from natural springs. The climate is Mediterranean[8], subtropical, with mild and wet winters and hot summers (Vallès, 2000c). In the Balearic Islands, September and October are the months with the highest frequency of strong winds and tornadoes in the Balearic Islands (Gayà *et al.*, 2001).

Ibiza's landscape provides a variety of resources such as olives, figs, and almonds (Miguélez, 1989: 11), clay, salt (see Vilá, 1953), and marine resources. Today, the vegetation consists of pines, savin, oak and shrubs such as heather and juniper (Gómez, 1995: 445). The agricultural landscape reveals mainly dry-farmed crops such as pulses and cereals (Miguélez, 1989: 11).

Although some ancient traditional crafts such as basket making, pottery and textiles are still produced today, the present economy relies primarily on tourism and construction (Móra, 2000). Agriculture and stockbreeding account for less than 3% of economic activity, and fishing even less (Clapés, 2000). Other industries present since ancient times such as salt-mines or quarrying account for even a smaller percentage of the economic activity (Cuesta, 2000).

[8] Questions should be raised as to what is regarded as Mediterranean and how its boundaries are defined (see Abulafia, 2003). Although generalisations will be used to aid in reconstructing the past, caution must be taken at least with regard to climate and geology as they show a lot of variation in the Mediterranean (Rackham, 2003: 33; also see Houston, 1964; Shiel, 1999).

1.6 Ibiza: historical background

The human remains analysed in this study came from two periods. The earliest dated to the Punic period. The later material derived from contexts dated to the Late Antiquity and Early Byzantine period. Amongst this later material, some tombs may be dated to the years of the Vandal presence in Ibiza.

Before exploring these two periods in detail, it is worth examining the wider historical background. This will allow an understanding of each period within a greater context. It will also provide an opportunity to learn about the colonization process.

1.6.1 Prehistory

At present there are no traces of early hominids in the Mediterranean islands. Some controversial evidence of Middle Pleistocene *Homo* has been found in Sicily and Sardinia (Schüle, 1993: 399). A maxilla and a temporal bone from Sardinia have been dated to c. 9120 +- 380 BP (Spoor and Sondar, 1986).

With regard to Ibiza, the earliest colonization is still an unresolved matter[9]. It appears that the strait between the island and the Iberian Peninsula would have ensured Ibiza's isolation even when the sea level was low (Schüle, 1993: 401). During the Messinian Salinity Crisis around six or five MYA, perhaps these two areas may have been connected (Schüle, 1993: 401, 404), allowing the possibility of land animal migration (Hsü *et al.*, 1977: 402). After this event, Ibiza and Formentera would remain geographically isolated from the rest of the islands and the Spanish mainland, even when the sea level was at its lowest around 18,000 years ago (Shackleton *et al.*, 1984). This isolation, however, did not necessarily mean that flightless mammals could not have reached the island (see Diamond, 1987). In fact, prior to human colonization, since the Pliocene or the beginning of the Pleistocene until the early Holocene, some Ibizan sites have yielded remains of fauna such as rodents, birds, bats, lizards, fish and molluscs (Alcover *et al.*, 1994; Alcover and Bover, 2002).

At the site of *Es Pouàs* in Ibiza three phases of faunal episodes have been identified (Alcover and Bover, 2002: 101). The lowest level, dated to 4860 and 4450 BC, contains archaeological deposits that, although they do not include human remains, do provide evidence for human activity (Alcover *et al.*, 1994). If colonization took place around this time, it would coincide with environmental changes (e.g. more

[9] Colonization of an island depends on a range of biogeographical factors (see Cherry, 1984). Amongst others, these factors include size, geomorphology, location, climate, sea currents and winds, ecology, visibility, natural resources and the potential to exploit them (Tarradell, 1955; Schüle, 1970, 1993: 401; Cherry, 1990; Cunliffe, 1995: 15; Rodríguez and González, 2003). Maritime technology and navigation skills would also be important (e.g. see Tilley, 1994), although flightless mammals have been able to colonize islands through rafting, swimming and even ice travel (Diamond, 1987). The demographic characteristics of the settlers, such as their group size, age and sex composition is also crucial to a successful colonisation (Rodríguez and González, 2003).

aridity) in the Mediterranean as evidenced by palaeohydrological (see Magny *et al.*, 2002) and palynological studies (see Yll *et al.*, 1997; Jalut *et al.*, 2000). In the Sahara for instance (see Shaw, 1976), this aridity was probably associated with the abandonment of human settlements in this region around 6800 BP onwards (Magny *et al.*, 2002: 49, 56). Thus, human migrations would have likely occurred at this time. There is also evidence for maritime technology and navigation in the Mediterranean at that time (see Johnstone, 1988; Calcagno, 1997; Parker, 1992: 1).

1.6.2 From Prehistory to the Phoenician colonization[10]

Despite limited evidence, the current state of historical research has yielded a few conclusions with regard to the prehistoric period in the Balearic Islands. On the one hand there are biogeographical data indicating human presence before the development of metallurgy and campaniform pottery around 3000 BC (Calvo *et al.*, 2002: 182-183). On the other hand, it seems that between 2300 and 2100 BC there are settlements appearing associated with copper metallurgy, agriculture and herding (Calvo *et al.*, 2002: 182-183). Later, at least in Majorca, these activities only became an economic strategy in the middle of the first millennium BC (Hernández-Gasch *et al.*, 2002).

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[10] According to *The Oxford English Dictionary* (1989, 2nd edition, Vol. III. Clarendon Press, Oxford) the word 'colonization' is taken to mean the establishment of a colony. 'Colony' is defined as the community of individuals, either the original colonizers and/or their descendants that establish themselves in a new place but that continue to maintain a connection with their place of origin. With regard to archaeological issues, Van Dommelen (2002), in the example of Punic and Roman Sardinia, provides a cautionary note with regard to the notion of 'colonialism' and 'colonial'.

At present, the prehistory of Ibiza is relatively little known. Although smaller Mediterranean islands have been colonized since the fifth or fourth millennia BC, there are only untested hypotheses for Ibiza. As seen earlier on, the limited evidence such as the fauna from caves such as *S'avenc des Pouàs* in Ibiza, suggest the introduction of domestic animals such as goats by human settlers from the Iberian Peninsula at the beginning of the fifth and middle of the fourth millennia BC (Alcover *et al.*, 1994: 237; Costa, 2000b; Costa and Benito, 2000; Costa and Guerrero, 2001: 32). The island is certainly visible from the Iberian Peninsula on a clear day.

With regard to human presence, the evidence suggests continuous human occupation since the third millennium BC (Guerrero, 2001; Costa and Benito, 2000; Costa and Guerrero, 2001, 2002). Zooarchaeological remains from *Puig des ses Torretes* in Ibiza have provided dates of 2100 and 1900 BC for this settlement (Costa and Guerrero, 2001: 33). The earliest known human remains in Ibiza derive from the burial site of *Can Sergent*. At least five individuals were interred here and they include the skeletons of three adult males, one adult female and one infant (González and Lalueza, 2000). Radiocarbon dates from the bones have produced calibrated dates of around 720 BC and 550 BC and provide a *terminus ante quem* for the settlement (Fernández and Topp, 1984: 767; Costa, 2000b: 351; Costa and Guerrero, 2001: 39). If the evidence from Formentera[11] can be considered, the excavations at the megalithic burial site of *Ca Na Costa* (Fernández *et al.,* 1988), dated to circa 2000 BC (Costa and

[11] Formentera is a neighbouring island of 77 km^2 and with a surface, including smaller surrounding islands, ranging between 81.70 and 83.20 km^2 (Prats and Marí, 1999). Together with Ibiza, they form the group of the Pitiusic Islands or *Illes Pitiüses*. Formentera's population in 2003 was just under 8,000 inhabitants (INE, 2003). The island is closely linked to Ibiza in geographical, historical and ecological terms.

Guerrero, 2001: 35), provide the earliest human remains yet discovered in the Pitiusic islands.

The anthropological studies on human remains from *Ca Na Costa* (Gómez and Reverte, 1988) and *Can Sergent* (González and Lalueza, 2001) reveal differences in dental wear. Although the sample sizes are too small to be representative of the period, the analysis of wear patterns nevertheless suggests a possible hunter-gatherer diet based on proteins and vegetables for those buried in the former site, and an agricultural diet based predominantly on flours and semolina in the sample of the latter site (Costa and Guerrero, 2003: 494).

With regard to material culture, while in the Chalcolithic (c.2100-1600 BC) there were open habitat dwellings in Ibiza (Costa, 2000b); the Bronze Age (c. 1600-600 BC) is characterised by an increase in fortified strongholds, cave dwellings like *es Cuieram* and *cova Xives*, as well as artefacts such as coarse pottery, grinding-stones, bronze objects and stone tools (Gómez, 1995: 447; Costa and Fernández, 1995; Kaufman, 2000: 33-34). Following the Bronze Age[12], the establishment of people belonging to the Phoenician culture took place.

[12] These chronological frameworks are merely convenient labels for those researchers studying the past. It must be acknowledged that these chronological frameworks are not always strictly defined and the change from one period to another is not always clear cut with regard to culture.

1.6.3 Phoenician Ibiza

The Phoenician colonization can be considered to be the root of the Carthaginian culture (Tarradell, 1955: 66). Thus, it is important to have some knowledge of the Phoenician colonization of Ibiza in order to understand the Punic period. In addition, some information from Phoenician times can be seen associated with human mortality and morbidity. For instance, Phoenician merchants introduced the house mouse into Iberia (Morales *et al.*, 1995). This may have influenced the presence of certain diseases in human settlements.

The Phoenicians were people from the Eastern Mediterranean and more specifically, the area of present day Lebanon. Their economy relied on trade rather than agricultural exploitation and in the first millennium BC they were the principal carriers of goods and ideas throughout the Mediterranean (Hammond, 1972: 87, 91). The Phoenician colonial activities had started since at least the twelfth century BC. At least by the end of the tenth century BC they had established trading centres in the Eastern and also in the Central Mediterranean areas, as can be interpreted through evidence from Sardinia (Negbi, 1992). At this time they were also trading with India and by approximately 600 BC, they seem to have circumnavigated Africa (Casson, 1974: 45-46, 61). Although they had previously navigated and explored around the Western

Mediterranean, it was around the eighth century BC when they expanded to the West and established trading centres and outposts such as in Spain (Chapa, 1997: 141)[13].

It was in the seventh century BC that the Phoenician trade saw its greatest expansion both in the Atlantic and the Mediterranean areas. At this time trading posts were established in Morocco, Spain and Portugal, with the town of Cadiz (Spain) playing a central role (Aubet, 1995: 51). Initially, Phoenicians acted as merchants focusing on trade rather than acquisition of territory (Sherratt and Sherratt, 1993: 367). Gradually they would set up colonies where, apart from commercial activity, they would exploit and acquire raw materials from the land and the sea (Wagner and Alvar, 1989: 102). Many of the establishments in Iberia were clearly associated with the exploitation of mineral resources (Schüle, 1970: 455). For instance, Cadiz and Ibiza could offer the exploitation of their salt resources (Vives, 1942: 10; also see Vilá, 1953).

Following the establishment of outposts in the Western Mediterranean such as Cadiz and Malaga in Spain, and Carthage in North Africa, Ibiza became an important centre in an international trade network (Aubet, 1995: 60). Due to its location, as well as the sea currents and winds in that part of the Mediterranean, it became a convenient stopping place in several east-west and north-south Phoenician trade routes (Ruiz de Arbulo, 1991; Aubet, 1993a; also see Moreno, 2003). In addition, it was centrally

[13] For an overview of the indigenous people at the time of the Phoenician colonisation and their interaction with the Phoenicians see, for instance, the work of Harrison (1988), Aubet (1993a) and Chapa (1997).

located with regard to other harbours in the western Mediterranean (Chapman, 1990: 260, 263).

Based on current knowledge, Phoenicians established an early settlement at *sa Caleta* in the south-western part of Ibiza. This settlement has been dated to the eighth century BC (Ramon, 1991, 2003). Through the study of the material culture, the inhabitants appear to have come from the area of the Strait of Gibraltar (Aubet, 1993a: 272; Ramon, 1994a: 364). The site at *sa Caleta* was a completely urbanized settlement with juxtaposed buildings, small streets and squares, and circular ovens (Ramon, 2003a: 153-154, 156). Its surface area probably reached over 40,000 m^2, but it was only inhabited for about fifty years, after which the population probably moved to what is today *Eivissa* (Ramon, 1992, 2000a, 2003: 153, 159). Reasons for this abandonment are unclear. Based on data on tornadoes and waterspouts in the area (Gayà *et al.*, 2001: 254 and Figure 1) it was perhaps the physical environment that was an acting agent. *Eivissa,* amongst other advantages stated below, offered a better shelter.

With regard to *Eivissa*, however, it is unclear whether this settlement was founded by the inhabitants of *sa Caleta*, or whether it already existed prior to this site's apparent abandonment (Ramon, 1994a: 364). Greek and Etruscan pottery finds on *Eivissa* may suggest that this Phoenician centre was a slightly later site (Ramon, 1994a: 365). No cemetery has been found associated with the site at *sa Caleta*. Although the sea may have been used as a grave (see Pollard, 1999), a large cemetery, *Puig des Molins*, has in fact been found in *Eivissa*. Anthropological studies on *circa* 30

Phoenician cremations from this necropolis have been undertaken (Gómez, 1989, 1990). Despite problems with sample representativity, ageing and sexing methods, the study by F. Gómez (1989, 199) reveals the presence of young men, women and children that suggest to the author the arrival of young Phoenician families.

The Phoenicians, who had commercial interests, saw the potential advantages of the area that would become *Eivissa*. It was a natural protected port surrounded by fertile soils, a promontory in a strategic position, and sandy beaches for the landing of vessels. In Phoenician times it became a distribution centre of goods such as scarab-seals and alabaster vessels. These products came from various parts of the Mediterranean including Egypt, Greece, Sicily, Etruria and Sardinia (Costa and Fernández, 1995; Kaufman, 2000). Some of the Egyptian scarab-seals found at *Puig des Molins*, *Eivissa*'s cemetery, may date to the seventh century or even earlier (Baqués, 1974: 143). Pottery fragments, water cisterns and some building structures discovered in the town date back to the seventh century BC (Ramon, 1992, 2000a).

Pottery discovered from sites in *Eivissa*, such as that found at *Puig de Vila* or at *Punta d'en Joan Tur Esquerrer*, indicate a high percentage of locally made amphorae dated to around 625-600 BC (Ramon, 1994a: 353, 364). With regard to the cemetery of *Puig des Molins*, the oldest tombs, which are cremations, date from the seventh or mid-sixth centuries BC (Costa and Fernández, 1986-1989: 256-257).

From the beginning of the sixth century BC onwards some of these settlements or areas of activity were abandoned and Ibiza experienced changes such as those regarding funerary customs: a generalised use of rock-cut fossae alongside possible animal sacrifices, as well as food and drink rituals at the cremation grave (Costa and Fernández, 1986-1989: 259-260). With regard to commerce, there was a shift in trade routes. There was an increase in imports from the area of the central Mediterranean, in particular Sicily and Sardinia, and it was Ibiza that may have acted as a redistribution centre for these products to northeast Spain and the south of France (Ramón, 1982; Costa and Gómez, 1987: 53).

From all this available evidence, therefore, *Eivissa* cannot be regarded as a mere port of call as previously thought (e.g. see Wagner and Alvar, 1989: 87), but as a proper colonial settlement with agricultural potential, a great natural bay, and pottery workshops apparently functioning soon after the town's establishment (Ramon, 1994a: 365).

1.6.3.1 Times of change: from Phoenician to Punic colony

In 573 BC the Phoenician city of Tyre, situated in the area of present-day Lebanon, fell to Babylon, which was located in present-day Iraq. This defeat, alongside other factors, resulted in what has been regarded as a sixth century 'crisis', where Phoenicians were losing control over their colonies in the western Mediterranean

(Aubet, 1995)[14]. The earlier economic system was disrupted, resulting in an economic and political separation between the eastern and the western Mediterranean[15]. This division would later increase the maritime importance of Ibiza in the Western Mediterranean after *circa* 550 BC (Cunliffe, 1995: 19). Carthage, a city in North Africa that had been founded by the Phoenicians, took economic and political control of the colonies in the Western and Central Mediterranean. Because of Carthage's economic, cultural and political influence at this time, the period is known today as the Carthaginian or Punic period.

At this time, due to conflicts of interests between Carthage and the Phocaean Greek and Etruscan merchants, the economic system would become more centralised. It had moved from a system of exchange of certain products and precious metals, to a more diversified trade production based in a few centres such as Cadiz, Malaga and Ibiza (Aubet, 1995: 61-62).

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[14] The use of the word 'crisis' in Andalusia may be inappropriate and a term such as 'phase of readjustment' more preferable (Cunliffe, 1995: 19-20).

[15] The classification of the eastern Mediterranean and the western Mediterranean is based on the geological nature of the seabed. These two areas remain separated by the Sicilian-Ionian base (Houston, 1964: 37).

1.6.4 The Punic (Carthaginian) period[16]

In the Iberian Peninsula, the transition between the Phoenician period, generally speaking between the eighth and sixth centuries BC, and the Punic period (5th-3rd BC approximately) is still a matter of discussion in terms of continuity or discontinuity, and presence or absence of social and economic crisis (Aubet, 1995: 47). Chapa (1997: 141) suggests that the Punic colonisation was not aimed at territorial colonization, but it was rather focused on the economic potential of the distribution centre. Apparently, there was no real resistance from the indigenous population towards those individuals of Punic origin, who had established themselves in the Iberian coast with their markets and their own cultural identity (Chapa, 1997: 149).

In the Punic period, Ibiza's strategic location served to control the passage to the Strait of Gibraltar from any enemy ships, either military or commercial (Aubet, 1993a: 166).

From the sixth century BC, Carthage's influence on Ibiza was marked by deep transformations in the social, economic, political, ideological and religious spheres.

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[16] The classification of 'Phoenician', 'Punic' and 'Carthaginian' requires clarification. Seeking their definitions is complex and debatable (e.g. see Moscati, 1988). Tarradell and Font (1945: 245) indicate that 'Phoenician' meant 'oriental' (from Phoenicia), while 'Punic' was the name given by the Romans to the Carthaginians. For practical reasons, this thesis uses the word 'Phoenician' to refer to those establishments directly founded by individuals who came from the eastern Mediterranean, and before the 6th century BC. After this date the word 'Punic' is used to refer to those areas in the central and western Mediterranean under the influence of Carthage. Finally, 'Carthaginian' is used to refer to what belonged or derived from the city of Carthage, both people and products.

These changes included an apparent demographic growth, colonization of the rural landscape, agricultural activity, different funerary rites, intensive production of goods and the creation of a coin mint (Costa and Fernández, 1986-1989, 1995, 2000; Kaufman, 2000) [17].

An apparent increase in population has been attested by the presence during the Punic period of thousands of hypogea or rock-cut tombs in the cemetery of *Puig des Molins*. It has been estimated that at least around 3000 Punic hypogea were present (Tarradell, 1955: 86). It has been argued that this increase in tomb numbers in the Punic period is due to the immigration of peoples instead of the reproductive growth of the population (Tarradell, 1974: 261; Costa, 1994). Similar patterns of demographic growth can be seen in other islands such as Malta (see Said-Zammit, 1997). Reasons for colonization and migration are unclear, but one of the possible contributing factors

[17] Although the Phoenician and Punic roots of Ibiza appear to be very certain, the Greek influences cannot be ignored. Some earlier authors believed that Ibiza could have been a Greek colony. Pérez-Cabrero (1911: 6) thought that the Aegeans were the first to settle in Ibiza. Furthermore, Oikonomides (1983c) reinterpreted five coins from Ibiza as having a Greek inscription rather than a Latin one. Hence, he considered Ibiza an Ionian colony and that Majorca and Minorca, where the *Odyssey* seems to have shipwrecked, might have been Rhodian colonies. Besides, the Greek term 'Pitiussa' most likely had the ending –ουσσα (-oussa), possibly suggesting that the name was given during early Greek (Euboean) explorations in the second or beginning of the first millennium (García Alonso, 1996). Further information regarding Greek and Phoenician interaction can be found in the work edited by Costa and Fernández (2003d). As a matter of fact, many Greek materials were present in Punic Ibiza especially from the fifth century onwards and with a peak of acquisitions, such as for the *lekythoi*, in the fourth century BC (Tarradell and Font, 1975; see also Blázquez, 1966). However, these Greek products were predominantly present in the funerary rather than the domestic context (Tarradell and Font, 1975: 264-265). This phenomenon was not unique to the island but also occurs in other parts of the Mediterranean (Tarradell and Font, 1975: 264). In fact, earlier in the mid-sixth century BC intensification of Greek imports was already occurring in SE Spain (Cunliffe, 1995: 20). Greek establishments in the north of Spain and south of France were certainly commercialising with Punic traders (see Cabrera, 2000). In Ibiza, Greek influence has been present in the material culture of the Punic colony (e.g. see Costa and Gómez, 1987). Some of these products with Greek influence such as some scarabs (Baqués, 1974), terracotta objects (Astruc, 1957; Tarradell and Font, 1975: 266), possibly amphorae (see Ramon, 1995: 252) and even coins (see Planas *et al.*, 1989: 19-20, 177) appear throughout the Punic period. This could be a reflection of a possible participation of Ibiza in Greek and Etruscan trade routes, and perhaps the presence of Greek merchants in the island, before the control of Carthage from *circa* 540 BC onwards (Costa and Gómez, 1987: 55).

might have been overpopulation in Carthage at that time (Whittaker, 1978: 75-76; Dilke, 1985: 132). In the early years of archaeological enquiry in Ibiza (see Mañá, 1948: 202), the high density of tombs was explained as a result of the island being a 'sacred' land where people came to be buried. In the light of more recent archaeological discoveries, this theory has been refuted and lacks evidence (Tarradell and Font, 1975: 243; Fernández, 1986: 164).

Changes in the funerary rites were apparent in the sixth century BC. There was a decrease in cremations, the appearance of the rite of inhumation, the introduction of a new type of tomb (hypogeum) and new grave-goods originating from the central Mediterranean (Costa and Fernández, 1986-1989; Gómez *et al.*, 1990; Ramon, 1992). These changes in the burial rites suggest the arrival of immigrants (Gómez *et al.*, 1990; Costa and Fernández, 1986-1989).

Deities from the Phoenician-Punic pantheon, especially Tanit, were also venerated in Punic times. Sanctuaries were being created, others extended and used intensively such as *Es Cuieram* (Almagro and De Fortuny, 1971; Aubet, 1968, 1982; Ramon, 1982; Ramón, 1985b) and possibly *Cap des Llibrell* (Ramon, 1987-1988). The functions of such sanctuaries may not have been necessarily religious, but may have also served as economic centres where political negotiations or exchange of wealth took place (Prados-Torreira, 1997).

Trade was intensified and Ibizan local pottery exported to other parts of the western and central Mediterranean increasingly until 150 BC after which production and exportation gradually declined (Ramon, 1981: 35-36). Pottery workshops in the surroundings of *Eivissa* have provided evidence for massive production, especially in the fourth and third centuries BC (Ramon, 1990-1991, 1997, 1998).

1.6.5 Roman times

After Rome's victory over Carthage in 146 BC, 'Romanization' probably started at a slow rate, and perhaps slower in the rural compared to the urban areas. The presence of the Punic language and ideology would still be present in the earlier years and with this regard the label 'Romanization' may be abandoned (van Dommelen, 2001: 80). In Malta the Punic culture survived until the first century AD even if Roman rule had been present since 218 BC (Said-Zammit, 1997). In Ibiza, for instance, the Punic image of the god Bes continued to appear in Roman coins (Kaufman, 2000: 107).

The Roman period began with economic prosperity, alongside commercial, agricultural, salt and mining activities and an increase in amphora production (Kaufman, 2000: 107). This prosperity was brought in by improved technology in agriculture, oil production and the fishing industry (Costa and Fernández, 1995; Ramon, 2000b, 2002). However, as part of the Roman Empire, Ibiza could not compete with the larger markets and this resulted in the abandonment of some rural settlements in the first century AD (Kaufman, 2000: 116-117). With regard to trade, Ibiza's

location still served as a suitable stopover point in the routes from north-south and east-west, according to the presence of luxury goods from places such as Syria, Greece and Italy (Ramon, 2000b). However, compared to the Punic period, Ibiza's importance decreased.

1.6.6 'Dark Ages': Late Antiquity, Vandal presence and the Byzantine period

Conventionally, Late Antiquity refers to the fourth and fifth centuries AD, roughly stretching from the collapse of the Roman Empire in the West and the emergence of Christianity. Reforms largely under emperor Diocletian (254 AD-313 AD) saw the transformation of Iberia into seven provinces between the third and fifth centuries AD, *Baleares* being one of them (Keay, 2003: 198). At this time there were transformations in the urban topography. Limited construction was present and some urban areas were abandoned (Keay, 2003: 200-201). With regard to rural areas, the pattern in Spain seemed to show the abandonment of certain settlements but also, by contrast, the enlargement and urbanization of villas (Keay, 2003: 206).

The Vandal presence in the Iberian Peninsula consisted of a short period between 409-429 AD with a strong military capacity and organized raids (Arce, 2002: 75). The extent to which the Vandals respected and used engineering and architectural structures that already existed is unclear (Arce, 2002: 85). With regard to Ibiza, the Vandals occupied the island later, in 455 AD, and possible evidence of fire, destruction

and abandonment of rural settlements at this time has been reported (Ramon, 1985, 1995a). The aim of raids in the Balearic Islands is still unclear. The islands were certainly close to the south of France, Italy and North Africa, and strategically positioned to block the Roman communications to those areas (Arce, 2002: 81). The islands were also important with regard to commerce (Gurt *et al.*, 1994: 165).

With regard to the Byzantine period, the majority of historians define the Byzantine Empire[18] as starting with the foundation of Constantinople in 324 AD and ending in 1453 AD as a result of the intrusion by the Ottoman Turks (Mango, 1980: 1). Three periods could be divided according to particular events; the earliest period starting in the fourth century AD and ending in the seventh century AD with the rise of Islam, the Arab expansion and Persian invasions (Mango, 1980: 1, 4).

In Spain, emperor Justinian (483 AD-565 AD) re-conquered from the Visigoths former Roman territories in the southern coast, but these settlements were only in 'Byzantine' hands for under a century (Salvador, 1990; Mango, 1980: 21). The first disembarkation of Byzantines in Iberia took place in 522 AD and their dominion would end with the destruction of Carthage by the Visigoths in 621-624 AD and later with Islamic incursions (Ramallo and Vizcaíno, 2002; Salvador, 1990). The Byzantine presence in *Hispania*, restricted to a few military and commercial enclaves along a narrow strip in the coastal areas as well as the Balearic Islands, did not form a clear

[18] The term 'Byzantine' can be controversial and should only be regarded as a convenient label. The concept of 'Byzantine Empire' never existed and was just a Roman state centred in Constantinople while those inhabiting other areas of the 'Empire' would have been regarded as 'Romanoi' or 'Christians' (Mango, 1980:1).

territorial unity (Ripoll, 1996: 261). Although the frontier of the Byzantine Empire in Spain is debatable (Ripoll, 1996; Salvador, 1990), it covered the coastal fringe roughly from Denia in the east to the mouth of the river Guadalquivir in the south (García, 1972: 128). Ibiza was also under Byzantine rule (Ramon, 1985) as were the rest of the Balearic Islands. The coastal sites provided control over the Straits of Gibraltar and therefore opening and securing commercial routes (García, 1972: 152-153; Ripoll, 1996; Martí, 2001: 19). A strong link with North Africa is clear in Spain from the imported products such as oil, wine and fish sauce contained in amphorae (Hitchner, 1991b: 32-33; Ramallo and Vizcaíno, 2002: 316).

An important military and political centre was established in Cartagena and the enclaves in Iberia, the Balearics and Ceuta came to depend, administratively, on the province of *Mauretania Secunda* (Rippoll, 1996: 254). In Ibiza, although documentary and archaeological evidence is scarce, while the Vandal period left clear signs of destruction, the start of the Byzantine period in Ibiza from 535 AD resulted in a slight revival of the economy (Ramon, 1985, 1986, 1995a, 2000b; Costa and Fernández, 1995). There was also a reoccupation and rebuilding of some rural settlements (Ramon, 1995a; González and Pacheco, 2002), although never at a scale comparable to previous periods. In Ibiza, the Byzantine influence in terms of Christianity is clear and reflected in the urban cemeteries with regard to the position of the body and some personal grave-goods (Ramon, pers. comm.), although the diffusion of material objects does not necessarily indicate any assimilation of culture (Mango *et al.*, 1991: 562-563). More precisely, a preserved document between the bishop of Cartagena and that of Ibiza

indicates that Christianity and Judaism were present (Salvador, 1990). Lastly, Greek inscriptions on bronze censers from Majorca and Minorca dating between the sixth and eighth centuries AD, may suggest that the islands were part of Byzantium or that Byzantine merchants may have been trading on the islands (Oikonomides, 1983b: 142).

In Ibiza, the Byzantine period came to an end in the seventh century AD, possibly associated with the disruption in trade resulting from the control of Carthage by the Arabs in 698 AD as well as later in the Iberian Peninsula (Hitchner, 1991b: 33; Gurt *et al.*, 1994: 165). At this time and up until the official 902 AD date for the start of the Islamic period, there is a gap in the archaeological record although Islamic incursions seem to have taken place (see Kaufman, 2000).

1.6.7 From the Islamic period to the present day

The official date for the occupation of Ibiza by Muslim forces is 902 AD when it became integrated into Al-Andalus (Gurrea and Martín, 2000).

Innovations during the Islamic period were religious, linguistic and technological, amongst others, and may have been brought in by a large number of immigrants (Kaufman, 2000: 151-154). Gómez (1989) has commented that some mandibles from Muslims buried in Ibiza at this time have similar morphological characteristics to north-African mandibles. A technological innovation brought into

Ibiza during this period is the *feixa*. These were agricultural systems that were applied on reclaimed swampy lands in the harbour of Ibiza (Foster, 1952: 227, 229).

On the 8th of August of 1235 AD, the Crown of Aragon conquered the island[19], after which Christianity was imposed, a cathedral was built and the Catalan language introduced. The post-medieval period is briefly summarised (see Joan, 1997). After the Black Death in the fourteenth century, the strategic position of the island made it vulnerable to other 'potential invaders'. Threats from Turkish pirates motivated the construction of the Renaissance walls in the sixteenth century and of fortified churches and lookout towers in later centuries (Posadas, 1992; Serra, 1999). Plagues arrived in the seventeenth century and malaria was noticed in the eighteenth century, possibly alongside tuberculosis, rheumatism and measles (Gómez, 1989: 328-332).

In the twentieth century Ibiza witnessed part of the Civil War from 1936 to 1939 (see Parron, 2000). For the early 1950s, Foster (1952: 229) provides an insight into the subsistence at the time:

> *In the districts of Ibiza and Santa Eulalia large quantities of salt are produced through natural evaporation of sea water; except for this, agriculture is the principal occupation of the islanders. Olives, almonds, algarrobas, grapes, cereals, and vegetables are the chief crops, grown primarily on unirrigated ground.*

[19] Other terms have been used such as 'Catalan Conquest' or 'Re-conquest' but these, perhaps somewhat politically biased, are debatable and not entirely correct (R.J. Cooper, pers. comm.).

The 1970s saw a tourist 'boom' that has since then been ever present (Cooper, 1974; Ramón Fajarnés, 2000). More recently, despite its unique fame in the nightclub and DJ industry, its rich heritage and marine biology were awarded the status of World Heritage Site in 1999. Today it is a very cosmopolitan island with many influences. However, the influence of the ancient past is still present in its architecture, arts and crafts, as well as in the character of its people.

1.7 Past and present anthropological work on human remains in Ibiza

> *Anthropology is the science of man, the science devoted to the comparative study of man as a physical and cultural being. The physical anthropologist studies man's physical characters, their origin, evolution, and present state of development* (...).
>
> Montagu (1960: 3)

Some studies were done before the twentieth century on coins from Ibiza and other material (reviews in Planas *et al.*, 1989: 21-23; Fernández, 2000). However, the beginning of archaeology in Ibiza has really been regarded as starting in the early 20th century AD with the work of Juan Román y Calvet and later by his son Carlos Román Ferrer, and the foundation in 1903 of the archaeological society, 'Sociedad Arqueológica Ebusitana' (Tarradell, 1974: 244; Fernández, 2000).

After the initial archaeological excavations of necropoli between 1903 and 1906, the museum, 'Museo Arqueológico de Ibiza', was founded in 1907 (Tarradell, 1974: 244; Tarradell and Font, 1975: 13, 15). A first phase of Punic discoveries in Ibiza took place thereafter but between 1910 and 1920 large-scale looting took place (Tarradell, 1974: 245; Tarradell and Font, 1975: 16, 20). Further information on the development of general archaeology in Ibiza is reviewed elsewhere (Tarradell, 1974; Tarradell and Font, 1975; Fernández, 1986: 151-158, 2000, 2001).

In these early excavations, the human skeletal material appeared to be of little value and interest. The first known published anthropological report was based on one Punic skull from Ibiza studied by Francisco de las Barras de Aragón (1930). This was followed by Santiago Alcobé´s (1940, 1943) studies on ten skulls from the Roman necropolis of *Can Flit*, probably dated to the third and fourth centuries AD (Colominas, 1942). After a period of over 30 years, Ilse Schwidetzky (1979) published a study based on a small Punic sample from *Puig des Molins* and a Roman sample from *Sant Antoni* studied by. As with Alcobé, these studies focused on cranial measurements and skull typologies in an attempt to understand the origin of the population. Work in the 1980s included the first studies on cremations from Ibiza. These were undertaken by Francisco Gómez Bellard (1983, 1985, 1989) and José Manuel Reverte Coma (1986b). Gómez Bellard (1989) also completed the first doctoral thesis based on medical anthropology in Ibiza. This thesis included, amongst many other interesting aspects, information on the demography and pathology of rural Punic inhumations, Roman cremations, Muslim inhumations and data on the living population. It appears that from

this time onwards, human remains in Ibiza have been viewed in a different light and seen as having an important role to play in interpreting the island's archaeological record. This appreciation of the valuable information obtained from skeletal remains, both human and non-human, has been constantly increasing up to today. In 1988 the first study on prehistoric remains was published from a site in Formentera, *Ca Na Costa* (Gómez-Bellard and Reverte Coma, 1988). In recent years, skeletal remains have been sent to the Spanish mainland for study. These have included Punic (González and Lalueza 1992, 2001; González, 1996) as well as Prehistoric bones (González and Lalueza, 2000). A modest number of four individuals representing the Late Antiquity-Byzantine period has also been published (Márquez, 2002).

Latterly, most research, which is still in progress, includes reports on Phoenician cremations and Punic inhumations (Gómez; and present author), Late Antiquity and Byzantine cemeteries (this thesis), and on more focused topics such as 'the origin of the Punic population' (Márquez-Grant, 2005, in press), diet inferred from dental calculus (Jordi Juan, pers. comm.), and palaeodietary analysis using stable isotopes (Márquez-Grant *et al.*, 2003; see also Márquez, 2003). In recent excavations (*Puig des Molins, Avinguda d'Espanya)*, the present author has collected, directly from bones *in situ*, samples for possible DNA analysis in the future.

Today, archaeology is an active discipline in Ibiza. Several excavations usually take place every year under the direction of the council (*Consell Insular d'Eivissa i Formentera*), the town hall (*Ajuntament d'Eivissa*), the museum (*Museu Arqueològic*

d'Eivissa i Formentera), private archaeological units or freelance archaeologists. Many of these excavations continue to yield human remains and great opportunities for further work. This could include analysis of skeletons from the medieval and post-medieval periods in order to understand the evolution of certain diseases.

Although there is a lack of specialist equipment and of specialists in physical anthropology on the island, the osteologist is increasingly proving to be an important part of the excavation team.

1.8 Considerations - evaluating morbidity in human skeletal remains

> *There are many sources of information on the history of disease including ancient medical documents, historical records, art, and the physical remains of ancient people (...). Undoubtedly human skeletons represent the most ubiquitous source of information on ancient diseases. Unfortunately this fact must be tempered with the knowledge that relatively few morbid conditions affect the skeleton in a way that leaves visible changes in dry bones.*
> (Ortner and Putschar, 1981: 2).

1.8.1 Dental and skeletal methods employed in assessing morbidity

Health can be defined as the state of physical and mental well-being. Disease can correspond to the physical, physiological or mental conditions that affect health.

Illness is the way in which a person experiences that disease. Morbidity refers to the prevalence of disease in a population.

The various dental and skeletal methods used in archaeological studies to make inferences about the health status of the population have included examination of growth (including stature), sexual dimorphism, dental asymmetry, enamel defects, infectious disease, and indicators of anaemia (e.g. *cribra orbitalia*). Most of these have been regarded as indicators of physiological stress (e.g. see Goodman *et al.*, 1984b, 1988; Goodman and Armelagos, 1989; Bush, 1991; Bush and Zvelebil, 1991; Ribot and Roberts, 1996; Lewis and Roberts, 1997; Humphrey and King, 2002) [20].

In biological anthropology, a 'stress' constitutes a physiological disruption that results from unfavourable environmental circumstances (Larsen, 1997: 6). These physical disruptions can be viewed as physical responses, either adaptive or maladaptive, that threaten the well-being of the individual (McElroy and Townsend, 2004: 264-265). These stressors can involve internal factors such as the genetic makeup, as well as external factors such as culture (Goodman *et al.*, 1984b, 1988; Goodman, 1991; Humphrey and King, 2000). The way in which humans adapt to the

[20] The concept of 'stress' was first developed by Hans Seyle in relation to hormones, although it has been employed in many different ways (Harrison, 1982: 198). For the development of this concept and discussion with regard to its use in physical anthropology, see Goodman *et al.* (1988) and Campillo (2001). *The Oxford English Dictionary* (1989, 2nd edition, Vol. XVI. Clarendon Press, Oxford) defines stress as 'An adverse circumstance that disturbs, or is likely to disturb, the normal physiological or psychological functioning of an individual; such circumstances collectively' (entry '3g', pages 885-886). With this regard, therefore, this thesis uses the word 'stress' to refer only to physiological disturbances that result in dental or skeletal anomalies. Often, trauma and osteoarthritis have been regarded in the literature as resulting from 'stress', although the term here has been related to mechanical stress. With this regard 'Physical strain or pressure exerted upon a material object; the strain of load or weight' (dictionary entry '5a', page 886).

environment is of interest to anthropologists (Harrison, 1982: 195). This adaptation will depend on biocultural factors (Ortner, 1983).

Culture can buffer or create stress (Ortner, 1983; Goodman and Armelagos, 1989). Examples of each are medical advances and industrial pollution. Today, long hours watching television is associated with obesity (Frary and Johnson, 2000), while motor vehicle accidents and drug abuse are a common cause of death among young adults (see Viciana, 2004). In the past, for instance, uncleaned pottery containers may have caused gastro-enteritis (Brothwell, 1967). Different socio-economic classes will respond unequally to stress (Schell, 1997).

Other dental and skeletal markers to assess morbidity have been less widely used. These include cranial base height and pelvic inlet morphology in relation to 'nutritional status' (Angel, 1982; Goodman *et al.*, 1984); vertebral lesions, Schmorl's nodes, in response to physical stress (e.g. Robb *et al.*, 2001); and Harris lines in long bones as a reflection of growth interruptions (McHenry and Schulz, 1976; Clarke, 1982; Mays, 1995). Another method has focused on the dimensions of the neural canal of vertebrae (VNC) perhaps reflecting certain anomalies and associated with a reduced life span (Clark *et al.*, 1986). Dental size and dental asymmetry have also been used as they are affected by both genetic and environmental factors (Garn *et al.*, 1979; Harris and Nweeia, 1980; Townsend *et al.*, 1994; Manzi *et al.*, 1997; Humphrey and King, 2000). In North America, the differences in asymmetry between agriculturalists and hunter-gatherers have been attributed largely to nutritional stress (Larsen, 1997a).

Dental crowding can also be taken into account because it can be dependent on health and nutrition during growth and development (see Price, 1945; Perzigian, 1977).

There are other sources of information related to morbidity that can be obtained from the skeleton, such as trauma and osteoarthritis. These two conditions, alongside periostitis, oral pathology, *cribra orbitalia* and skeletal robusticity have been included as a means of calculating a 'health index' for the population (Steckel *et al.*, 2002; Steckel, 2005). Other dental and skeletal indicators, all of which are not necessarily pathological, have aided in reconstructing lifestyle patterns, and may help to interpret morbidity rates. For instance, bone mass and exercise influence skeletal health (Karlsson, 2001; Heaney, 2002; Eastell and Lambert, 2002). Clues about exercise or activity patterns may be inferred from bone biomechanical adaptations (e.g. see Ruff, 2000), muscle markers (e.g. see Cameron, 1934; Dutour, 1986; Kelley and Angel, 1987; Kennedy, 1989; Lai and Novell, 1992; Molleson and Hodgson, 1993; Hawkey and Merbs, 1995; Capasso *et al.*, 1998; Robb, 1998; Guijo *et al.*, 1999b; Stirland, 2000; Al-Oumaoui *et al.*, 2004; Weiss, 2004) and some environmentally-induced non-metric traits (see Berry and Berry, 1967; Berry, 1975; Hauser and De Stefano, 1989) such as squatting facets. There is also the possibility to investigate activity-induced dental wear (e.g. Molleson, 1994; Turner and Anderson, 2003; Bonfiglioli *et al.*, 2004).

Nutrition, diet and subsistence economy play an important role in disease prevalence. For instance, malnourished individuals will be more susceptible to infectious diseases or growth disruptions. Diet will influence dental disease prevalence.

Subsistence patterns, such as farming, might influence rates of osteoarthritis. With regard to dietary reconstruction, the analysis of oral pathology (such as dental caries, abscess and *ante-mortem* tooth loss) is relevant.

The use of the above research opportunities is dependent on skeletal preservation, the nature of the burial assemblages (e.g. articulated, disarticulated) and the facilities available (e.g. microscopic, radiographic). In view of these requirements and with regard to the hypothesis, this thesis focused on the most commonly employed skeletal and dental indicators of health (Table 1.3), all of which were examined macroscopically. These relate to growth disturbances, infectious disease, trauma, osteoarthritis, as well as any indicators of diet (e.g. dental caries).

Table 1.3. Dental and skeletal indicators employed in the current research.

Indicator of health	**Elements employed**	**Age range in which stress can occur**
Stature	Adult long bones	Childhood and adolescence
Linear enamel hypoplasia	Permanent teeth	Childhood (and adolescence when including the third molar)
Cribra orbitalia	Skull	Primarily childhood
Periostitis	Long bones (tibiae)	All
Oral disease	All teeth and adult dental sockets	All
Trauma	All bones	All
Osteoarthritis	Adult long bone	Adulthood

In addition to this, two non-metric traits were examined: squatting facets and *torus auditivus*. Respectively, these provide information on habitual activities such as squatting and those related to exploitation of marine resources (e.g. diving).

With regard to these indicators of health and activity patterns, their relevant chapters (chapters 3 to 6) provide information on definitions, aetiology, materials and the methods employed.

1.8.2 The role of mortality and fertility

Mortality has been used often as a good indicator of a population's adaptation to the environment (Goodman *et al.*, 1988). Kelley and Angel (1987) regard longevity as the total outcome of "life stresses" on the individual. Longevity is a result of the combination of genetic, environmental, technological and behavioural factors such as the amount of sport practiced or alcohol intake (Angel, 1984; Abbott, 2004: 117). Females may live longer on average due to a biological basis to help the reproductive success of children and grandchildren (Hawkes, 2004).

Mortality and fertility have been used in palaeodemographical studies to infer something about a population's successful adaptation to the environment, and hence often the influence of nutrition and disease (Angel, 1969; Acsádi and Nemeskéri, 1970; Waldron, 2001). For instance, in underdeveloped countries or in societies with poor nutrition and sanitation there is a tendency for high infant mortality (Waldron, 1994, 2001). While 'mortality' can be defined as the corresponding process that results in death; 'fertility' can be regarded as the process which produces births (Hinde, 2002: 19).

1.8.2.1 Mortality

Mortality is influenced by environmental hazards such as pathogen loads, as well as social and cultural factors such as nutrition and medical care (Howell, 1976: 33). A lifestyle resulting in obesity, together with genetic susceptibility, might increase the risk of cardiovascular disease, stroke and kidney failure (Howe, 1972: 62; Ward, 1983; Cooper *et al.*, 1999). Female pregnancy might affect mortality rates due to a variety of factors (Wells, 1975; Ortner, 1998: 81). In developing countries maternal mortality accounts for between 50% and 98% of female deaths (Ortner, 1998: 81; see an archaeological example in Campillo *et al.*, 1998). Individual behaviour, such as suicide or assassination, influences mortality (Chamberlain, 2000a). The imposition of laws in the past (e.g. Rouche, 1987: 460; Lascaratos and Poulakou-Rebelakou, 2000) will have buffered against some of these behaviours.

Infant mortality is a good indicator of the overall health of the population (Goodman *et al.*, 1988). Infant mortality between birth and one year of age is the best indication of a population's health, socio-economic well-being and quality of life (Stockwell, 1993). The high rate of mortality during the first five years of life results from the child being more at risk from a combination of infection and malnutrition, although this may have begun earlier in the intra-uterine life (Eveleth and Tanner, 1990: 194). Child survival depends both on the genetic makeup of the individual but also on the environment in which he or she is born and brought up: socio-economic factors, his or her immune system, nutrition, adult carers, cultural values, age at

weaning, work requirement of parents, ethnicity, season in which child was born, water resources, housing, social welfare and medical care (Chamberlain, 2000b; Rousham and Humphrey, 2002; Ingvarsson-Sundström, 2003). However, cultural factors such as infanticide and child sacrifice can also cause a high mortality rate.

Childhood deaths can be viewed as a 'wasted' parental investment as they are of 'value' to parents in terms of biological (e.g. transmission of genes) and socio-economic insurance for parents (Chamberlain, 2000b: 209). Nevertheless, infanticide (Hausfater and Blaffer, 1984; Scrimshaw, 1984), the killing of a person after birth, was common in the past[21]. Infanticide has been traced archaeologically in a number of studies both from Punic, Roman and Byzantine contexts (Moffatt, 1986: 714-716; Smith and Kahila, 1992; Mays, 1993, 2000a; Faerman *et al.*, 1998; Green, 1998; Scott, 1999; Mays and Faerman, 2001; Harris, 2004). It may have been practised under a number of different circumstances such as the inability of the family to care for the newborn, the sex of a child, multiple births or perceived physical impairment (Dasen, 1997: 58-61). For instance, people with hearing impairment may have been abandoned in ancient Greece or drowned in Roman times, although it does not seem to be necessarily the case in Punic contexts (see Macías *et al.*, 1999).

[21] Today, apart from direct killing, deaths may also result indirectly from child abandonment, as often seen reported in national newspapers. Child abandonment or exposure was common in the past, for instance in Roman society (Harris, 1994). For practical reasons, the term 'infanticide' is used here to cover the death of a child through direct killing or indirectly through abandonment. However, it must be noted that arriving at a definition of infanticide is not easy, and other terms such as 'pedicide' may be more appropriate in some situations (Dickemann, 1984).

In a religious context, sacrificing can symbolize the destruction or removal of something or someone in order to get something beneficial back (Green, 1998: 169). The most conclusive evidence for child sacrifice in the Punic world comes from Carthage and Sicily, and yet whether the children died from sacrifice or natural causes is highly debated (see Weyl, 1968; Fedele, 1977; Benichou-Safar, 1981; Sager and Wolff, 1984; Lipiński, 1988; Brown, 1991; Aubet, 1993a; Lancel, 1995; Moscati, 1996; Avishani and Smith, 2002; Schwartz *et al.*, 2002). Sacrifice in Carthaginian times involved newborn babies although older individuals between 1 and 3 years were also killed (Lancel, 1995: 249-250; Schwartz *et al.*, 2002).

1.8.2.2 Fertility

While fecundity is the ability of a female to become pregnant or a male's ability to contribute to a pregnancy, fertility is the actual reproductive output (live births) (McElroy and Townsend, 2004: 238-239). There are many factors that contribute to fecundity and fertility in past populations (McElroy and Townsend, 2004). Physiological characteristics such as fatness contribute to a woman's reproductive success (see Howell, 1976). Extended lactational amenorrhea would have reduced the number of offspring (Stuart-Macadam, 1998: 57). Environmental factors are also important. Nutrition influences the age of menarche (Gracey, 1987: 185). In antiquity, cultural factors include the provision of benefits to parents with more than three children (Dasen, 1997: 56; Veyne, 1987a: 13), prostitution (Brown, 1987: 242; Sherratt and Sherratt, 1993: 367; Taylor, 1996: 205, 207; Blázquez, 2003: 359; Clarke, 2003:

60), abortion and methods of contraception (Veyne, 1987a: 12; Cappel, 1991: 607-608; Blázquez, 2003: 447)[22], leading a monastic life and castration in men (Moffatt, 1986: 717-719; Bullough, 2002: 3, 6). More indirectly, climatic factors such as rainfall affecting food supply might influence fertility rates (Ward and Weiss, 1976: 18).

1.8.3 Palaeodemography in Ibiza: problems

Palaeodemography aims to reconstruct the demography of past populations. This can be attempted by examining the age and sex composition of the population, the mortality rate in different age categories, the survivorship curve and life expectancy. Partly due to some of the factors affecting mortality and fertility (Section 1.8.2), palaeodemographic interpretation is complex.

In addition, there are many methodological problems that have been highlighted in the literature (Acsádi and Nemeskéri, 1970; Brothwell, 1971, 1972; Bocquet-Appel and Masset, 1982, 1985; Buikstra and Konigsberg, 1985; Buikstra and Mielke, 1985; Johansson and Horowitz, 1986; Boddington, 1987; Wood *et al.*, 1992; Masset, 1999; Ubelaker, 1999; Chamberlain, 2000a; Milner *et al.*, 2000; Scheidel, 2001; Konigsberg and Frankenberg, 2002)[23]. Model life tables from pre-industrial or developing countries

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[22] See also on-line information from a colloquium entitled "Antiqua Medicina: *Aspects in Ancient Medicine*", held at the Health System of the University of Virginia, in 1997. The information regarding contraception can be found in the section on 'Ancient Gynaecology' at www.med.virginia.edu/hs-library/historical/antiqua/textg.htm. The use of contraception would also depend on the religious beliefs at the time, for instance the prohibition of contraceptive methods in Christian times and the promotion of procreation (Blázquez, 2003: 455; Fulghum, 2003a: 139, 2003b: 276-278; Walker, 2003: 218).

[23] These problems are related to the study of human skeletal remains. However, palaeodemography also concerns the demographic study of cemeteries where epigraphic evidence (tombstones) is available. Even in these cases, where ages at death are given, there are problems relating to under-representation of infant

(see Acsádi and Nemeskéri, 1970) and, more recently, statistical methods have been developed to attempt to counteract some of these problems (see Chamberlain, 2000a; Hoppa and Vaupel, 2002).

These problems include concerns with the accuracy of age and sex estimation, sampling procedures, and the fact that demographic reconstructions only represent a mean for the whole period of use of a cemetery. However, the most important problem is that of sample representativity (Brothwell, 1972: 75; Waldron, 1994; Dutour *et al.*, 2003: 154). How representative is the sample of the period and the once living population? Not all those that died were buried, not all of those buried were excavated, neither were they all preserved and not all might have been submitted for anthropological analysis.

Preservation may be biased towards young adult skeletons, with the fragile bones of juveniles and the elderly often not as well preserved (Walker *et al.*, 1988; Guy *et al.*, 1997; Dutour *et al.*, 2003). Under-representation of infants and children is a common problem and can greatly affect the demographic survivorship curves (Chamberlain, 2000a). This under-representation has been explained by different factors ranging from cultural, preservation and excavation biases (Chamberlain, 2000b: 210; Wagner *et al.*, 2000: 614-615). For example, there is archaeological evidence for infants buried elsewhere (e.g. Carrilero and López, 1994: 261; Filloy, 1997; Scott, 1999: 126; Chapa, 2003: 120-121). Disturbances in cemeteries (e.g. vandalism) will

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deaths, problems in sample representativity, and inaccuracy (exaggeration, underestimation) of age at death (Durand, 1960; Hopkins, 1987; Salmon, 1987).

also affect the preservation of skeletal samples. Violation of tombs was a criminal offence in Late Antiquity although it still kept occurring (Toynbee, 1971: 76; Johnson, 1997: 39-40).

Some bodies may have not been buried, as observed in many cultures (see Parker-Pearson, 1999). Others, such as murderers, women who died in childbirth, suicide victims, and people perceived to have some disability may have been treated differently and buried elsewhere (Taylor, 2002: 239; Hope, 2000). In long voyages, deaths in ship crews might require dropping the corpse(s) into the sea in order to avoid disease amongst the sailors (Pollard, 1999: 40). In times of war, many healthy young adults would have been enlisted in the army. Those soldiers who died in battle, or who were captured and later sold as slaves (see Thompson, 2003), would have been buried far from their homeland. Alternatively, some cemetery samples may have been biased towards one gender preference, for example the presence of males only in most medieval military contexts (e.g. see Boylston *et al.*, 2000) and monastic cemeteries (e.g. Hershkovitz *et al.*, 1995; Sheridan, 1999).

The requirements for palaeodemographic analysis include sample representativity, accurate knowledge of sex and age of the individuals, migration information, background information on burial context, suitable demographic methods, the detection of all age categories present in the cemetery, knowledge on whether burials are placed randomly, and selection of the excavation for osteological analysis (Acsádi and Nemeskéri, 1970: 57-58; Ubelaker, 1999: 135-136). Many of these

requirements could not be met with regard to the Ibizan material. Therefore, the analysis (Chapter 2) was restricted to obtaining the minimum number of individuals in each sample, and an age and sex profile of the population when possible.

1.8.4 Ibiza: predicted trends in stature, morbidity rates and nutrition

Most of the indicators mentioned in preceding sections are a result of a combination of genetic and environmental factors.

With regard to the hypothesis, economic prosperity in the Punic period should reveal low morbidity rates in the population, both in the urban and rural, in males and females, and in all age groups. In comparison with the Late Antiquity-Early Byzantine period, the Punic population should display lower morbidity levels, assuming economic prosperity leads to better health. With regard to stature, the average stature from Period 1 should be higher than in Period 2. With regard to nutrition, in the former period there should be better and more adequate nutrition among the population than in the latter period.

Certain trends can be predicted in relation to the characteristics of each dental and skeletal parameter. For instance, enamel hypoplasia is common in individuals living in underdeveloped countries today and in marginal groups of society where nutrition is inadequate and where living conditions are poor (see Dobney and Goodman, 1991; Larsen, 1997a; Agarwal *et al.*, 2003). Severe nutritional deprivation

during the Great Chinese Famine (1959-1961) is correlated with a high frequency of enamel hypoplasias (Zhou and Corruccini, 1998). In addition, some of the highest frequencies of LEH have been found in past American slave populations, probably associated with factors such as poor nutrition, bad hygiene, improper housing and disease (Blakey *et al.*, 1994: 382). Such associations have also been put forward as an explanation for the increase in hypoplasia in a sample of Australian aborigines from recent times (Littleton, 2005).

Deteriorating conditions may also lead to a higher incidence of dental caries in archaeological populations where the poorer classes would mainly consume cereals as opposed to meat (e.g. Manzi *et al.*, 1999; Bonfiglioli *et al.*, 2003), the latter foodstuff being less caries promoting. High frequencies of dental caries can appear in individuals or populations who base their diet mainly on vegetables (Hillson, 1979). In general, low socio-economic status is associated with an increase in caries. This is because poor people have to rely on cheaper foodstuffs such as carbohydrates (e.g. bread) other than meat or fish.

With regard to stature, trends in increased stature during the last century (e.g. Olivier, 1980; Padez, 2002) have been attributed to general improvements in living conditions. In China, economic reforms in the 1970s were reflected in an increase in mean stature height (Shen *et al.*, 1996).

When infectious diseases are considered, their presence on the skeleton reflects bacterial infection (Roberts and Manchester, 1995: 125). The presence of infections may be associated with malnutrition, poor sanitation, and living conditions in general. Trauma may be present more often at times of social unrest (e.g. Van Gerven *et al.*, 1995). Predicting these trends is not as straightforward, however, and the problems and limitations of such predictions and interpretations are discussed below.

1.8.5 Problems and limitations in palaeopathology

Palaeopathology is the discipline that studies disease in human remains from the past, although it can also be applied to non-human remains (fauna).

One limitation affecting assessment of morbidity in the past is that the majority of diseases do not leave their trace on the bone. In some cases, soft tissue trauma, some blood-vessel disorders, congenital torticollis, and neurological diseases may be inferred from skeletal abnormalities (Dastugue, 1980: 3). This limitation also affects the analysis of cause of death, which in archaeological skeletal remains is almost impossible to identify. Many deaths are caused by organ failure and would require soft tissue preservation (see Roberts, 1996). The context provides clues but even in a battle assemblage, for instance, although the general assumption of death in battle is correct and will account for most deaths, in some individuals the primary reasons may be others. For instance, a heart attack in a soldier during a battle may have provided an opportunity to his enemy to ensure death by a blow to the head.

There are also problems of diagnosis (Dastugue, 1980). The majority of diagnosis on skeletons is limited by visual examination, either microscopic or macroscopic. Bone lesions only involve either bone formation and/or bone destruction and it is not always possible to obtain a more specific diagnosis. Where diagnosis is obtained, this may only be a mere approximation, alongside a number of differential diagnoses (Dastugue, 1980: 5)[24]. In addition, diagnosis is dependent on preservation. Reliable identification of specific infections such as leprosy, tuberculosis or syphilis (see Roberts and Manchester, 1995) will require good preservation and presence of elements where the lesions manifest themselves, in these cases the skull, spine, long bones and hand and foot bones. Even if a skeleton is complete, it may be that the bone surfaces are too deteriorated to allow palaeopathological examination.

1.8.5.1 Further considerations

There are other minor considerations in relation to the predictions of better health in Period 1 due to economic development and overall prosperity. In relation to caries, it may be that an improvement in living standards might be correlated with degeneration of oral health (Price, 1945; Bennike, 1985). Other contradictory results

[24] It is worth highlighting the importance of *in situ* observations by an osteologist. Some abnormalities such as scoliosis or locomotor problems in articulated skeletons can only be seen on the field (Dastugue, 1980). For instance, scoliosis, which is an abnormal lateral curvature in the spine, would require observation of most of the vertebral column in the laboratory. However, when lifted from the ground, vertebrae may have fragmented and reconstruction in the laboratory may be difficult. Likewise, possible cause of death may be viewed with regard to warfare projectiles embedded in bones (e.g. Armendariz *et al.*, 1994), although closer examination of bones *in situ* would be required by the osteologist before lifting the skeletons.

may be that intensive economic productivity in Period 1, as evidenced through coin production (Planas *et al.*, 1989), intensive pottery manufacture (Ramon, 1995, 1998, 1990-1991) and agricultural activity (Gómez, 1986), would have resulted in an increase in trauma (e.g. fracture) and joint disease (e.g. osteoarthritis). Costa and Fernández (2000) have commented that economic development and increased intensification might lead to a slave-like production system with the workforce getting poorer. This would be in contrast with the Late Antiquity-Early Byzantine period where rural occupation is almost non-existent (Gómez, 2000: 35).

Although it may be debatable, there is some logic in assuming that osteoarthritis and bone fractures can result from mechanical demands on the joints (Jurmain, 1980, 1991) and accidental injuries to the bones respectively. If this is true, then the workers in Period 1 might have been more at risk of acquiring these conditions if production of goods was more intense in this period.

The relationship between increased productivity associated with increased risk of injury is observed below in Diagram 1.1:

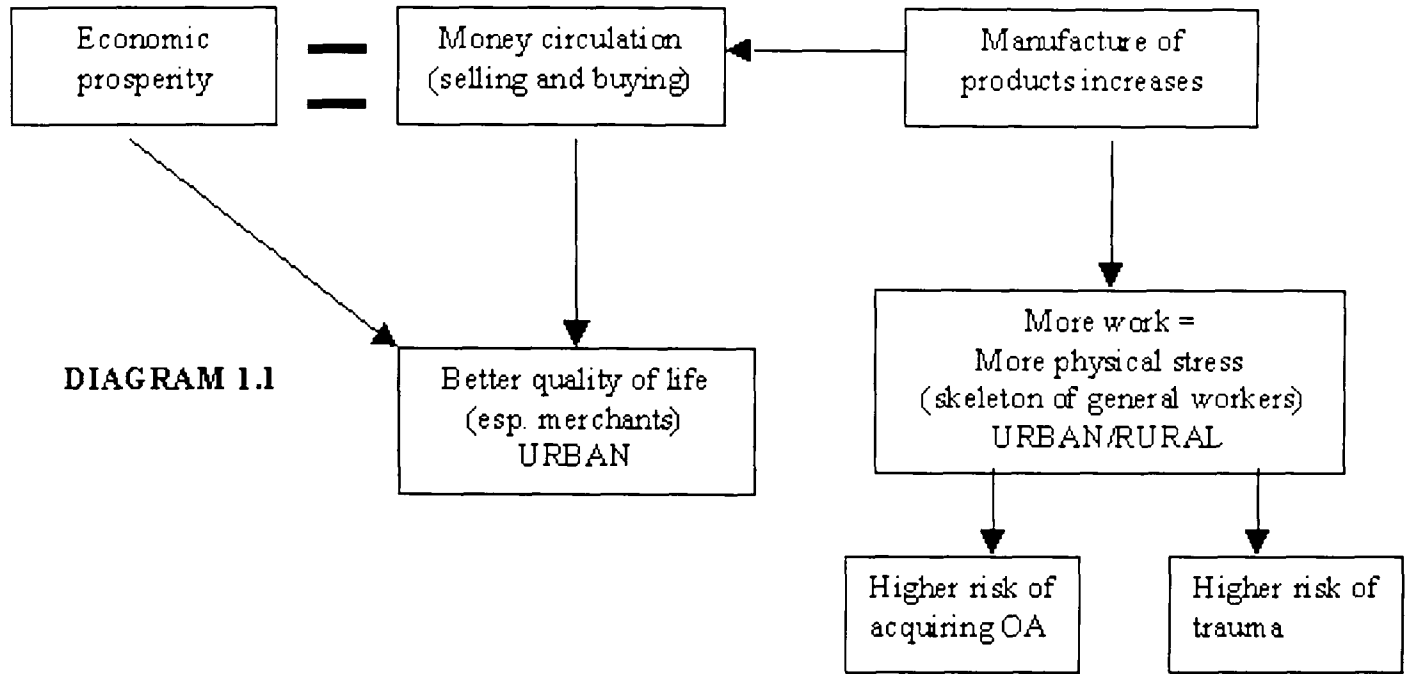


DIAGRAM 1.1

If there is more commerce there is more demand on products, and therefore more pressure on those people to produce. Those labourers especially from the lower economic classes would be working to obtain raw materials and to manufacture products, therefore increasing the risk of occupational related injuries. Cases in clinical medicine seem to reveal that activity subjecting the joints to repetitive movements, to overuse and extreme loading and torsion are correlated with presence of osteoarthritis (Arokoski *et al.*, 2000: 188). Farmers have a high prevalence of hip and knee OA and other musculo-skeletal disorders associated with heavy workloads and working in difficult positions (Jordan *et al.*, 1995; Park *et al.*, 2001; Walker-Bone and Palmer, 2002; Holmberg *et al.*, 2003). Potters also suffer from a number of musculo-skeletal disorders (Laraqui *et al.*, 2000). To complicate matters further, however, exercise can help prevent osteoarthritis unless intensive high levels of impact and torsional loading

are present in the occupations (Knüsel, 1993; Lane, 1996; Manninen *et al.*, 2001; Waldron, 2001; Conaghan, 2002; Jones *et al.*, 2003).

Moreover, with regard to trauma, a sample from a more favourable living environment might show higher frequencies of trauma than a sample from a squalid environment. Simple examples of this are pastimes such as sport or sport-related activities, such as equestrianism, which were present in ancient times (see Harris, 1972; Milner, 2004). Today children playing can end up fracturing bones (Norton *et al.*, 2004) and the past is no exception to this. In Byzantine times there are references to children *'falling down wells, cracking their heads on rocks, and falling off buildings while playing'* (Moffatt, 1986: 707). Matters can be more complex if exercise is taken into account. Continued exercise in older individuals may reduce the fracture prevalence in the population (Karlsson, 2002). This relationship between fracture and exercise is not only associated with a stronger skeleton, but also with better mobility and quicker reflexes (Karlsson, 2002: 699).

Finally, sex[25] and age biases need to be considered. Some fractures are age and gender-specific (see van Staa *et al.*, 2001; Glencross and Sawchuk, 2003; Dimich-Ward *et al.*, 2004). With regard to sex, there are differences in the immune response to

[25] Sex refers to biological sex, as opposed to gender, the social construct. These two concepts are different (Nelson, 1997; Walker and Collins, 1998). Armelagos (1998: 1) points out that 'There is a consensus in anthropology that sex is defined by the biological differences between males and females determined at the moment of conception and enhanced in subsequent physiological development. Sexual differences include features of the chromosome, genitalia, and other anatomical structures related to secondary sexual development. There is also agreement that gender is the cultural construct in which individuals are socially classified into categories such as male and female, or masculine and feminine in our culture. Other cultural systems recognize more than two gender classes'. An individual's gender identity may even change with age (Ingvarsson-Sundström, 2003: 168).

disease (Stini, 1985; Armelagos, 1998; Grauer and Stuart-Macadam, 1998; Ortner, 1998; Roberts *et al.*, 1998). There is an enhanced immune system in women, probably associated with the hazards of pregnancy and childbirth (Stini, 1985; Ortner, 1998). By contrast, pregnancy might predispose women to dental caries (Laine, 2002).

An example of how age is important is reflected in the following example. Population A may have a higher prevalence of osteoarthritis than Population B. It could be interpreted that Population A suffered more physical demands and harder life conditions than Population B, but in fact Population A may be the healthiest. Osteoarthritis is common among older individuals. Many young adults in Population B, for whatever reasons, may have not been successful (e.g. malnourished, too frail, maladaptive) in reaching old age (see Wood *et al.*, 1992). By contrast, Population A had a large proportion of older individuals, exhibiting therefore the success of the population to live longer. The older an individual became, the higher the probability of acquiring lesions such as trauma and osteoarthritis due to longer exposure to their contributing factors during life. For instance, Grauer (1993) found that diseases were more frequent with increasing age in a sample from Medieval York. This age factor introduces a word of caution when comparing disease prevalence between samples (Glencross and Sawchuk, 2003).

1.8.5.2 The 'Osteological paradox' (Wood *et al.*, 1992)

Wood and colleagues (1992) highlighted some potential problems that are significant when interpreting morbidity rates from past populations. The number of individuals at risk of illness or death in the population is unknown, as is their susceptibility and length of exposure to disease.

Moreover, a skeleton with disease may have belonged to a healthier individual than that from a skeleton without disease (Wood *et al.*, 1992), hence the paradox. An example with infectious disease is applicable. Infections begin as a vascular phenomenon and what is observed in the bone is the chronic stage of the infection (Ortner and Putschar, 1981: 104-105). Individuals that are exposed to an infection and that have a poor diet, poor sanitation and unfavourable living conditions are more vulnerable to early death than others (Larsen, 1997a). The stress factors must be severe and/or of a long duration if they are to leave a mark on the skeleton (Goodman *et al.*, 1988: 177). Furthermore, the human body requires a relatively good immune response if the disease is to result in bone changes, although not too good as to allow recovery before reaching skeletal involvement (Ortner, 1998: 79). Only a small percentage of the infected population will exhibit skeletal lesions. Those with the lesions are more likely to be better nourished which in turn increases the immune system and resistance to disease (Wood *et al.*, 1992; Ortner, 1998: 80, 82). The absence of a lesion can indicate that the person did not suffer from any infection, that the person suffered from an infection but recovered quickly or the person was too frail to resist the disease and died

immediately (Wood *et al.*, 1992). Hence, it is important to note that in theory *'periods of malnutrition can lead to decreased evidence of skeletal disease in archaeological populations, creating the impression of better health when, in fact, individuals were very sick and died quickly'* (Ortner, 1998: 82). For this reason, skeletal lesions cannot be interpreted in a straightforward way (Wood *et al.* 1992). Similar problems of interpretation arise with dental defects such as linear enamel hypoplasia (LEH).

1.9 A biocultural approach

> *Stated very simply, the individual is the expression of five interacting and interdependent fundamental factors: (1) a system of genetic relations, (2) a system of developmental relationships influenced by the maternal uterine environment, (3) family environment, (4) general socio-economic environment, and (5) general physical environment.*
>
> (Montagu, 1960: 503)

As stated before, a biocultural approach takes into account information from a number of disciplines (e.g. climatology, zooarchaeology) and from a number of sources (e.g. documentary, faunal remains, pollen analysis, artefacts). The kind of information studied can vary from one period to another depending on available evidence. In Ibiza there was more archaeological information available for the Punic period while the Byzantine period provided more documentary sources. Nevertheless, hopefully this study will provide a first step towards putting in place a biocultural framework within which to assess the skeletal remains studied in Ibiza.

Human adaptation and ability to cope in a particular environment depends on genetics, physiology and culture (McElroy and Townsend, 2004: 80). Climate, population density, patterns of migration, industrial innovations, land use, microbial adaptation, will determine the relationship between disease organisms and humans (McNeill, 1976: 108-109; Mackerness, 1998: 2, 9). Wells (1964: 17) summarises this interaction by stating that 'The pattern of disease or injury that affects any group of people is never a matter of chance. It is invariably the expression of stresses and strains to which they were exposed, a response to everything in their environment and behaviour. It reflects their genetic inheritance (which is their internal environment), the climate in which they lived, the soil that gave them sustenance and the animals or plants that shared their homeland. It is influenced by their daily occupations, their habits of diet, their choice of dwelling and clothes, their social structure, even their folklore and mythology'.

The biological anthropologist should have a perception that includes biocultural, evolutionary and cross-cultural perspectives (Stuart-Macadam, 1998: 45-46; see also Roberts and Cox, 2003). The reconstruction of health and disease in a population cannot be complete without considering the wider economic, social, political, technological, cultural and environmental contexts amongst others. The different skeletal indicators are thus best interpreted in combination with other archaeological, historical and scientific data. This approach has been known as the 'biocultural approach' or 'bioarchaeological approach' (e.g. see Bush and Zvelebil, 1991; Sheridan, 1999).

By taking into account data from a number of disciplines, the aim was to attempt to create an overall framework in which to interpret the health of the populations, and to understand some of the factors that might have contributed to disease prevalence. Thus, there was a need to consider additional sources such as documentary evidence, faunal remains, burial practices and settlement patterns will aid in the reconstruction of morbidity. This additional information will be integrated in discussions below.

1.9.1 Climate and ecology

Celsius (1st BC-1st AD), in his work *De Medicina* (Book II.I.8-12), already noted how weather affected disease. The science of biometeorology includes how climatic factors affect the health of people and animals. Themes researched include mortality in relation to temperature (see Howe, 1972: 17-18; Bowden *et al.*, 1981; Baker, 1988), pollen concentrations, clothing in relation to body thermoregulation, climate in relation to food poisoning and the influence of climate on emotional states and disease[26].

[26] See the *International Journal of Biometeorology* (International Society of Biometeorology). Environmental factors such as climate in relation to disease could also be classified under 'Medical Geography'. This discipline involves 'the comparative study of the incidence of disease and the distribution of physiological traits in people belonging to different communities throughout the world and the correlation of these data with features of the environment.' (Howe, 1972: 2). The foundations of medical geography are attributed to Hippocrates in his treatise *Airs, Waters, and Places* (Grmek, 1989: 94).

Island colonisation, cultural diversity and the social, economic and political changes in society, can be determined by the physical environment (Shackleton *et al.*, 1984: 308; Cunliffe, 1995: 5, 6, 9; Pagel and Mace, 2004). Climate may have affected subsistence due to changes in food availability. For instance, increased arid conditions contributed to a change from a hunter-gatherer to a pastoral nomadic economy in pre-Neolithic Sahara (Shaw, 1976); or a different pattern of mollusc consumption in ancient Spain due to sea-surface temperature (Serrano *et al.*, 1997).

Temperature, humidity and water habitats (Borca, 2000) will regulate the distribution of insects that might bring disease. Insects are important in transmitting disease and the distribution of species is regulated by factors such as temperature, humidity, dead wood and water habitats (Kenward and Allison, 1994; Lamb, 1982: 154; Howe, 1972: 45). The quality of the water supply and the degree of hardness can be associated with cardiovascular disease (Howe, 1972: 34-35, 37), while fluoride will protect teeth from dental caries (Hillson, 1996; Jones and Worthington, 2000). Natural catastrophes such as earthquakes would have affected mortality rates in archaeological populations (see Gasparini, 1989; Guidoboni, 1989; Stiros, 2001). Shipwrecks found around Ibiza (see Parker, 1992) may have been the result of climatic factors, such as tornadoes and waterspouts affecting the Balearics today (Gayà *et al.*, 2001). Lead pollution affects health. Large-scale lead pollution especially during the Punic wars has been confirmed through scientific data (Hong *et al.*, 1996; Rosman *et al.*, 1997; Renberg *et al.*, 2001).

From 8000 BP southern Europe has seen a general increase in temperature (Mann *et al.*, 1998; Davis *et al.*, 2003; Luterbacher *et al.*, 2004). Data from the Balearic Islands is very limited, but provides evidence of a change in vegetation since 4000-2000 BP associated to human influence (Yll *et al.*, 1999). Data from Europe have shown a maximum rainfall at around 400 BC, in contrast to periods of drought at around 300-400 AD (Lamb, 1968, 1982). Sea levels were also higher just after the Roman period (Lamb, 1982: 145) and some coastal towns in North Africa were submerged as a result (Oueslati, 1995).

1.9.2 Subsistence and economy

Subsistence depends on geographical and climatic factors too. The geomorphology of the Ibizan land makes it a hostile environment for agriculture in which a much greater effort is required from human technological adaptations (Miguélez, 1989: 9). Information on subsistence economy can be found from material culture (e.g. tools, settlement patterns, buildings) and biological remains such as palynological, botanical and faunal remains. Archaeobotanical studies in Spain have provided insights into olive cultivation since prehistoric times (Terral and Arnold-Simard, 1996; Terral, 2000; Terral *et al.*, 2004). The vine has also been cultivated and produced since ancient times (Guerrero, 1995b; Olmos and Sánchez, 1995), as well as *garum* (Curtis, 1991; Prowse *et al.*, 2004) and honey (Bonet and Mata, 1997).

Artefactual evidence has provided clues as to trade and products. Pottery is the most obvious example. Fish scales have been found in amphorae from the western Mediterranean (Maniatis *et al.*, 1984: 205). Shipwrecks, some just off the coast of Ibiza, have also been a wealthy source of information (e.g. Vilar-Sancho and Mañá, 1964, 1965; Cerdà, 1978; Guerrero *et al.*, 1987; Parker, 1992). The island also traded with glass artefacts (see Ruano *et al.*, 1996), likely with salt (Fernández Uriel, 2000) and other materials that have not been preserved such as wool, perfumed-oil and agricultural products (Gill, 1988).

1.9.3 Settlement patterns

A city may have several boundaries such as a physical, a ritual, a commercial, an economic and a legal one, sometimes not corresponding with each other (Patterson, 2000: 86). Settlement evidence may identify industrial areas and locations as to industrial pollution and waste. Housing is important in terms of disease. Respiratory diseases may be more prevalent from indoor pollution in poorly ventilated houses (Kilpatrick, 2001). Cohabitation between humans and animals, such as in medieval rural houses from Britain, may also influence the presence of disease (Roberts *et al.*, 1998: 107). In addition, hospitals in Christian cities can be identified (Miller, 1985) and may provide information about basic care for the poor.

Demographic analysis, either from settlement size or number of tombs, may inform about population density. Increased population density facilitates the spread of

infections. Punic and Roman towns were densely populated (Aubet, 1993b: 153, 166; 1995: 58; Carreras, 1995-1996) and Punic Ibiza was no exception (Mañá, 1948: 206; Costa, 1994; Julbe and Pascuet, 2001). Information on Punic architecture derives from studies of other cities as well as Phoenician establishments (see Cintas, 1976; Ramon, 2003a; Aubet, 1995, 2000; Maass-Lindemann, 1994: 282-283). Punic *Eivissa* would have comprised a great port (see Schulz and Maass-Lindemann, 1997), defensive walls and living dwellings, in an area well over 21 hectares excluding the main harbour area and the periphery where the pottery workshops were located (Ramon, 2002). Information on water supply is relevant to disease. Punic and Roman water cisterns, drainage pipes and catchment chambers have been found in Ibiza (Ramon, 1995a, 2000a, 2002) as well as Carthage (Wilson, 1998: 65-68, Fantar, 1993: 33-34).

Differences in rural and urban architecture in Punic Ibiza have been observed (Díes and Matamoros, 1989). Rural settlements in Punic Ibiza were dispersed throughout the countryside (Román; 1920; Gómez; 1986, 2000; Tarradell *et al.*, 2000; Ramon, 2001: 74-75). These rural units would probably consist, at least in the beginning of the fifth and fourth centuries BC, of small human groups, possibly families or blood related individuals, as well as free-men (Benito *et al.* 2000: 307), although servants may have been present too (Fernández and Fuentes, 1983; Gómez, 2000: 357). Some ethnographic evidence from traditional houses today is also useful (Miguélez, 1989) and shows some resemblance to buildings from ancient times (see Ramon, 1995a).

Much information can be found with regard to Roman, Late Antique and Byzantine towns and houses (Mango, 1980; Veyne, 1987b; Patterson, 2000; Foss, 2002). Some information may be relevant with regard to squatting facets. Little furniture was present in Roman homes apart from beds, round tables and wardrobes (Veyne, 1987b: 315-316). The presence of aqueducts and baths in towns, as well as the location of cemeteries, can be considered when interpreting health.

1.9.4 Medical care, dental care and personal hygiene

When skeletal lesions are considered, whether the disease affected the bone, and to what extent, can depend on health care[27]. Some mortality may be prevented through medical care. Knowledge of medicine, surgery, pharmacy and treatment for a variety of diseases has been present since as far back as the second millennium (Hæger, 1988; Borobia, 1990, 1991a; Nutton, 1996; Weatherall, 1996; Porter, 1996a, 1997).

Little is known about medicine and medical care in Punic times (Yuval, 1972; Borobia, 1991b). Medical surgical implements have not been clearly identified in Punic tombs (Borobia, 1991b: 28)[28]. There is evidence in relation to magic, beliefs, and deities such as Eshmun and Tanit (Borobia, 1991b). These deities were related to healing and fertility respectively and were venerated in Ibiza (Fernández, 1975). Anthropological studies inform about illnesses being brought by infraction of a taboo,

[27] Folk medicine in Ibiza has been brilliantly compiled by Gómez (1989).

[28] There is mention that some objects found at *Puig des Molins* may be surgical instruments (Mañá, 1953: 123; Fernández, 1992: 193), but these have not yet been published. These tools include knives, needles, pliers and spatulas. Future research could examine these artefacts and study whether they were related to medical practice.

by evil spirits or as a punishment from the gods (Borobia, 1990: 16-17). Treatment or prevention of these beliefs may employ amulets, talismans, scars, plants, massages, minerals, colours, blood, perfumes, sacrifices or representations of body parts (Millàs, 1923; Borobia, 1990; van Dommelen, 1997: 318; Fulghum, 2003b: 281). *Garum*, a common foodstuff of the ancient diet, was also known for its medical properties, especially for disorders of the digestive tract (Curtis, 1991).

Medical knowledge in Late Antiquity and Byzantine times is better known (Hadot, 1998)[29]. Doctors would come from a variety of backgrounds (Hadot, 1998: 249-250). In Ibiza, there is epigraphic evidence for the presence of at least one doctor since the second century AD (Juan, 1988: 51). In Byzantium two tendencies in medicine were present: one based on magico-religious beliefs, associated with the opening of institutions to provide shelter and food since the fourth century AD; the other based on the Graeco-Roman medical tradition (Risse, 1993: 12), including advances such as varicose vain surgery (Lascaratos *et al.*, 2001). Care of the sick was recognised as a religious duty (McNeill, 1976: 121-122). In the fifth century AD healing was enhanced with religion (Porter, 1997: 83). Christian cities had hospitals for the poor, the homeless, and the sick (Miller, 1985). Apart from medical treatment, amulets and prayers were present as a course of action (Fulghum, 2003b: 276).

[29] See http://www.med.virginia.edu/hs-library/historical/antiqua/anthome.html for access to information such as Greek and Roman Medicine, ancient gynaecology, Byzantine medicine, and surgical instruments.

Medicine of Graeco-Roman origin was also successful. Examples of surgical interventions on skulls have been found in Spain (Baxarias *et al.*, 1999) and Carthage (Brisko and Dozier, 1986), dated to Late Antiquity and Byzantine times respectively.

Evidence for dental care, such as treatment for toothache, tools for extracting teeth and dental prosthesis can be traced as early as the seventh or sixth centuries BC (Celsius, *De Medicina*, VI.13; Pliny, *Natural History*, Books XX; XXIII.54; XXVIII.49; Clawson, 1934; Brisko and Dozier, 1986; Emptoz, 1987).

Clothing can influence susceptibility to abnormalities such as rickets (see Beck, 1997) or injuries from working without appropriate gear. Clothing also relates to personal hygiene (Roberts and Cox, 2003: 8). If poor people owned few clothing items, especially made from wool, then washing would be restricted, thus influencing the presence of parasites such as ticks and fleas (Roberts and Cox, 2003: 256).

Clothing may also indicate biomechanical pathologies, for example, through wearing bad shoes. Ill-fitted shoes may result in degenerative joints in the big toe (Farwell and Molleson, 1993: 199). In addition, the raw materials may indicate which industries were present and therefore which professions in society. It can also inform about social classes, profession and even on attitudes towards hygiene and sexuality. It will also reveal adaptations to hot and cold weather that may affect prevalence of disease, such as respiratory infections.

Information on Punic clothing has derived from documentary evidence but also from terracotta figurines, some of which have been found in Ibiza (Charles-Picard and Charles-Picard, 1958; San Nicolás, 1983, 1984a). More information is available, however, for clothing in Roman and Byzantine times (Houston, 1947; Rouche, 1987: 453-454). Clothing items such as brooches, belts and other jewellery have also been reported (Houston, 1947; Campbell and Cutler, 1991: 319; Kazhdan, 1991: 280) and are worth bearing in mind when interpreting the funerary record with regard to age, sex and gender.

1.9.5 Professional occupations

Occupations can lead to pathological conditions. An example of occupation related pathology is found in the skeleton of the famous cellist and composer Luigi Boccherini (1743-1805), where abnormalities had resulted from incorrect posture and repetitive stress (Ciranni and Fornaciari, 2003). Evidence for musical instruments in the past exists, with music and song performed in public events such as worship of gods, sacrifices, festivals or other ceremonies (West, 1992). Some terracotta figurines from Ibiza represent themes related to music (San Nicolás, 1987: 78-79).

Punic grave-goods related to professions such as scissors, saws and awls have come from some Ibizan tombs (Tarradell and Font, 1975: 211). In Carthage, epigraphic evidence has provided information about a number of occupations in urban dwellers in

Punic and later periods (P.G. Mosca in Stager and Wolff, 1984: 47; Hopper, 1979; Foss, 2002: 87). Documentary sources, especially for Byzantine times, have also been informative on gender roles (Fulghum, 2003a).

Pottery was a popular industry in Ibiza. The activities, the stresses on the human body, the working environment and clothing with regard to health and safety, fumes and high temperatures, will have an effect on mortality and morbidity. Ethnographic evidence for pottery production (Annis, 1985; Nicholson and Patterson, 1985; Laraqui *et al.*, 2000), experimental archaeology (e.g. Ramos and Fuentes, 1998) and study of techniques employed in manufacture of products (e.g. San Nicolás, 1983, 1984b, 1987), help in understanding some of the physical demands of the potters[30].

1.9.6 Violence and warfare

> *And it is on account of the fertility of these regions* [Majorca and Minorca] *that the inhabitants are peaceable, as is also the case with the people on the island of Ebusus. (...). On account of the same fertility of their islands, however, the inhabitants are ever the object of plots, albeit they are peaceable; still they are spoken of as the best of slingers. (...). And their training in the use of slings used to be such, from childhood up, that they would not so much as give bread to their children unless they first hit it with the sling'.*
>
> Strabo, *Geography of Strabo*, III.5.1

Information on violence can be crucial in explaining some demographic and injury patterns that might be present. Quesada (1997) has studied the weapons and

[30] It would be of interest to undertake a study on Ibizan potters today who use traditional techniques, and investigate whether any common trends in morbidity are present.

armoury in the Iberian Peninsula from the sixth century BC to the first century AD. Amongst the Greek, Celtic and other pre-Roman cultures, the armoury, weapons and fighting style of the Carthaginians are the least known (Quesada, 1997: 56). With regard to Punic ships, a ram may have served to damage and sink enemy ships (Basch and Frost, 1975). Balearic slingers were famous and have been mentioned by classical authors (Quesada, 1997: 441).

The opinion of many local archaeologists is that the inhabitants of Ibiza were apparently peaceful people. Metal objects that can be interpreted as weapons are very rare in the Punic tombs (Tarradell and Font, 1975: 209). One of few examples in Ibiza is an iron spear from the site of *Ca na Jondala* (Tarradell *et al.*, 2000). Lead slingshots have been found around *Eivissa* (Macabich, 1947, 132-133; Planas and Madrid, 1992). Twenty-five small bronze arrowheads have also been found dating to the Phoenician and Punic periods (Ramon, 1983). However, whether they were used for military purposes or solely for hunting is unclear (Tarradell and Font, 1975: 209-211; Ramon, 1983). In terms of skeletal remains, Gómez (1989: 321-322) indicates that trauma was rare in Ibiza and the low incidence is a reflection of a pacific and sedentary lifestyle.

Nevertheless, military incursions or attacks on Ibiza have been recorded by Livy (Book XII.20) who reported an unsuccessful siege on *Eivissa* by the Romans in 217 BC, and for this reason an attack on the rural areas (Costa, 2000a). The city walls were reported briefly by Diodorus and lookout towers have been identified archaeologically

(Díes, 1990). Ibiza's possible involvement in the Punic Wars must not be ignored[31] (see Costa, 2000a).

1.9.7 Plague

Plagues may be considered in view of any peaks in mortality at a young adult age. Documentary evidence for plague has shown that this was present in Late Antiquity and Early Byzantine Europe, spreading quickly from Asia (McNeill, 1976; Audoin-Rouzeau and Vigne, 1997; Kiple, 1997; Porter, 1997; Panagiotakopulu, 2004). Whether plague was in Ibiza cannot be confirmed, but the general pattern of its spread throughout Europe as observed in the literature makes this plausible[32]. Since mortality was almost immediate, no bones lesions can be traced. The demographic profile, however, may provide clues (Margerison and Knüsel, 2002).

1.9.8 Migrations

People bring diseases with them. Where armies marched there were pathogens emerging (Kiple, 1996: 25). Sea travel, which was quicker, safer and easier than on land, played a significant role in the spread of diseases (McNeill, 1976: 107-108; Grmek, 1989: 89). The history of Ibiza has revealed a clear discontinuity in languages through time (Punic, Latin, Greek, Arabic, Catalan, etc.) and burial customs (cremation,

[31] For information regarding Roman weapons and armoury, see Feugère (2002). Information on these aspects might clarify any possible injury in a Punic skull caused by Roman weapons.
[32] It is worth emphasizing the need for future study and careful excavation of non-human animal remains in Ibiza. It would be interesting to know whether remains of *Rattus rattus* were present in Ibiza at this time and in sufficient numbers.

inhumation, pagan, Christian, Islamic) possibly suggesting the arrival of immigrants, bringing in their own culture and their own genes. Diodorus (V. 16) mentioned that Ibiza consisted of people from different nationalities, although with a majority of Phoenicians.

These different genetic contributions may have an effect on disease prevalence. In fact, migrations to new lands may have been facilitated if disease-resistant colonizers introduced diseases to other populations not accustomed to it (McNeill, 1976). Porter (1997: 26) believes that ancient Iberians became hyper-immune because they had survived a 'dangerous' environment due to the immigration of a variety of peoples of Atlantic, Mediterranean, African and Asian origin. Grmek (1989: 90) shared a similar opinion with regard to Greece. Furthermore, slavery brought to many places people from all over the Mediterranean and continental Europe (Thompson, 2003: 3-4). Business (e.g. trade) and visiting temples were another motivation for population movements in the past (Casson, 1974: 147).

Rapid cultural change can be a severe stressor that affects the health of the population (McElroy and Townsend, 2004: 310). When one population intrudes on another and the level of culture and technology is different then the whole ecosystem is disrupted and the entire population experiences stress and maybe some cost to individual health (McElroy and Townsend, 2004: 313). Within the same geographical region, migrations between rural and urban were common and migrating from one to another could have also produced physiological stress (Bogin, 1988b).

1.9.9 A biocultural framework

The following table lists the key factors affecting morbidity that have to be considered before undertaking skeletal analysis. Inferences are also provided for the two main periods studied in this thesis. Hopefully this will provide a biocultural framework, which will be added to by further research in Ibiza.

Table 1.4. Some inferences about each period before undertaking skeletal analysis.

Factors	Punic	Late Antiquity-Early Byzantine
Climate and ecology	More lead pollution Rainfall – good for harvest - more water supply	Less lead pollution Aridity – droughts, limited water More earthquake activity
Subsistence	Similar in both periods but -probably less pig consumption -wider variety of foodstuffs due to trade?	Similar in both periods but - less variety of foodstuffs? - crops affected by climate?
Settlement pattern	- higher population density since it was a prosperous city - more economic activity = more industries = more pollution - larger rural population	- less population density as reduction of settlements - economic decline = less industries = less pollution. - less rural population
Medical care	Similar in both periods Medicine present	Similar in both periods Medicine and doctors present With Christianity, more hospitals to care for the poor
Occupations	Active people due to economy = more physical demands on the skeleton?	Less active people in town = homelessness and poverty? More people leading a monastic life?
Plague	None recorded	Bubonic plague since the 6th AD
Violence and War	Punic wars? Roman siege and raid on Ibiza Ibizan slingers participating in war? Good defensive system	No wars Vandal raids? Islamic incursions?
Migration	More contact between people through trade North African and sub-Saharan immigration?	Already a substratum of population in Ibiza Some immigrants from the Eastern Mediterranean? Rural-urban migration as abandonment of sites?
Other	Child sacrifice? Infanticide?	Infanticide?

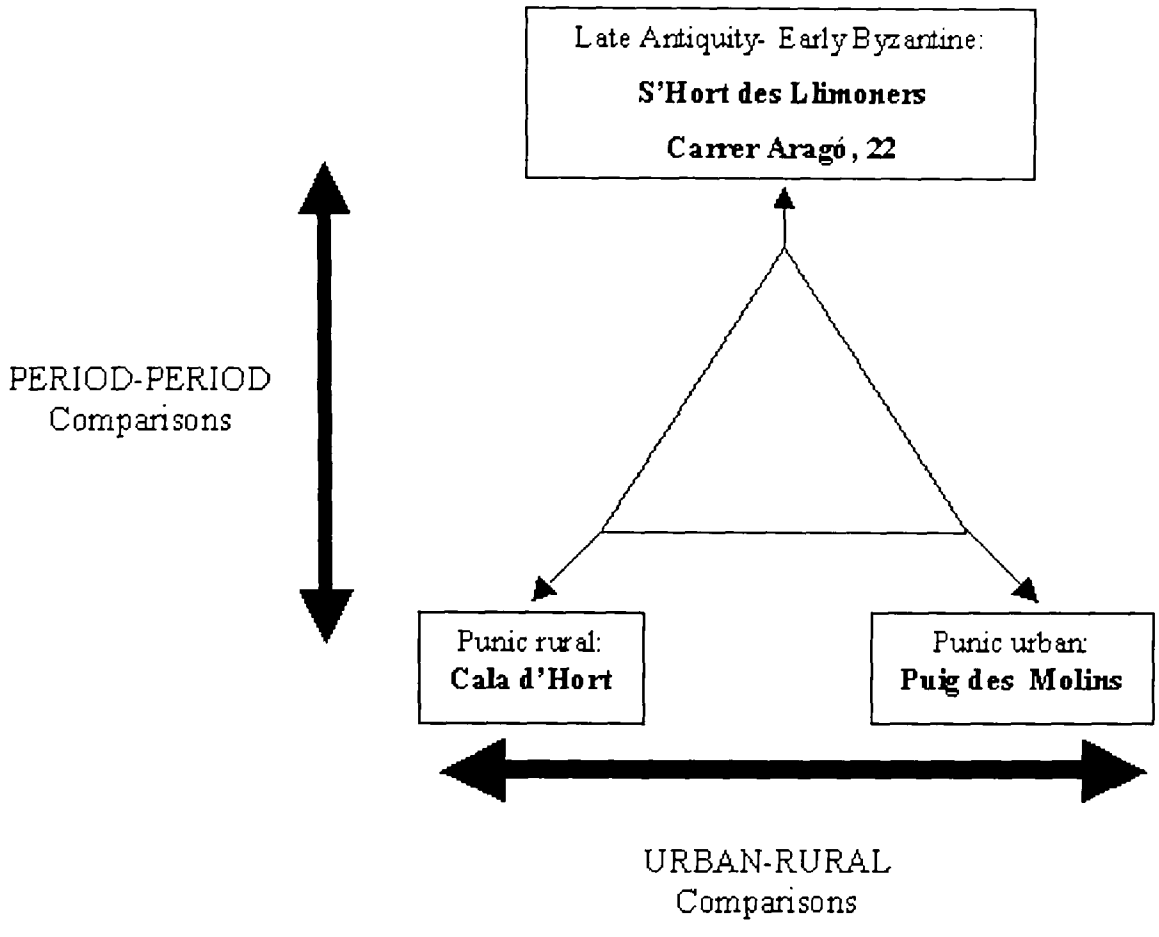
2 CHAPTER TWO – THE SKELETAL SAMPLES

The remaining part of my work relates to the bones....
Celsius (25 BC-50 AD), *De Medicina* (Book VIII. 1)

In this chapter, the osteological material is described. This includes archaeological information on each site, the state of preservation of the skeletal remains and the structure of the dead population under study: the minimum number of individuals, their age and sex composition.

2.1 The materials: the skeletal samples employed

The human osteological material from Ibiza belonged to one Punic rural cemetery, three samples from the large Punic urban cemetery and two sites belonging to the Late Antiquity-Early Byzantine period. The chart below illustrates the sites, contexts, and objectives (comparisons) addressed in this work.



2.1.1 The Punic rural necropolis: *Ses Païsses de Cala d'Hort*

This Punic necropolis, also known as *Can Sorà*, is located in the SW of the island (see Ill. 1.2). The cemetery is part of a larger archaeological complex including two buildings used since Pre-Roman times, two Byzantine tombs, and later additions such as the more recent farmsteads. The Punic necropolis (Ill. 2.1, Ill. 2.2) was used as a burial place between the fifth century BC to circa 100 BC or 75 BC (Ramon, 1995a, pers. comm. 2001). During its excavation in 1917 by Carlos Román Ferrer, 18 tombs were discovered (Román, 1920). The human bones studied in this thesis were recovered during excavations directed by Dr. Joan Ramon Torres in the 1980s and 1990s. Unfortunately, these bones had already been disturbed in the earlier 1917 excavations.

Their scientific value was ignored at the time. While the most complete archaeological artefacts had been removed, the bones had been left there, disturbed, commingled and out of their original contexts (Ramon, pers. comm.).

2.1.2 The Punic urban necropolis: *Puig des Molins*

The human bones from the Punic urban context derive from three excavated sectors of the cemetery of *Puig des Molins* (Ill. 2.3, Ill. 2.4).

Puig des Molins is a necropolis located on a slope in the southern part of the present city of *Eivissa*, at 51 metres above sea level and at 500 metres from the old town. The cemetery was used as a burial place starting from the seventh century BC with Phoenician cremations and ending in the thirteenth century AD with Islamic burials (Fernández, 1983a, 1986, 1992; Costa and Fernández, 2003a, 2003b).

At the end of seventh century BC the cemetery may have occupied an area between 6,000 and 10,000 m^2 (Ramon, 1996, 2003b), but in Punic times this area would have extended to at least 50,000 m^2 (Costa and Fernández, 2003b: 161). It was in the fifth and fourth centuries BC that the cemetery experienced a period of maximum usage (Fernández, 1983a; Gómez, 1984; Costa and Fernández, 2003a, 2003b). During the Late Antiquity and Byzantine periods the cemetery had been extended further north reaching the level of the present day streets *Avinguda d'Espanya* and *Carrer Aragó* (Costa and Fernández, 2003: 161).

Within Punic times, the use of the necropolis can be summarized into the following phases (after Fernández, 1983a):

A) Early Punic stage (c.530/525 to 450 BC): Inhumation is the predominant burial rite although some cremations are present. Rock-cut graves are the most predominant tomb type.

B) Middle Punic stage (c.450-200 BC): There is a great expansion of the cemetery with an estimated 6000-7000 hypogea[33] present between 450-350 BC. A decrease in the number of tombs is apparent between 350 BC and 200 BC, with about 10% of them being reused.

C) Late Punic stage (200-25 BC): A return to cremations, coexisting alongside inhumations.

This cemetery has been studied much in terms of burial rites, phases of decline and prosperity, grave-goods and its extension (e.g. see Mañá, 1948, 1953; Tarradell and Font, 1975; Fernández *et al.*, 1984; Fernández, 1983a, 1986, 1992; Gómez, 1984; Gómez *et al.*, 1990; Ramon, 1994a, 1996, 2003b; Costa and Fernández, 2003a, 2003b).

[33] These subterranean rock-cut tombs have average dimensions between 2 and 6 metres long, 1 and 1.5 metres in height, the ground floor being between 2 and 7 metres deep from the present-day surface, with entrance shafts on average about 0.80 wide (Gómez, 1984; Fernández, 1986; Mañá, 1948: 205). Sometimes, hypogea contain one or more sarcophagi, not oriented in any particular order, with an average length of 2.10 or 2,20 metres long, 0,70 metres wide and 0,70 metres high, and walls between 0.07 and 0.10 metres thick (Mañá, 1948: 206-207, 1953: 122-123; Fernández, 1983a, 1986; Gómez, 1984).

Although a significant part of the necropolis is protected today, other areas are covered with buildings. Only during modern construction works have some of these areas been investigated. The human bones analysed in the present thesis were uncovered during two rescue excavations in *Eivissa* located close to each other: *Via Romana, 28-30* and *Via Romana, 47.* In addition, bones from a different sector excavated in the years 2000 and 2001 were also available for analysis (see Section 2.1.4). These samples were later pooled into a single one as they belonged to the same cemetery.

2.1.2.1 Via Romana, 28-30

In this sector eleven trenches, 2 x 2 m^2, were excavated in 1998 although earlier excavations had taken place in the 1940s. The tombs ranged from sixth century BC Phoenician cremations, Punic inhumations (5th-2nd BC) and Roman tombs dating to c.100-250 AD (Ramon, 1998). Although all human remains were catalogued, only the Punic material was of interest in this thesis.

2.1.2.2 Via Romana, 47

This sector is situated in the N-NW slope of *Puig des Molins*. Some excavations were undertaken in the 1940s and 1950s, but the material employed here comes from the excavations by Rosa Gurrea and Joan Ramon in 1990 and 1991. The site is located between 12 and 17 metres above sea level and the excavated sector only covered about

75 m^2 (Ill. 2.5). The tombs date between the sixth and the third centuries BC (Gurrea and Ramon, unpublished). Phoenician cremations and Punic inhumations were discovered. Only data from the Punic period was included in this thesis. The Punic material derived from inhumations in one hypogeum, in fossae (Ill. 2.6) and in amphorae.

2.1.3 The Late Antiquity-Early Byzantine necropolis: *S'Hort des Llimoners*

The cemetery of *S'Hort des Llimoners* was located 750 m N-NW from the citadel. Rescue excavations of this urban or extra-urban cemetery were undertaken in 1998 under the direction of Dr. Joan Ramon Torres and covered an area just over 1000 m^2 (Ramon, pers. comm.; Ramon *et al.,* 2005). The funerary space occupied about 550 m^2. The graves surrounded two funerary structures, which were located at either side of a Roman road (Ramon *et al.*, 2005). The cemetery was first used probably at the end of the third century AD and extended until the seventh century AD. Dates for an early tomb (Ill. 2.7) gave an uncalibrated age of 1789 +- 27 BP, and for a later tomb an age of 1412 +- 27 BP respectively[34]. The majority of tombs, however, belonged to the fourth and sixth centuries AD (Ramon *et al.*, 2005).

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[34] These analyses were undertaken at the Oxford Radiocarbon Accelerator Unit. The analyses were funded by the *Consell Insular d'Eivissa i Formentera* after a petition from Dr. Joan Ramon. The dates are uncalibrated in radiocarbon years BP ('Before Present' = 1950 AD) using the half-life of 5568 years. Calibrated, the 95.4% probability for each tomb is the following: from 130 AD to 340 AD for tomb HLL819 (OxA-12467), 595 AD to 675 AD for individual HLL202 (OxA-12468). Another sample from tomb HLL214-B (OxA12469) was also analysed and revealed a date of 420 AD to 570 AD.

2.1.4 Further materials to be used

In order to enlarge the sample size other skeletal data were employed when possible. Opportunities were provided to study an additional skeletal sample from the cemetery of *Puig des Molins.* This sector was excavated in the years 2000 and 2001 under the direction of Dr. Jordi Fernández and Ana Mezquida. The material employed included an inhumation (PM00/IN.6) excavated in 2000, and remains that were excavated in 2001 from interior levels of hypogeum II.

In addition, funding was later provided to increase the Late Antiquity-Early Byzantine sample[35]. The site of *Carrer Aragó, 33* (see Ramon, 1995b), excavated in the 1980s (Ill. 2.8), was available for study.

Information on these sites was very limited, with reports unpublished and still in process of completion. These, nevertheless, were coeval with the other sites of the same period, thus were pooled into one sample according to their chronology: the Punic period for the former, and the Late Antiquity-Early Byzantine period for the latter (Table 2.1).

[35] Research grant awarded to the author by the *Consell Insular d'Eivissa i Formentera* in 2003.

Table 2.1. Site and skeletal samples analysed in the present study.

Period	Site name	Site Code
Punic (rural context)	Ses Païsses de Cala d'Hort (Can Sorà)	PCHN
Punic (urban context)	Via Romana, 28-30	VR28
	Via Romana, 47	VR47
	Puig des Molins (Hipogeum II and inhumation 5 from the 2001 excavations)	PM01
Late Antiquity-Early Byzantine	S'Hort des Llimoners	HLL
	Carrer Aragó, 33	AR33

Other studies on Ibizan skeletal remains published by other authors (see Chapter 1, Section 1.7) were only used for some only limited parts of the analysis, since the different authors have employed different recording procedures[36]. Some of the methods employed, such as cranial suture closure, are unreliable when used as a sole age indicator (see below). In addition, the published studies have tended to report pathologies, except dental disease, as isolated cases rather than frequencies.

The use of other osteological data was restricted to Punic long bone measurements for stature, available from the rural site of *Can Marines* (Gómez, 1989). The published Punic sites of *Cas Jurat* (González-Martín and Lalueza, 1992) and *Ca n'Eloi* (González-Martín and Lalueza, 2001), located in the regions of *Sant Antoni* and *Santa Eulària* respectively, provided frequencies for oral pathology.

[36] A need for standardisation is required. Discussions between anthropologists undertaking analysis on Ibizan material in the future should take place in order to establish some standards. This would be of great benefit and increase the potential value of studies on human skeletal remains on the island. Further discussions with archaeologists can attempt to list important research questions and avenues that may be tackled in the future.

2.1.5 Period and site selection

The sites were selected in view of the hypothesis. At the same time, testing the hypothesis was dependent on the material available. The main objectives of this work were focused on the Punic period. It is recalled that Ibiza was a well-known and prosperous island at this time according to material culture. The study of the human remains could provide a different perspective, the 'biological version' of that period.

Since several Punic sites have yielded human remains, testing the hypothesis appeared to be viable. The urban and rural samples were available when this research started. They comprise now the largest collection of Punic material studied on Ibiza at present, both for Punic rural and Punic urban contexts.

In order to comprehend and interpret the results from the bone data, another period, perhaps with different economic circumstance, would be helpful to understand the meaning of potentially different results. Prehistoric remains yielded a very small sample in Ibiza (n = 5) and were thus not appropriate. Phoenician cremations were avoided since inhumations were preferred for comparative purposes where more information on health and disease could be gathered from the bones. Islamic samples were also available (e.g. Márquez-Grant, 1999a, 1999b) but at the time, they too were a reduced sample. Excavated medieval and post-medieval remains from the cathedral in *Eivissa* (see Gurrea and Martín, 1999) also constituted a small sample size and were biased towards a highly selected part of society buried in the building.

Overall, the best representative period in terms of sample size was the Late Antiquity-Early Byzantine period. Also, evidence existed to indicate that in this period some settlements were abandoned, population growth declined, trade was at a much lower scale, and possible Vandal incursions, plagues and earthquakes were ravaging the Mediterranean at the time.

All the sites selected for this thesis, both Punic and Late Antiquity-Early Byzantine ones, provided further advantages. Apart from the remains from the year 2001 excavations at *Puig des Molins,* all the other excavations involved wholly, or at least partially, the direction of the same archaeologist, Dr. Joan Ramon. This provided a more standardised excavation methodology. Although these excavations took place at different times and although by both experienced and inexperienced volunteers, being excavated under the direction of the same person meant that a better interpretation could be given with regard to bone recovery, absence or presence of infant remains and other issues relating to taphonomy, preservation and the demographic structure of the population. The excavations in 2000 and 2001 at *Puig des Molins* directed by Dr. Jordi Fernández and Ana Mezquida, provided the advantage that they were recent, carefully excavated by experienced archaeologists and not a rescue excavation in nature. Moreover, since all the human osteological material from these sites was studied by the present author this provided methodological standardisation throughout the study, which benefited the comparisons. As the present research was gathered over several years, with the author's experience enhanced more recently, the remains studied in the

years 1999 and 2000 (site PCHN) were revised in 2003 with special emphasis given to oral pathology. This was undertaken to overcome the bias of better recording and more reliable diagnosis with the more recently analysed material.

2.1.5.1 Problems of overlap between periods

No period in Ibiza is clear-cut from the preceding or the following period, with possible long transitional phases and some cultural continuity surviving from one period into another. One of the problems may be that some skeletons from the Roman period may be included accidentally or deliberately in Punic tombs. This is especially true in *Puig des Molins* (Fernández, pers. comm.). Remains from Roman times are known to be present inside Punic hypogea due to *post-mortem* disturbances such as the collapsing of the earth where Roman burials may have been positioned (Fernández, 1986: 164).

In order to minimize this error, a few measures were taken. At the site of VR28, those individuals associated with the presence of *terra sigillata* or other Roman materials, for instance bones in context 800 according to the site report (Ramon, 1998), were excluded from the analysis[37]. At the site of VR47, the Phoenician cremations were excluded (Gurrea and Ramon, unpublished). From the 2000 and 2001 excavations, only those buried within hypogeum II were included, as well as the burial from inhumation number six (PM00/IN.6) which has been identified by the directors as Punic according

[37] All the human remains from all the sites were studied including any Phoenician cremations and any Roman material. However, these remains were not the focus of this thesis.

to the presence of a 'razor blade' (Mezquida, pers. comm.). In hypogeum II only contexts [062] and [066] were considered, while layer [049] was excluded. This latter context was located at the entrance shaft and was likely to include Roman burials disturbed due to soil movement. Further levels from the same hypogeum could not be analysed because they were not completely excavated at the time.

The inhumations recovered from the Punic rural necropolis (PCHN) were all studied as they have been regarded to be solely from the Punic period (Ramon, 1995a). A small percentage of individuals, however, from the Roman period may be expected as the associated settlements were occupied at this time.

Overlapping with Roman tombs is likely to account for only a small percentage of the sample[38]. This is partly due to the fact that early Roman burials were usually cremations, and cremated bone was not considered here. Also, later Roman burials were clearly defined by tomb type, grave-goods and different cemeteries. Furthermore, in the urban context, funerary space for Roman inhumations may have extended

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[38] Hypothetically, if there were to be a number of early Roman burials in the samples, how much of a problem is this overlap? This overlap might turn out to be insignificant. People living during a transitional phase may have been born in Punic times and died in Roman times, with at least some Punic customs surviving. Punic customs continued into the Roman period not only in Ibiza, but also in other parts of Spain such as in Villaricos and Cadiz (Belén, 1997: 131). Roman coins in Ibiza also continued to be minted with Punic iconography (see Planas *et al.*, 1989). In west central Sardinia continuity between the Punic and the Roman Republican periods also existed in the third and second centuries BC, although a 'newer' culture seems to have emerged (van Dommelen, 2001, 2002). In this view, it is rather a chronological than a purely cultural matter. Moreover, since in this thesis the focus was on the Punic period with regard to the Late Antiquity-Early Byzantine period, then any problems of overlap between Punic and early Roman burials are minimized. The problem might have been more complex and significant if comparisons were to be made between skeletons from strictly Punic tombs and early Roman ones.

northwards in the third century AD (Fernández, 1986: 175). With regard to Islamic burials, these were clearly differentiated through their burial rite and body position.

With regard to the later period, because there are tombs ranging primarily from the fourth to the sixth centuries and the majority of these could not be attributed to a more specific century, the sample has been pooled under one Late Antiquity-Early Byzantine category.

Finally, Benjamí Costa (pers. comm.) has warned that within the overall prosperous Punic period there were periods of decline. This is also obvious today when in the same decade there can be decline and prosperity, poverty and wealth, peace and war, health and disease. Apart from problems with relative dating, this potential problem cannot be overcome in the present samples as most were found disturbed, bringing difficulties in assigning one particular burial to a particular century. Unfortunately, therefore, the data can only serve for the average of the whole use of a cemetery, a limitation imposed in most anthropological studies.

2.1.5.2 Rural-urban contexts

Comparisons were made between Punic rural and Punic urban samples. The various cemeteries studied can be clearly classified into rural and urban. The human remains from the rural population clearly belonged to people that worked and lived there. Most of the rural settlements appear to have had their own cemeteries.

However, is there any guarantee that those buried in the city were solely urban dwellers? At the urban cemetery of *Puig des Molins* people from the town's periphery and surrounding rural areas may have been buried here (see Ramon, 1996). Even if this is so, those peasants[39] that may have worked in the periphery of the town, probably interacted and were more involved with urban life (e.g. diet, public facilities) than those in relatively more remote areas (such as site PCHN).

Some peasants may have migrated later in life to the city and may have died away from their settlements. Thus, in the case of some individual cases, disturbances during growth may have happened within the rural environment, rather than within the urban environment in which they later lived and were buried. Moreover, migrations from rural to urban settings can affect the health of the migrants (Bogin, 1988b). Whatever the extent of these considerations may be, what is of relevance here is the comparison between those who were buried in the urban cemeteries compared to those in the rural. This different burial setting itself is likely to correlate with different lifestyles.

[39] According to Layton (2002: 65) 'a *peasant* is a cultivator whose productive activities are primarily directed toward his/her household's subsistence needs, but who is under some degree of economic and political obligation to powerful outsiders and/or carries out subsidiary production for a market operating in the wider society. Peasants also interact on a daily basis with other members of their local community.' In this thesis it seems correct to use this definition for those inhabitants in the rural settlements, which would have interacted commercially with the wider community in which they lived.

2.1.5.3 Dating considerations

Apart from tomb typology and burial rite, dating of each cemetery has relied primarily on pottery. Classifications have relied on the observer's perceptions and bias may have been introduced during artefact analysis (Beck and Jones, 1989). The specialist in human bones cannot judge those dates assigned by the specialists to pottery artefacts. Some schemes, however, may need re-visiting if they were developed in the early twentieth century from material outside Ibiza. Modern studies on relative data through seriation could also be reinforced with absolute dating techniques (for a summary see, for instance, Greene, 1983; Renfrew and Bahn, 1991).

With regard to the Ibizan material, Greek pottery (e.g. Attic) found in Punic tombs has been extensively studied and can produce more secure chronologies than Punic pottery (Tarradell and Font, 1975: 70, 99). Unfortunately, due to post-burial disturbance, many tombs could not be dated to a specific century.

2.1.5.4 Taphonomic considerations

Taphonomy (see Behrensmeyer, 1984) can be defined, conventionally, as any process affecting bone between burial and discovery. However, it could also be understood, more widely, as any process affecting bone between the individual's death until its storage and handling in the laboratory. These alterations in bone may result from cremation of the body, soil acidity, temperature, disturbance by rodents, *post-*

mortem rituals and vandalism. The decay of grave-goods containing acid materials for instance, is also related to the decay of the human body after death (see Janaway, 1996).

Unfortunately, the Punic remains have not been free from disturbance. This disturbance has caused disarticulation of skeletons and has limited the potential of palaeopathological analysis. Punic tombs were reused for burial and some previously interred skeletons were moved to secondary contexts. Some *post-mortem* rituals such as food and drink libations may have been present, as has been suggested for Phoenician times (Rodero, 2001: 86).

In the Islamic period, there is evidence that the Punic tombs at *Puig des Molins* were raided and their sidewalls broken in order to interconnect hypogea (Mañá, 1948: 203; 1953: 122; Pericot, 1972: 119). The tombs may even have served as living dwellings (Vives, 1942: 24). The extent of this disturbance can be portrayed in an example of a terracotta figurine. The figurine was reconstructed from fragments that were found in five different hypogea (Vives, 1942).

Soil movement has also caused disruption. It is likely that a Roman funerary inscription found in the mouth of a hypogeum at *Puig des Molins* may have fallen into it due to soil movements (Mañá, 1953: 123). At the rural site (PCHN), the skeletal material has also been affected by the erosion and instability of the terrain, with some roofs of hypogea having to be demolished during the 1917 excavation (Román, 1920) (Ill. 2.9, Ill. 2.10). This surely damaged the underlying bones. Disturbances have also

been caused by the earlier excavations where only artefacts were recovered. Olive trees had also been cultivated in the area, causing some soil movements and wreckage of tomb entrance shafts. In the last century, vandalism produced further disturbance, but this was later reduced when the area was fenced. Bones from some sites have also been stored in inadequate conditions due to limited facilities in the island. This has affected bone degradation.

With regard to Late Antiquity and Byzantine burial sites, such as in Carthage (Humphrey, 1988), looting was certainly present (Kilgore and Jurmain, 1988: 259) and laws imposed bans on this *violatio sepulcri* (Johnson, 1997: 39-40; Toynbee, 1971: 76). Moreover, new graves had been cut into earlier graves, with gravediggers placing recognized bones in pits rather than in tombs (Ellis and Humphrey, 1988: 329). *Post-mortem* rituals may have caused further disturbances. Throughout the year the dead were commemorated and funerary meals would be eaten at the tomb (Toynbee, 1971: 51). Opening of tombs would have taken place at different times (for different deaths) in sepulchres, either with regard to *sepulchra familiaria*, *sepulchra hereditaria* or those owned by various families (Johnson, 1997). Secondary burials and disturbance was clearly observed in Ibiza at site HLL (Ill. 2.11, Ill. 2.12) and site AR33 (Ill. 2.13).

Recovery of certain skeletal elements may have been affected by the presence of inexperienced volunteer diggers. Unfortunately, prior to excavation, machine diggers have damaged a relatively small number of graves in site HLL. Post-excavation handling has resulted in further bone fragmentation. With regard to AR33, unfortunate

accidents during handling and transport have resulted in bone fragmentation and mixing of contexts. Labels have also been lost or erased through the passage of time. Today, however, considerable efforts are being made to improve conditions and the institutions have been successful in carrying out such improvements.

These are limitations affecting the anthropological analysis. However, these are *real* practical problems in archaeology and anthropology and all attempts should still be made to retrieve information from the human remains.

2.1.5.5 Methodological considerations regarding ancestry

It is important to understand as much as possible the background of the population under study, i.e. their ancestral origins. Chapter 1 saw how immigration could affect health.

In addition, different genetic backgrounds (e.g. European, sub-Saharan African) will require different methods of anthropological analysis. For instance, formulae for computing stature are different when applied to individuals with a European as opposed to an African genetic background (see Chapter 3).

Brothwell (1972: 80) pointed out that one of the difficult questions in archaeology is to what extent cultural change in a particular place is affected by large-scale immigration. Tarradell and Font (1975: 248) already mentioned the problem of

the colonization of Ibiza with regard to the origin of the people and highlighted the lack of anthropological studies[40].

Most answers are inclined towards North African (Carthaginian) immigration. This North African 'link' is supported from the presence of ostrich eggs in tombs (see studies by Astruc, 1957; Gómez *et al.*, 1990), scarabs (Fernández and Padró, 1982) possibly architecture (this is debatable, but see Díes and Matamoros, 1989; García-Delgado, 1992) and the characteristics of the Ibizan hound (McDonald, 1980; Delalix, 1987; Pedro, 1996; Cesarino, 1997: 98).

Circa 600 BC there seems to be a shift from pottery away from the Straits of Gibraltar towards a new market in the central Mediterranean. The types of grave-goods, their quantity and a change in burial rite seem to confirm this (Costa and Fernández, 1986-1989; Gómez *et al.*, 1990) as well as the amphorae evidence (Ramon, 1992). This change in burial rite may be related to the arrival of immigrants (Costa and Gómez, 1987: 53; Costa and Fernández, 1986-1989: 262; Gómez *et al.*, 1990; Guerrero, 1997: 248). Moreover, it seems that administration representatives from Carthage would be sent to Ibiza (Guerrero, 1997: 249). Ramon (1992) believes that rather than a sudden wave of immigrants coming to the island it was a gradual and progressive process.

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[40] *'L'antropologia física és un dels buits més lamentables dins la investigació dels fenòmens colonials, i molt concretament en el cas fenício-cartaginès'* (Tarradell and Font, 1975: 249).

In addition, before the mid-sixth century BC, Ibiza had formed part of the Phoenician trading routes and perhaps also of the Greek and Etruscan routes. It should not then be surprising that some Greek merchants may have established themselves in Ibiza before Punic times (Costa and Gómez, 1987: 55). An Iberian inscription found in Ibiza and perhaps associated with human bones (García and Bellido, 1948: 285) points to an Ilirian (Albanian) origin (Vallejo, 1948), although this needs re-examination.

Biological anthropology is relevant to this question since it deals with the individuals themselves, not with material culture. Craniometric studies have been undertaken (Schwidetzky, 1979; González and Lalueza, 1995, 2001) and genetic studies on the living population today (Picornell *et al.*, 1996; Crespí *et al.*, 2002). The craniometric studies have not been able to relate Ibiza to any population. The studies have revealed homogeneity in the populations in the Western Mediterranean[41] regardless of cultural background and chronology[42]. Despite cranial morphology being influenced by age, sex, genetics, climate, pathology, nutrition and culture (Price, 1945; Weiner, 1954; Carlson, 1976; Carlson and van Gerven, 1977; Ruff, 1980; Beals *et al.*, 1984; Rothhammer and Silva, 1990; Franciscus and Long, 1991; Gerszten, 1993; Hernández *et al.*, 1997; Kaifu, 1997; Bharati *et al.*, 2001), recent analysis with forensic methods suggest the presence of sub-Saharan individuals (Márquez-Grant, 2005, in press). Other archaeological evidence in Ibiza such as coins and terracotta figurines also

[41] This homogeneity also occurs in the central Mediterranean area (for Malta see Schwidetzky and Ramaswamy, 1980). However, these studies need to be revised with further data and more recent statistical programmes.

[42] An exception to this is the Medieval Jewish sample from Barcelona (González and Lalueza, 1995, 2001; Lalueza *et al.*, 1996).

portrays the presence of individuals with sub-Saharan physical characteristics. In ancient Greece and Rome, sub-Saharan Africans were integrated in society and there is much archaeological evidence for their presence (see Snowden, 1970).

With regard to the genetic analyses, Ibiza distinguishes herself from the rest of the Balearic Islands in that it is genetically closer to the Middle East and North Africa, although the North African affinity is not entirely clear and may be a consequence of the Islamic period rather than the Punic period (Picornell, pers. comm.).

In Late Antiquity and Early Byzantine Iberia, the population would be Hispano-Roman with other groups such as Jews, Visigoths, Orientals and Africans distributed in a random way (Salvador, 1990: 140). Inscriptions from Spain dated between the fifth and seventh centuries AD have revealed the presence of merchants from a variety of origins including Greek, Syrian and possibly Egyptian (García, 1972). A bronze censer from the Balearic Islands dating between he sixth and eight centuries AD seems to have come from the area of Sicily and had an inscription of a Greek female name (Oikonomides, 1983b: 144).

Thus, immigrants from a variety of geographical regions appear to have been present in Ibiza. However, it was not possible to determine the precise ancestral origin of each skeleton.

2.1.5.6 The population: society, beliefs, and death

A teacher before teaching a class must know something about his or her students: their behaviour, their family background, their achievements, their religious beliefs and ethnicities. Likewise, the anthropologist before analysing human remains should know something about the sample: what kind of people were interred, their beliefs and their social organisation amongst others.

Religious or ideological beliefs[43] are also worth investigating in relation to health and disease. Navajo Indians abandon houses when someone dies (Haley, 1999: 6), while in Greece the lament of the dead is an important funeral procedure and the present of clay figurines or paintings in vases may represent those mourners (Kurtz and Boardman, 1972: 27-28).

By studying attitudes towards death some information can be obtained about society. It will also aid in explaining some attitudes towards hygiene (e.g. burial location). Phoenician cremations (e.g. see Gómez *et al.*, 1990; Pereira, 2001; Rodero, 2001) may have been more hygienic than inhumations. Information on types of burial and rituals will provide clues to some of the taphonomic considerations that should be taken into account. Notions of infant, child and adult might be important when examining grave-goods and any spatial analysis with regard to pathology. In addition,

[43] Tringham and Conkey (1998: 40-42) highlight that words such as 'religion', 'temples' and 'rituals' should not be used so casually as they are based on modern Western perceptions. For instance, words like 'temple', 'altar', 'ritual' and 'goddess' should be substituted for more neutral words such as 'structure', 'mound', and 'figurine'.

grave-goods might reveal an egalitarian society with regard to sex and gender. This will aid any interpretation with regard to similarities or differences in disease prevalence according to sex and/or gender. Different type of tombs may reflect socio-economic differentiation[44] and pathologies for each of the groups may be obtained. In the Ibizan site HLL, there were certainly differences in tomb type probably related to different social and economic backgrounds (Ramon *et al.*, 2005).

Differences in grave-goods, however, may have related to different cultural influences on a particular individual. At an international level, a multitude of cultures merged into a 'cultural symbiosis' (Ramon, 1994: 363; see also van Dommelen, 1997: 309). Moreover, however, a variety of cultures[45] will likely exist within a predominant 'official culture'. There might be many cultures within one period, for instance a Punic culture, an indigenous culture, a sailor's culture and a sub-Saharan culture. The culture of the city may be different to the culture of the countryside, as has been interpreted for Sardinia (van Dommelen, 1997: 318). In addition grave-goods may relate to personal

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[44] There have been some questions relating whether the differences between a hypogeum and a fossa reflect different social status (see Tarradell and Font, 1975: 52; Marí and Hachuel, 1990) but further work needs carrying out alongside biological data. Funerary interpretations are complex and many interpretations may be given to grave-goods, ritual and tomb type among other observation of the burial record (see Ucko, 1969; Parker-Pearson, 1999). Furthermore, things that are valuable for us today such as gold may not have been as valuable as fine textiles in the past while some wealth may not have been left in the tomb but passed down to the heirs (Sagona, 2002: 282). Tattoos or hairstyles may have been indicative of social status. Egyptians tattooed themselves and the tattooed images were also used for protection (Cintas, 1946: 13). Body proportions in the past such as obesity may reflect a sign of well-being as opposed to thin people that may have been regarded as poor and ill (Parker, 2003: 17). In the same way, if smells can be taken into account (see Bartosiewicz, 2003), then perhaps some social classes could be distinguished not necessarily from clothes but also through smells such as blacksmiths smelling of smoke, farmers of pigs and cows, fishermen of fish and so on. In addition, one has to think of perishable items that may have been grave-goods such as some foodstuffs or clothes. Also, some natural raw materials may have some significance. A shell or stone that may seem normal today might have represented a specific meaning.

[45] By no means do I intend to define culture, a complex definition in itself. The term has been used here to express groups within a population that may have similar beliefs, may have a similar ancestral origin. Analogies with today may relate to different people influenced by certain music, a certain cult, a certain local dialect for instance.

hygiene or clothes. At Carthage, evidence has been found for combs, razors and fibulae (Benichou-Safar, 1982). Gravegoods may also indicate the type of industries or crafts that were present.

There is no space to dwell into these issues here regarding the Punic, Late Antiquity and Byzantine periods. Perceptions of infancy, childhood, adulthood and family structure are largely available for the latter periods (Moffatt, 1986; Néradau, 1987; Veyne, 1987a, 1987b; Cappel, 1991; Herrin and Kazhdan, 1991; Herrin *et al.*, 1991; Talbot, 1991; Curchin, 2000-2001; Harlow and Laurence, 2002; Rawson, 2003; see also Chapa, 2003). Similarly the word 'family' had different meanings in Antiquity (Curchin, 1997: 536, 2000-2001: 539) and any information with this regard may help interpret prevalence of congenital disease, for instance, in an ossuary.

As to the people interred in a cemetery, documentary, epigraphic and other artefactual evidence may serve here. This will provide some clues as to the representativity of the sample with regard to the once living population. Slaves and servants may have worked in rural areas in Punic Ibiza (Fernández and Fuentes, 1983: 191; Gómez, 2000: 357).

With regard to Ibiza, different deities were venerated (Ferron, 1969; Fernández, 1975; see also Tarradell and Font, 1975; Fernández-Miranda, 1983; Almagro and Barón de Esponellá, 1970). These divinities could be found represented in terracotta figurines (see San Nicolás, 1987; García Alfonso, 1990) and amulets (Cintas, 1946; Tarradell and

Font, 1975). These amulets may have been used for protection. Today in Scotland, some fishermen wear amulets to protect them from drowning (Pollard, 1999: 39). Sanctuaries may have also been used to symbolise the colonisers' first landing area (Tarradell, 1955: 104), or to bring good luck in the beginning of a 'new life in a new place'. At these places 'sexual' figures have also been found, perhaps relating to fertility (Taylor, 2003: 97). Symbols promoting fertility were also present in Roman and Byzantine times (Clarke, 2003: 97; Walker, 2003: 219).

Death can be perceived differently both at a population and individual level and interpreting attitudes towards death is not straightforward. Even today, medical personnel cannot agree still on the dividing line between life and death since there is a diversity of opinion (Haley, 1999: 2). The tombs in Punic times cannot be dealt with in detail here but the characteristics of the tombs can be found elsewhere and are usually similar between rural and urban sites (e.g. see Pérez-Cabrero, 1911; Tarradell and Font, 1975; Fernández, 1980, 1981, 1983b, 1986; Ramon, 1996; Tarradell *et al.*, 2000; Costa and Fernández, 2003a; also see Lancel, 1995: 215-216). Any interpretation on placement of grave-goods in relation to the body should consider cadaveric spasms, *rigor mortis* and the time of burial (Knüsel *et al.*, 1996; also see Janaway, 1996). Burial ritual or location may be related to mental illness (see Porter, 1996b).

Funerary grave-goods from Ibiza have provided evidence of Punic ritual and possible beliefs. For instance animal-shaped vessels or *askos* (e.g. see Fernández and Fuentes, 1983) may indicate the importance of the represented animals in terms of

subsistence (Gimbutas, 1989: 75, 77, 79). These also appear to be correlated with the age of the deceased person (Huysecom, 2003). Animals also appear in other terracotta figurines or in jewellery and may have represented deities (Blázquez, 1966; San Nicolás, 1984b). Other Punic grave-goods include scarabs (Cintas, 1946; Blázquez, 1967, 1970-1971; Baqués, 1974; López, 1994; Boardman, 2003), ostrich eggs (Astruc, 1957; also see possible meanings in Laufer, 1926; Tarradell and Font, 1975: 190; Gimbutas, 1989: 213; Lancel, 1995: 219; Collon, 1998; Manlius, 2001; Rodero, 2001: 80) and terracotta figurines (e.g. Astruc, 1957; San Nicolás, 1987) amongst others (see Costa and Fernández, 2003c).

Funeral practices in Late Antiquity-Early Byzantine periods are also well documented (e.g. see Toynbee, 1971: 40). Different tomb types have been present perhaps according to age and/or socio-economic status. For instance, an amphora burial in Ibiza (HLL814) related to a 15-20 year old (this study), compared to other contemporary burials from Spanish areas nearby in which much younger individuals were interred (Gómez and De Miguel, 1997; Magariño and López, 1997; González, 2001: 105-106). Byzantine customs can be reviewed with regard to taphonomic interest, for instance the time passed between death and burial and, likewise, the location of a cemetery with regard to population hygiene. Most of this information comes from documentary evidence (Kyriakis, 1974; Abrahamse, 1984; Brown, 1987; Karpozilos *et al.*, 1991; Kazhdan and Bouras, 1991; Laos *et al.*, 1991; Podskalsky *et al.*, 1991; Teteriatnikov and Karpozilos, 1991; Michaeli, 1996; Marshall, 2000).

2.2 Materials: methods of anthropological analysis

> *One day a farmer found a bone; he thought at first it was a stone, and threw it at a passing snake ere he discovered his mistake. But when he knew it was a bone, and not a diamond or a stone, he took it to an ancient sage, who said: "In prehistoric age, this was the shin-bone of a Thordineriomegantosaur-megopiumper-mastodon-letheriumsohelpmejohn". The farmer cried: Dad bin my eyes! Was ever so wondrous wise? He gazes a piece of bone, that I supposed to be a stone, and, with confidence sublime, he looks across the void of time, and gives this fossil bone a name, the fragment of some creature's frame! To have knowledge, sir, as thine, I'd give those fertile farms of mine." "Don't envy me", the sage replied, and shook his weary head, and sighed, "Your life to me seems full and sweet – you always have enough to eat"*
>
> 'Uncle Walt', by Walt Mason, Chicago, 1910.
> (Taken from *AJPA*, 1950, Vol. 18: 294)

Information was first gathered about each site in discussion with site directors. Plans, drawings and photographs of the tombs were consulted. This allowed for an understanding of the nature of the assemblages, *post-mortem* or taphonomic modifications and ways on how to approach the analysis with regard to identifying the number of individuals in a sample (e.g. according to individual tombs, according to repeated bone elements in commingled assemblages).

Before analysis, recommendations and guidelines were taken from Brothwell (1981, 1987), Sease (1987), McKinley and Roberts (1993), Buikstra and Ubelaker, (1994), Bass (1995), Ubelaker (1999), English Heritage (2002), and Brickley and McKinley (2004). Due to difficulties in soil removal, all bones were cleaned with a soft brush and tepid water. Cleaning allowed for labelling, reconstruction, age estimation and pathological examination. Bones and teeth were later left to dry naturally, not under direct sunlight. Some samples that were brought in consisted of blocks of earth

containing a skull (Ill. 2.14). In these cases, a 'mini-excavation' in the laboratory proceeded.

Each bone and tooth fragment was clearly labelled with waterproof ink in an appropriate place, trying to avoid anatomically important sites. Labels included site name abbreviation, tomb number and, on occasions, context or a specific catalogue reference[46].

Some bone fragments were kept unwashed for possible DNA analysis or to facilitate radiocarbon dating in the future. About 250 mg from several individuals was submitted for stable isotope analysis[47]. When possible, a soil sample from each tomb was kept, especially that from the surrounding skull and abdominal areas[48].

Faunal remains and other materials were separated from the human remains. Some faunal remains were also submitted for stable isotope analysis and others were merely identified to the species level (e.g. following Hillson, 2002) while awaiting

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[46] The labels for each site were: *Ses Païsses de Cala d'Hort necropolis* = **PCHN**, followed by the hypogeum number. A bone from hypogeum 10 would be labelled PCHN-H10. If a specific bone was referenced for a particular reason, it was referenced as PCHN-H10-T1; in this case indicating 'documented tibia 1 from PCHN-H10'. Abbreviations for other bones were C (skull), M (mandible), H (humerus), U (ulna), R (radius), F (femur) and Fib (fibula). Bones and teeth from *Via Romana, 47* and *Via Romana, 28-30*, were labelled **VR47** and **VR28** respectively, along with their tomb number or stratigraphic unit (e.g.VR47/U15, VR28/307). The site of *S'Hort des Llimoners* was labelled **HLL** followed by the tomb number and context within that tomb as assigned by the archaeologist (e.g. HLL203.1). Material from the 2000 and 2001 excavations at *Puig des Molins* was labelled **PM00** and **PM01** respectively, followed by the stratigraphic unit (e.g. PM01/UE66). Human remains from *Carrer Aragó, 33* were labelled **AR33** followed by the box (letters) in which the remains were presented to the anthropologist (e.g. AR33-A).

[47] This is part of a research project that aims to reconstruct the dietary patterns of past populations in Ibiza. The results may be able to show how much of the diet was based on terrestrial and marine protein, as well as the quantity of meat consumption or animal derived products. Funding for the project was awarded by the British Academy to Dr. M.P. Richards in 2001.

[48] In abdominal areas, food remains may be present as well as kidney stones or foetal remains in females.

specialist zooarchaeological analysis. Pottery fragments and other artefacts such as beads were described and handed to the site director for their study.

Photographs were taken on as many human remains as possible. A Nikon F-70 camera was used with 100 ASA 35 mm colour films, the bones placed on top of a dark background receiving appropriate lighting. A 5 cm scale, the site and tomb number usually accompanied the tooth or bone to be photographed. Some drawings were also made, particularly with regard to dental wear.

Most bones were reconstructed, especially those that would provide measurements or would contribute to estimating the minimum number of individuals (MNI). Bone reconstruction was undertaken with great care and with reversible glue when possible. A small proportion of bones were left unreconstructed, as not all reconstruction is worthwhile in terms of effort and time (English Heritage, 2002: 4). Descriptions were written on the general state of bone preservation (e.g. weathering, fragmentation). Each skeletal and dental fragment was inventoried. Human bone identification was facilitated by reference to White and Folkens (1991), Bass (1995), and Scheuer and Black (2000a). Tooth identification benefited from White and Folkens (1991) and Hillson (1996).

Smaller shaft and small cranial vault fragments were only counted and weighed. Data collection employed detailed recording sheets (see archives; also see Buikstra and

Ubelaker, 1994), alongside field notes. The most relevant information was introduced into 'Microsoft Excel' spreadsheets.

Completeness was described usually by segments present such as proximal epiphysis, proximal third, middle third, distal third and distal epiphysis in the case of long bones; head, shaft, and base in the case of metatarsals and metacarpals; complete vertebrae, body, complete neural arch, in the case of vertebrae; and so on. The state of preservation within each fragment was also indicated such as *post-mortem* erosion, *post-mortem* fracture or area missing *post-mortem*.

Information on age and sex indicators, stature, pathology and some relevant non-metric traits were also gathered. Data collection was only based on macroscopic observation of the human skeletal remains, under normal light conditions. Although microscopic methods might be slightly more reliable (Aiello and Molleson, 1993; Ericksen, 1997; also see Lucy *et al.*, 1995), macroscopic examination is quicker, inexpensive, non-destructive and requires less equipment. Radiographic facilities were not available during the analysis. In the original recording notes, however, reference was made to those pathological bones that would benefit from a radiograph if the opportunities arose in the future. This study of the material also included 'routine' analysis that should be in any anthropological study: cranial and post-cranial measurements, non-metric traits, other pathology and some description of muscle markers. Data for cranial indices, dental measurements, mandibular measurements, limb ratio, platymeria, platycnemia, body weight have been obtained. However, only the most relevant to the objectives of this thesis were employed here.

After analysis, the material was carefully packed and later stored and curated at the local museum (*Museu Arqueològic d'Eivissa i Formentera).*

2.3 Materials: preservation

The bones from the Punic rural site PCHN were very fragmented *post-mortem.* Some fragments could not be reconstructed due to adhered soil. Most skeletal elements were represented in the assemblage, with the exception of the hyoid bone and ear ossicles. Adult bones were primarily recovered rather than subadult bones. Except for two crania, the remaining skulls were represented by hundreds of small fragments.

The Punic urban sectors VR28, VR47 and PM01 differed between themselves in terms of preservation. In sector VR28, many skeletal landmarks (e.g. radial notch, epiphyses) were eroded or missing *post-mortem.* Most teeth were found loose, and ribs and vertebrae were very incomplete. Due to the poor state of preservation of bone surfaces, some bones were not available for palaeopathological examination. Several infant skeletons were preserved, partly thanks to their burial inside amphorae, which provided some protection.

VR47 provided the worst state of preservation amongst all the sites. Skeletal preservation was extremely poor (Ill. 2.15). Tooth enamel was also severely affected (Ill. 2.16). Surprisingly, due to weathering of the bones some pathological conditions

(e.g. infectious disease) could not be observed and this limited the palaeopathological data. Deterioration was so bad that siding a bone was extremely difficult in a number of cases. Unfortunately, the sample provided the preservation (partial) of only four epiphyses, severely limiting the sample size for analysis of joint disease (osteoarthritis). Three of these partially preserved epiphyses, the sternal end of a clavicle and the head of a left and right femur, belonged to the skeleton that was buried in the only hypogeum in the area (VR47/H). This tomb may have provided a better seal from degrading environmental factors. The remaining epiphysis was the head of a first right metatarsal (skeleton VR47/U31). Metal artefacts in graves green-stained some skeletons (e.g. VR47/U40).

Material from PM01 was well preserved. All bones could be considered for palaeopathological examination. Many bones, subadult and adult, were complete and were used for stature estimation. Small and fragile bones such as carpals and hyoids were recovered, as well as ossified thyroid cartilage.

Bones and teeth from the site of *S'Hort des Llimoners* came from primary and secondary contexts. Preservation varied in the site. In some occasions small bones were recovered, including ear ossicles (Ill. 2.17) and foetal remains. This variation was partly due to different burial treatment to individuals, with some interred in coffins and deep stone cysts, and others in more superficial tombs and in secondary burials. Some skeletons could provide an important source of information, while others only provided little indication, if any, on age, sex and pathology due to their incompleteness and bad

state of preservation (Ill 2.18). *Post-mortem* erosion usually occurred around the epiphyseal edges, in trochanters and in some vertebrae.

At the site of *Carrer Aragó, 33* secondary burial contexts were present too, and with most tombs including many individuals (Ill. 2.19). Excavation photographs reveal a muddy ground with tombs full of water. Fortunately, most bones were in very good condition (Ill. 2.20). Fragile bones such as ribs and vertebrae were also well preserved.

2.4 Materials: population structure of the samples

In demography, population structure refers to the 'distribution of various characteristics [age, sex] across the members of the population' (Hinde, 2002: 19).

2.4.1 Minimum number of individuals (MNI)

The minimum number of individuals (MNI) is a conventional label used to represent the minimum count of individual skeletons in an assemblage. It does not necessarily represent the real number of skeletons in the sample. Seven different cervical vertebrae can belong to one individual or to seven different ones (each vertebrae from a different individual), so that the minimum in this case is the safest approach[49].

[49] A recent paper has highlighted some of the problems with MNI and has provided an insight into other methods for calculating the number of individuals in an assemblage (Adams and Konigsberg, 2004).

In order to calculate the MNI, a first count was made according to individual tomb boundaries. If one identified tomb presented only leg bones *in situ*, and in a clearly different tomb there were only arm bones *in situ*, the MNI for the site would be two.

Some tombs and sites contained several disarticulated and commingled skeletons. In the case of the Punic rural necropolis (PCHN), the MNI was calculated by counting the number of most commonly repeated bones. Because of the fragmented nature of the sample, in order to ensure a bone was not counted more than once, specific skeletal landmarks were used such as glabella, nuchal crest area, dens of axis, *fovea capitis* of left femur, and radial notch of left ulna. Thus, if the most repeated element was a right orbit, and 15 were present, then the MNI for that context would be 15.

Differences according to age and sex were also considered. Thus, if 15 left femoral heads were estimated as belonging to individuals over the age of 18 years, but then any other bone in the site indicated the presence of a 6 year old individual, the MNI for the assemblage would be 16. In the same way, if through sex discrimination functions there were 11 right femora of characteristic male dimensions and 7 left femora with characteristic female dimensions, the MNI would be 18. Obviously, possible differences in asymmetry between left and right would have to be taken into

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According to these authors the MNI provides underestimates. However, in view of the nature of the Ibizan assemblages and in order to provide a safe estimate, the MNI was calculated. The term implies a 'minimum' and this was thought to be the safest approach.

account. Additional distinctions between individuals such as bone robusticity, pathology and taphonomic appearance are less accurate, and were only taken into account in very clear cases.

If the side to which a bone belonged to was undetermined, the following system was applied. Imagine 10 proximal right radii, 7 left and 4 unsided. These four unsided bones would be divided until there was a level count for each side. Hence, three were first added to the left side in order to even the count (now 10 right and 10 left). The remaining radius would then be added to the side that initially registered more bones, in this case the right side. That would reveal a MNI of 11 as estimated from right radii. This may have underestimated the number of skeletons in an assemblage but the MNI is simply that, a minimum. Nevertheless, it was certainly safer than overestimating. Some authors would have divided the four unsided shafts equally into left and right sides. In this way, the results would provide 12 right and 9 left radii. With larger assemblages the overestimation can be significant.

2.4.2 Age-at-death determination

Subadult and adult skeletons were aged through a combination of methods. Ageing referred to the age of the individual at the time of his or her death. The methods provide an estimation of biological or skeletal age, which may be far from chronological age (number of days or years a person has lived since birth).

2.4.2.1 Age estimation in immature (subadult) skeletons

Tooth formation (Ill. 2.21) and eruption (Ill. 2.22) are currently the most accurate age indicators in subadult skeletons. Teeth are less likely to be affected by the environment than skeletal maturity. Ubelaker's (1999) dental development scheme was employed, both for deciduous[50] and permanent teeth. Loose teeth were classified according to the tooth formation stages given in Moorrees *et al.* (1963), while their age values were taken from Smith (1991). An age was given for each tooth and later the average was estimated for a particular skeleton.

Despite these schemes being based on particular American and European groups, they are recognised and applied throughout the world (Saunders *et al.*, 1993; Hillson, 1996: 146; see also Liversidge, 1994). Age estimation based on the third molar was taken with caution due to its variability with regard to formation and eruption (see Genovés, 1962: 45; McKern, 1970: 42; Bass, 1995: 13; Kullman, 1995).

In the absence of teeth, skeletal maturity was employed. Guidelines and charts on skeletal development were obtained from McKern and Stewart (1957), McKern (1970), Brothwell (1981, 1989), Schwartz (1995), Ubelaker (1999), and Scheuer and Black (2000a). When long bone epiphyseal union was recorded, five stages were considered (modified from McKern, 1970; and Buikstra and Ubelaker, 1994): unobservable, not fused (Ill. 2.23), semi-fused (Ill. 2.24), ¾ fused (Ill. 2.25), completely

[50] More recently, a more refined stage of development has been devised by Liversidge and Molleson (2004). Other methods such as permanent tooth length (Liversidge *et al.*, 1993) have also been developed.

fused. Some problems with epiphyseal union are the variability in the use of reference standards (Lampl and Johnston, 1996; Tanner *et al.*, 2001: 16-17), the influence of genetic and environmental factors (Tanner, 1962; Saunders, 1992: 6; Lampl and Johnstone, 1996; Tanner *et al.*, 2001: 16), and differences in growth patterns between males and females (Humphrey, 1998). Because the methods today are based on living populations there is also a need to calibrate these standards when possible (Molleson, 1986).

McKern and Stewart (1957) showed the extent of variability within a sample of dead soldiers from the Korean War. In general, however, they regarded complete union for the ankle, hip and elbow at age 20, the knee and wrist at age 23 and the shoulder at 24 years of age. In their Korean sample, complete fusion of the first and second segments of the sacrum was observed in all individuals over 33 years old, compared to only 63% of the 30-32 year-olds.

The lengths of long bone diaphyses were also valuable (see Merchant and Ubelaker, 1977; Hoppa, 1992; Scheuer and Black, 2000a), even though some of the reference data have derived from 'healthy' living populations (e.g. Maresh, 1943). Foetal remains were primarily aged in this way. If a bone was not complete, its approximate length could be estimated by reference to a complete bone of similar dimensions from the same site. This allowed the inclusion of many fragmented bones into specific age categories.

2.4.2.2 Age estimation of mature (adult) skeletons

Adult[51] skeletons, approximately over the age of 18-20 years, were estimated from a combination of methods depending on which anatomical parts had preserved.

This thesis considered the following ageing methods, in descending order of reliability: after skeletal maturity including the clavicle and sacrum (only applied to some skeletons), dental wear was prioritised, followed by the pubic symphysis in younger individual, and the auricular surface for older individuals. The presence or absence of degenerative changes on the bone, such as osteoarthritis (see Ubelaker, 1999), was only used to complement the age estimated from the previous methods. Whenever possible, a combination of methods was used. The combination of methods provides a more accurate result than relying solely on a single indicator (Bedford *et al.*, 1993). However, when there were result discrepancies between methods, priority was given to dental wear. In some populations, dental wear has seen to produce more reliable age estimates than the morphology of the pubic symphysis and the auricular surface (Mays, 2002).

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[51] These categories, 'subadult' and 'adult' are stated here in biological terms, according to skeletal maturity. Social perceptions of age are very different. This confusion could be problematic for archaeologists using skeletal data to interpret burial rites (see Lucy, 1994). A skeleton of a child of about 6 years may not be regarded as an 'infant' in that particular society. In fact, Gómez and colleagues (1992: 101) have also pointed out this out by asking at what age individuals become adults in social terms. It must also be noted that even if biological and cultural data are integrated, the ages given by the skeleton are only skeletal ages, not necessarily chronological ages. In fact, chronological age in the past may have been used in different ways. 'Social birth' may have occurred at a different time to biological birth (Ingvarsson-Sundström, 2003: 163, 166). Age may not even have been acknowledged or known at in some past populations (Cox, 2000b).

A strong correlation between dental wear (Ill. 2.26) and chronological age is supported by Walker and colleagues (1991), although they state that background information regarding diet, culinary practices, and sexual dimorphism in diet and temporal variation may be necessary. For instance, fern root causes heavy wear in Maori first molars (Kieser *et al.*, 2001). Eating kangaroo meat causes heavy wear in the front teeth of Australian Aborigines (Barrett, 1958). Other cultural and biological factors must also be taken into account (see Molleson and Cohen, 1990; Hillson, 1996; Townsend *et al.*, 1994).

In the Ibizan material, age estimation was initially recorded using the method devised by Miles (1963) and complemented by the schemes created by Brothwell (1981) and Li and Ji (1995). This latter method was included because it has been considered one of the most reliable methods for recording attrition (Ajmal *et al.*, 2001). It was based on a population with a diet based on rice, some vegetables, corn and meat (Li and Ji, 1995). However, later observations in the field revealed that the scheme produced exaggerated results in the Ibizan samples.

In Spain, the most used method is that of Brothwell (1981, 1987). However, it is of little help for those over 45 years of age (Miles, 2001), and cannot be calibrated as opposed to the method devised by Miles (1963). Observations taken during fieldwork (e.g. skeletons VR47/U28, AR33-G, AR33-H, HLL819) revealed how dental wear was reasonably well correlated with dental development and skeletal maturity (age range 6-30 years).

The method by Miles (1963) has produced reliable age determinations in a variety of populations (Nowell, 1978; Kieser *et al.*, 1983; Walker *et al.*, 1991: 176). Miles himself revised his 1963 method and indicated that in those individuals over 50 years old, the method underestimates as much as 10 or 15 years (Miles, 2001). In the present study however, there was no attempt to age more specifically those individuals older than 50 years.

When employing the Miles' (1963) chart, an age was assigned to any lower or upper molar tooth. An average age from all the available molars was finally calculated. Because third molar eruption is variable, its attrition age was omitted from the average calculation, as underestimates were likely present if its eruption occurred late in life. The pattern of eruption of the third molar is usually between the ages of 17 and 22, with a peak at 17-18 years, but eruption can be as late as 35 years (McKern, 1970: 42-43). Its eruption can depend on the genetic origin of the population, with African individuals possibly having an earlier eruption than European individuals (Chagula, 1960). It was only used to complement a given age (middle or old age) of a skeleton as determined from other methods.

Teeth with gross occlusal dental caries were excluded for age determination. Complete edentulous mandibles were classified into the older age category. Mandibles or maxillae with over 50% of teeth lost *ante-mortem* (Ill. 2.27) were also classified in the older age category (Mays, 1998, 2002; Miles, 2001). Although cultural factors may

result in tooth loss at a young age, the loss of much of the dentition is likely to correlate with older age (see Wols and Baker, 2004).

In combination with dental wear, or when the latter was not available, other methods were employed. Methods based on degenerative changes focus on two areas of the *os coxa* (pelvis): the auricular surface (Lovejoy *et al.*, 1985) and the pubic symphysis (Todd, 1920 for males –in Ubelaker, 1999; Gilbert and McKern, 1973 for females). According to Buikstra and Ubelaker (1994: 21), age determination from the pubic symphysis (PS) is the most reliable of the macroscopic methods available (Ill. 2.28). However, it has shown to produce underestimates in older individuals (Meindl *et al.*, 1985) amongst other problems (Suchey, 1979). The auricular surface (AS) patterns are more complex and difficult to score (Ill. 2.29), but they usually preserve better than the PS (Buikstra and Ubelaker, 1994: 24). There is, however, a need to re-evaluate this method (Cox, 2000b)[52].

The current general consensus is that the PS is a good predictor of age in individuals under 40 years of age (Katz and Suchey, 1986; Aiello and Molleson, 1993; Bedford *et al.*, 1993), while the AS works better in older adults (Lovejoy *et al.*, 1985; Bedford *et al.*, 1993). The reliability of such methods, however, is dependent on the genetic background of the skeletal population (see Katz and Suchey, 1989). In a small Asian sample, these age indicators underestimated true age by about 30 years in middle-aged and older adults (Schmitt, 2004).

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[52] Well after data collection on the Ibizan remains had started, this method was revised and modified by Buckberry and Chamberlain (2002). Mulhern and Jones (2005) have also re-evaluated the original method and that revised by Buckberry and Chamberlain (2002).

The methods based on the PS and AS are based on modern populations and forensic cases. The biological processes for mortality and morbidity were significantly different in the past (Hoppa, 2000). With this regard, further support is provided for dental attrition. The chart created by Miles (1963) was devised from Anglo-Saxon skulls, while Brothwell (1981) employed material dating from the Neolithic up to medieval times.

In accordance with other studies from Ibiza (e.g. González-Martín and Lalueza, 1992) cranial suture closure was also recorded. The spheno-occipital synchondrosis was employed to give a minimum adult age to a skull, assuming fusion is complete by about the age of 21 years (Genovés, 1962: 73; McKern, 1970: 51) or even later (Schwartz, 1995: 73; summary in Genovés, 1962: 57). Coronal, sagittal and lambdoid suture closure was recorded following Meindl and Lovejoy's (1985: 58) categories: open, minimal closure (up to 50% synostosis), significant closure (some portion of the suture still not completely fused), and complete obliteration. However, this method has proved ambiguous and unreliable. Suture closure is very variable (Genovés, 1962) and has shown to be independent from age (Key *et al.*, 1994; Hershkovitz *et al.*, 1997; Lynnerup and Jacobsen, 2003). Suture closure, therefore, was only employed with caution to complement other age indicators as a means to confirmation (young versus old).

Other techniques, such as those devised by İşcan and colleagues (1984, 1985; and Loth, 1986) on the fourth right rib, was not employed due to the difficulties identifying this rib in the laboratory[53].

2.4.2.3 Age categories

Establishing the age categories was complicated as there is much variation in the literature.

Some categories are defined by skeletal maturity and dental development (e.g. see Schwartz, 1995: 186; Bass, 1995: 13); others are defined by physiological changes such as puberty (see Comas, 1960; Timiras, 1994). In terms of dental development, a category commonly described is defined by the eruption of the permanent first molar. However, this boundary could be defined by the eruption of any other permanent tooth. In terms of skeletal development, an individual over the age of eighteen years is considered an 'adult' defined by the cessation of longitudinal growth of the long bones.

With regard to adults, this study aimed at providing comparative data for other Spanish studies. However, many palaeodemographic studies in Spain (e.g. Souich *et al.*, 1991; Caro and López, 2003) use the age categories in years 0-6, 7-12 (or even 0-12), 13-20, 21-40, 41-60, >60 years. These are similar to the ones used in previous Ibizan studies (González and Lalueza, 1992, 2001), with adult age categories being

[53] During excavation of articulated remains, it would be recommended that the archaeologist bag third, fourth and fifth ribs separately, since they may want to be used by the anthropologist for adult age determination.

18/20-40, 40-60, >60 years. However, it was felt that these age categories were not completely appropriate for the methods used in this thesis. In addition, distinguishing between a 50 year old (40-60 year category) and a 60 year old (>60 year category) may be rather tricky. For safety, a category of over 50 rather than 60 years was established.

At the other extreme, Gómez (1989) in his study of Ibizan remains provides narrower age categories of 5-year intervals (20-25, 25-30, etc.). These short age categories have been recommended for palaeodemographic analysis (Goodman *et al.*, 1984b; Ubelaker, 1999). However, narrowing down a skeleton to a five-year age group with the methods employed can be rather difficult.

After much consideration, the following age categories were used in this thesis: foetal/perinatal, 0-0.9 years, 1-4.9 years, 5-9.9 years, 10-14.9 years, <15 years undetermined, >15 years undetermined, 15-19.9 years, 20-29.9 years, 30-49.9 years, >50 years, and 'age unknown'.

The reasons for these categories were various. Deaths at the foetal and perinatal age are largely related to circumstances during pregnancy and the actual birth. The larynx also starts descending at this time, and this may cause indirect threats to life. Infanticide may have also affected this age group. Up to one year of age, mortality may be associated with breastfeeding (e.g. neglect) as well as infanticide (Ingvarsson-Sundsröm, 2003: 113). Between the ages of one and five years, weaning occurs and children are more exposed to the risk of malnutrition and infection and children are

more or less dependent on adult carers (Rousham and Humphrey, 2002: 124). Around the age of four or five years, children also start to become more active and participate more fully in society, which may result in accidents (Ingvarsson-Sundström, 2003: 114). Subadult age categories do have to be fairly broad also, as there is variability present due to sex, genetics, environment and ethnicity (Molleson, 1986; Johnston and Zimmer, 1989: 12).

The borderline between 'subadult and 'adult' has been 'artificially' defined at the age of 15 years. This boundary has been used in other studied (e.g. see Ingvarsson-Sundström, 2003; Kelley *et al.*, 1991). The age range between 5 and 15 years, has allowed authors to calculate the juvenility index: the number of dead in the 5-15 age range divided by the number of dead over 20 years of age (Bocquet-Appel and Masset, 1977). It also follows a demographic convention where individuals of this age onwards are less dependent on adults, have economic potential and reproductive self-sufficiency (Chamberlain, 2000b: 207). Furthermore, many bones with no epiphyses preserved *post-mortem* may be defined as adult (above 18 or 20 years) due to size, but experience with the Ibizan material revealed how bones of 15 year-olds could be larger than a fully matured adult. It is safer, therefore, to say that these bone shafts with apparent adult dimensions belong with much certainty to an individual over the age of 15 years. Also, from this age onwards, bone epiphyses start to fuse.

Within the adult category, a classified individual in the first age range of 15 to 20 years would be determined by incomplete fusion of long bones, PS pattern, dental

wear and perhaps emergence of the third molar. The category between 20 and 30 years also seemed appropriate. The minimum age of 20 years was defined mainly by complete fusion of long bone epiphyses and dental wear. The 30-year-old limit would coincide with the approximate time of complete fusion of the sternal end of the clavicle (Genovés, 1962: 59; McKern, 1970: 46; Szilvássy, 1980; Cox and Scheuer, 1996). In this regard, if the sternal end of a clavicle was not completely fused, the bone most likely belonged to a person younger than 30 years. In the same way, unfused first and second segments of a sacrum would tend to indicate a young adult (McKern, 1970: 48; Scheuer and Black, 2000a). The age boundary of 30 years has also been used elsewhere (e.g. see Cox, 2000b). It is up to this point where the age estimation can rely on skeletal maturity (McKern, 1970: 42). Approximately after the age of 30 years, the majority of methods rely on degenerative changes in the skeleton. After this age, the inclusion of an individual into categories such as 30-40, 40-50 or 35-45, can be difficult and imprecise. In order to minimize errors of allocating an individual into these middle-age categories, they were grouped under a wider age range (30-50 years). After the age of 50 years the diagnosis was easier, based on dental wear and *ante-mortem* tooth loss, clearer patterns in the auricular surface and complemented with marked degenerative changes (osteoarthritis) in the skeleton. In this sense, if the skeleton did not show young nor old features, it was likely to be in the range 30 to 50 years.

Some skeletons could only provide information such as 'under 15 years old' or 'over 15 years old' with no further specific age. For instance, an isolated long bone with a preserved fused epiphysis, would be identified as belonging to an individual over

the age of 15 years. Bones or skeletons that did not provide any clue as to their age were classified as 'age unknown'.

Table 2.2 illustrates the different age estimation methods employed in the different age categories.

Table 2.2. Age-at-death estimation methods employed to classify a skeleton into an age category.

Age (years)	Methods
Foetal/perinatal, 0-0.9, 1-4.9, 5-9.9, 10-14.9	Dental formation and eruption, immature skeleton, long bone lengths
15-19.9	Dental wear, immature skeleton. [Complementary: spheno-occipital synchondrosis, possibly third molar emergence]
20-29.9	Dental wear, fused long bones, unfused clavicle and sacrum, pubic symphysis, auricular surface
30-49.9	Dental wear, skeletal maturity, pubic symphysis, auricular surface.
>50	Dental wear, skeletal maturity, *ante-mortem* tooth loss, auricular surface, pubic symphysis. [Complementary: marked osteoarthritis, cranial suture obliteration]

2.4.3 Sex estimation

Methods of sex assessment are reviewed below for both subadult and adult individuals. In light of the problems with sex estimation in immature skeletons (Section 2.4.3.1), only adult individuals were sexed.

2.4.3.1 Subadult skeletons

Significant sexual dimorphism, for instance in cranial and mandibular morphology, has been identified in pre-pubertal skeletons (Weaver, 1980; Holcomb and Konigsberg, 1995; Molleson *et al.*, 1998), and methods have been devised (e.g. Schutkowski, 1993; Loth and Henneberg, 2001). Canines also appear to be sexually dimorphic (Moss and Moss-Salentijn, 1977; Ferembach *et al.*, 1980: 525; Farwell and Molleson, 1993: 180; Molleson *et al.*, 1998; Pettenati-Soubayroux *et al.*, 2002), although not in all populations (İşcan and Kedici, 2003). Problems also emerge with regard to mortality bias (Mays, 1998; Molleson and Cruse, 1998: 727; Mays and Cox, 2000).

Overall, sex determination in subadult individuals has been regarded as problematic (Saunders, 1992; for a review see Scheuer and Black, 2000a: 15-16). There is a significant overlap between males and females (Weaver, 1980; Scheuer, 2002). In addition, subadult skeletons of known age and sex used to devise methods are few and sometimes unobtainable. Currently, the problems seem to override the benefits. Therefore, although data such as canine measurements were taken from the Ibizan remains, sexing subadults was omitted in the present research[54].

[54] Further efforts can be made with new methods in the future. Questions can then be answered as to tomb type according to infant sex. It may also aid in reconstructing mortality profiles in infancy (Saunders and Barrans, 1999).

2.4.3.2 Adult sex determination

Recommendations on the determination of biological sex of adult skeletons, from around 18 years and over[55], were found in the literature (Genovés, 1959, 1962; Phenice, 1969; Acsádi and Nemeskéri, 1970; Ferembach *et al.*, 1980; Brothwell, 1981, 1987; Hoyme, 1984; Sutherland and Suchey, 1991; Buikstra and Ubelaker; 1994; Bass, 1995; Ubelaker, 1999). The visual examination employed traits from the pelvis and the skull (Table 2.3). Long bone dimensions were also considered. Partly due to overlaps between male and female traits, the following five classifications were used (after Buikstra and Ubelaker, 1994): 'female' (F), 'possibly female' (F?), 'ambiguous or undetermined' (?), 'possibly male' (M?), and 'male' (M). When only a small number of traits were used (three or less), especially the less reliable skull traits, for caution the procedure was as follows: if the traits were male, then the result would be M?; if female, then F?. The same procedure was followed if the sex assigned to an individual was based only on long bone measurements, or in conjunction with only one pelvic or skull trait.

As many traits as possible were recorded and an overall result was later given. Some traits were given more priority than others, particularly with regard to sex estimation from the skull. In the cranium (Ill. 2.30, Ill. 2.31), more priority was given to the glabella, mastoid process, and nuchal crest, rather than the frontal slope, the

[55] Excluding the skull, in some clear cases (e.g. HLL818) the pelvis was a successful sex indicator in individuals as young as 15-16 years old.

supraorbital margin and the temporal line[56]. The mandible may also be unreliable (see Maat *et al.*, 1997). The grades in Buikstra and Ubelaker (1994) for the mental eminence of the mandible does not seem to be a key diagnostic, at least in British populations, so other characteristics need considering such as overall size, width of the ascending ramus, gonial angle eversion, and shape of the chin viewed inferiorly (Brickley, 2004: 23).

The information in Table 2.3 may seem subjective (e.g. big, small) but scores for some traits were given following diagrams in Buikstra and Ubelaker (1994). Some traits were only used complementary such as the number of cusps in the first molar. In addition, the typical morphology of traits according to sex is 'stereotypical', they show the extreme ends of each sex group. Much overlap exists in between.

[56] These priorities are based on personal observations of other sites in Ibiza and from other collections outside Spain. In an Islamic cemetery from Ibiza studied by myself in 1999, the temporal line revealed no differences between males and females (unpublished data). Known female skulls in the collection of the Oxford University Museum of Natural History also presented supraorbital margins that were clearly male.

Table 2.3. Secondary sex characters.

Trait	Female	Male
PELVIS		
Overall pelvis	Lower but broader	Higher and narrower. S-shaped iliac crest
Subpubic angle	Broad	Narrow
Subpubic concavity	Present	Absent
Ischiopubic ramus ridge	Narrow	Broad
Ventral arc	Present	Absent
Obturator foramen	Triangular	Oval
Sciatic notch	Wide (>90 degrees)	Narrow (<90 degrees)
Arc composé	Not in line with AS margin	In line with AS margin
Auricular surface	Raised in general	Depressed in general
Pre-auricular sulcus	Deep and broad	Absent or narrow and shallow
Acetabulum	Relatively small	Relatively large
Alae of sacrum	Larger than body	Not larger than body
Sacral curvature	Straighter	More curved
SKULL		
Glabella	Smooth, small	Marked, robust, prominent
Supraciliary arches	Smooth, small	Marked, robust, prominent
Frontal slope	Vertical	Inclined
Supraorbital margin	Pinched, thin	Rounded, broad
Frontal and parietal bossing	Present	Usually absent
Orbital shape	Round	Quadrangular
Mastoid process	Small	Large
Posterior zygomatic arch	Very slightly marked	Marked
Nuchal crest	Smooth, absent	Marked, 'hook-type'
Dental arch	Elliptic	Round
Overall mandible	Gracile	Robust
Mental eminence	Small, smooth, round	Prominent, broad, square
Inferior body margin	Thin	Thick
Ascending ramus	Narrow	Broad
Gonial angle	Absent or slight eversion	Usually marked eversion
Lower M1	Sometimes 4-cusp	Usually 5-cusp
LONG BONES		
Long bone dimensions	Gracile appearance	Robust appearance

Overall, the pelvis is the most accurate sex indicator due to sexual differences with regard to pregnancy and childbirth in the female. The angle of the sciatic notch was the most represented pelvic trait amongst all the Ibizan assemblages (Ill. 2.32). A complete pelvis can provide 90-95% accuracy. In the pubis, the subpubic concavity,

subpubic angle (Ill. 2.33), the medial aspect of the ischio-pubic ramus and the ventral arc are highly accurate (Phenice, 1969; Kelley, 1978; Lovell, 1989; Anderson, 1990), although accuracy may decrease in older aged individuals (Lovell, 1989). Parturition features on the pelvis (Cox, 2000a; Bergfelder and Herrmann, 1980), such as the preauricular sulcus (Ill. 2.34), were less reliable (Holt, 1978; Kelley, 1979; Suchey *et al.*, 1979; Cox, 2000a).

Sex estimation from long bone measurements required the use of discriminant functions. No methods have been devised as yet for Ibiza. The functions employed derive from the work by Alemán *et al.* (1997) on a modern Spanish sample. The computer programme FORDISC 2.0 (Ousley and Jantz, 1996) was also employed as it included reference groups from a variety of ancestral origins. When the two methods provided different results for an isolated bone, then the bone was classified as 'undetermined sex'. In the Ibizan material, sex determination from long bones was important because most assemblages were disarticulated. It provided the only evidence for sex differences in palaeopathological analysis of trauma and osteoarthritis. During fieldwork, it was observed how the formulae of Alemán *et al.* (1997) correlated well with the sex obtained from the pelvis and the skull in the well preserved articulated skeletons[57]. Metric data was obtained with an osteometric board, a measuring tape and

[57] These conclusions on the reliability of these sex determination methods can be observed in the original skeletal archives. Other measurements were taken such as the circumference of the radial tuberosity (Safont *et al.*, 2000) and the dimensions of the occipital condyles (Holland, 1986) but these were not employed for sex determination. Measurements of innominate bones (e.g. Rissech and Malgosa, 1991, 1997) or the length of the sternum (Stewart and McCormick, 1983) were not undertaken due to the incompleteness of the remains.

a digital calliper Mitutoyo ABS. Bones severely affected by pathology (e.g. periostitis) were not measured.

An awareness of some problems in sex determination is valuable. There is no absolute sexual dimorphism (Blackless. *et al.*, 2000). It may also be possible to encounter skeletons of people that were born with genetic abnormalities involving the sex chromosomes (examples stated in Reynolds, 1978; Taylor, 1996; Blackless *et al.*, 2000). A further warning is that in order to obtain accurate sex and age determinations from skeletons, each method should be fully understood. This includes knowledge on how these traits have developed and have been affected in terms of biomechanics, hormones, activity, health, nutrition and occupation (Hoyme, 1989: 59-60). It would also be necessary to understand the range of variation by ethnic group, as well as the changing patterns from childhood to old age (Hoyme, 1989: 59-60).

Osteologists should notice that, usually, males under the age of 30 years have a more female appearance and may be misclassified as females; while post-menopausal females from about the age of 45 years, usually become more masculine, so that elderly women may be classified as men (Walker, 1995). The supraorbital ridge, for example, becomes more robust in elderly females (Walker, 1995: 40). These phenomena may be partly responsible for a bias towards the presence of males in archaeological populations; although higher infanticide in female children may also contribute to this bias (see Wicker, 1999).

There is a high probability that ancient Ibiza received immigrants from different regions and different ancestral backgrounds. Knowing the ancestry of the population does help in the determination of sex through skeletal traits. For instance, brow ridges are generally smaller in Asians and Blacks, while mastoid processes are smaller in females and Africans but larger in Europeans (Hoyme, 1989: 71-72). Unfortunately, no ancestry could be assigned to the skeletal remains in the Ibizan assemblages.

2.4.4 MNI, age and sex profile of the Ibizan samples

This section provides basic information on the demographic profile of the Ibizan samples.

2.4.4.1 The Punic rural sample: *Ses Païsses de Cala d'Hort*

A minimum number of 75 individuals were identified in this sample (Table 2.4). Due to the disarticulated and commingled nature of the bone assemblage, the MNI was achieved by counting the number of repeated bones, together with age and sex considerations.

Table 2.4. Population structure at the Punic rural site.

PCHN				
Age (years)	**Unknown sex**	**Female**	**Male**	**Total**
Foetal/perinatal	1	-	-	1
0-0.9	1	-	-	1
1-4.9	2	-	-	2
5-9.9	2	-	-	2
10-14.9	3	-	-	3
<15 undetermined	?	-	-	-
15-19.9	3	-	2	5
20-29.9	5	2	1	8
30-49.9	9	1	6	16
50+	3	1	1	5
>15 undetermined	26	2	4	32
Undetermined	-	-	-	-
TOTAL	55	6	14	**75**

The largest count was provided by 69 distal epiphyses of left humerii. Three of these left elements were unfused and belonged to subadult individuals. Hence, 66 of these bones belonged to adults. Considering other immature bones in the sample, a total of nine subadult individuals were identified, which brought the final MNI count to 75 individuals.

Because the largest count was provided by long bones, no specific adult age could be given to all these individuals. Some adults were classified into a specific age and sex category by examining the preserved mandibles, as these out-numbered any other skeletal element (e.g. pelvis) used in ageing and/or sexing. Age was achieved by examining dental wear, or in the case of older individuals, *ante-mortem* tooth loss. Sex was determined through the morphology of the mandible, and was complemented by mandibular measurements, which were introduced into FORDISC 2.0 (Ousley and Jantz, 1996).

2.4.4.2 The Punic urban sample: *Via Romana, 28-30*

The MNI for this site resulted in 23 individuals (Table 2.5). The MNI was calculated with the aid of the excavation plans. Cremations from this site were excluded as well as those contexts clearly associated with Roman materials[58] (see Ramon, 1998). Taking into account skeletons from the Punic period, the MNI was estimated by separating bones according to tomb boundaries, but also by repeated bone counts from those areas where bones were found disarticulated.

Table 2.5. Population structure at VR28.

VR28				
Age (years)	**Unknown sex**	**Female**	**Male**	**Total**
Foetal/perinatal	1	-	-	1
0-0.9	1	-	-	1
1-4.9	4	-	-	4
5-9.9	3	-	-	3
10-14.9	2	-	-	2
<15 undetermined	-	-	-	-
15-19.9	1	-	-	1
20-29.9	-	1	1	2
30-49.9	-	-	-	0
50+	-	1	-	1
>15 undetermined	3	2	2	7
Undetermined	1	-	-	1
TOTAL	16	4	3	**23**

[58] This human remains associated with Roman material and that were excluded from the Punic MNI count were those discovered in the upper layers of trench 300, all skeletons from trench 800 and all but the amphorae burial from trench 1200.

2.4.4.3 The Punic urban sample: *Via Romana, 47*

Excluding the Phoenician cremations, this site also yielded a minimum number of 23 Punic individuals. This calculation was obtained by counting individuals in each tomb who were later added to individuals from other tombs in order to estimate a MNI for the whole Punic sample. Table 2.56 divides the 23 individuals into age and sex categories.

Table 2.6. Population structure at VR47.

VR47				
Age (years)	**Unknown sex**	**Female**	**Male**	**Total**
Foetal/perinatal	-	-	-	0
0-0.9	-	-	-	0
1-4.9	4	-	-	4
5-9.9	1	-	-	1
10-14.9	1	-	-	1
<15 undetermined	1	-	-	I
15-19.9	1	1	-	2
20-29.9	-	-	-	0
30-49.9	-	1	2	3
50+	-	1	1	2
>15 undetermined	6	1	2	9
TOTAL	14	4	5	**23**

Around five additional amphorae burials were present in the excavation drawings and may have contained subadult skeletons but no bones from these contexts were submitted to the present anthropologist. In addition, another amphora burial (U66) was recorded but left unexcavated (Gurrea and Ramon, unpublished). These amphorae were not counted and added to the MNI since no bones from these contexts were analysed. However, it is worth bearing in mind that if these had been counted, they

would likely be included, in view of the data from other Punic amphora burials, in the under five year-old age category.

2.4.4.4 The Punic urban sample: *Puig des Molins* (2000-2001 excavations)

It can be recalled that bones selected from the year 2000 and 2001 excavations derived from an inhumation fossa (PM00/IN.6) and two stratigraphic contexts from hypogeum II (PM01/UE62, PM01/UE66) respectively. The human remains from the hypogeum were treated as disarticulated. In this case, MNI was dependent on the number of repeated skeletal elements, in conjunction with age and sex considerations. The subadult skeleton in the inhumation fossa was counted as one separate individual (MNI = 1) and then added to the MNI result from the hypogeum. The total MNI for this sample was 18 (Table 2.7).

Table 2.7. Demographic structure of the PM01 sample.

PM01				
Age (years)	**Unknown sex**	**Female**	**Male**	**Total**
Foetal/perinatal	-	-	-	0
0-0.9	-	-	-	0
1-4.9	2	-	-	2
5-9.9	1	-	-	1
10-14.9	-	-	-	0
<15 undetermined	-	-	-	-
15-19.9	-	1	1	2
20-29.9	1	1	-	2
30-49.9	-	-	3	3
50+	-	1	-	1
>15 undetermined	2	2	3	7
Undetermined	-	-	-	-
TOTAL	6	5	7	**18**

2.4.4.5 The total Punic urban assemblage

The three urban samples were pooled. This provided a MNI of 64 individuals for the Punic urban context (Table 2.8).

Table 2.8. Total Punic urban assemblage.

Punic urban sample				
Age (years)	**Unknown sex**	**Female**	**Male**	**Total**
Foetal/perinatal	1	-	-	I
0-0.9	1	-	-	1
1-4.9	10	-	-	10
5-9.9	5	-	-	5
10-14.9	3	-	-	3
<15 undetermined	1	-	-	1
15-19.9	2	2	1	5
20-29.9	1	2	1	4
30-49.9	-	1	5	6
50+	-	3	1	4
>15 undetermined	11	5	7	23
Undetermined	1	-	-	1
TOTAL	36	13	15	**64**

Finally, by pooling the MNI from the rural and urban contexts together, the Punic period was represented by a total of 139 individuals. Of these 139 individuals, 30 (21.5%) were subadults, 108 were adults, and one individual could not be aged. From these 108 adults, 29 (26.8%) were identified as males and 19 (17.5%) as females.

2.4.4.6 Late Antiquity-Early Byzantine sample: *S'Hort des Llimoners*

MNI calculation was complex for this site. The presence of several individuals in one tomb, the presence of both primary and secondary burials, overcrowding of burials, and *post-mortem* changes all contributed to this difficulty. An MNI for each tomb was calculated and then added to the total.

Excavation plans were of value, showing how bones from one burial overlapped with those of another burial. In fact, remains of an individual may be scattered in two different tombs. When in doubt about the MNI for a particular tomb, the minimum (rather than an overestimation) was employed. This site included the remains of at least 142 individuals (Table 2.9).

Table 2.9. Demographic structure at HLL.

HLL				
Age (years)	**Sex unknown**	**Female**	**Male**	**Total**
Foetal/perinatal	6	-	-	6
0-0.9	3	-	-	3
1-4.9	23	-	-	22
5-9.9	16	-	-	16
10-14.9	15	-	-	15
<15 undetermined	4	-	-	4
15-19.9	1	3	1	5
20-29.9	3	7	9	19
30-49.9	-	3	9	12
50+	3	3	6	12
>15 undetermined	14	4	8	26
Undetermined	1	-	-	1
TOTAL	89	20	33	**142**

2.4.4.7 Late Antiquity-Early Byzantine sample: *Carrer Aragó, 33*

This bone assemblage was tackled as a commingled assemblage. Many skeletons were articulated *in situ* during excavation, both in primary and secondary burials. Unfortunately, accidental events in the 1980s during post-excavation handling resulted in loss of context labels and commingling of bones. By counting the number of repeated bone elements and considering the information on age and sex, a MNI of 64 individuals was identified (Table 2.10). The indications to femur and dentition simply reflect the method (e.g. femur length) employed in ascribing those individuals into a particular category.

Table 2.10. Demographic structure at AR33.

AR33				
Age (years)	**Sex unknown**	**Female**	**Male**	**Total**
Foetal/perinatal	0	-	-	0
0-0.9	3 (femur)	-	-	3
1-4.9	8 (femur)	-	-	8
5-9.9	7 (femur)	-	-	7
10-14.9	7 (femur)	-	-	7
<15 undetermined	-	-	-	-
15-19.9	1 (dentition)	1 (dentition)	2 (dentition)	4
20-29.9	4 (dentition)	1 (dentition)	1 (dentition)	6
30-49.9	-	-	4 (dentition)	4
50+	1 (dentition)	-	2 (dentition)	3
>15 undetermined	15 (femur)	-	-	15
Undetermined	7 (femur)	-	-	7
TOTAL	53	2	9	**64**

With regard to the MNI, the left femur (proximal third) gave the highest count with 64 individuals. The left tibia provided the second largest count of 52 individuals.

The mandibles gave a minimum of 37 individuals. Because dentitions were less represented than femora in each subadult age category, it was the femur that determined the number of subadult individuals in each age range. The femur count recognised 32 individuals over the skeletal age of 15 years. In order to provide information on age and sex for these individuals, the mandible was employed rather than other skeletal elements that were less represented.

2.4.4.8 The total Late Antiquity-Early Byzantine assemblage

The two Late Antiquity-Early Byzantine samples were pooled. This provided a MNI of 206 (Table 2.11).

Table 2.11. Total Late Antiquity-Early Byzantine assemblage.

Late Antiquity- Early Byzantine period				
Age (years)	**Sex unknown**	**Female**	**Male**	**Total**
Foetal/perinatal	6	-	-	6
0-0.9	6	-	-	6
1-4.9	31	-	-	31
5-9.9	23	-	-	23
10-14.9	22	-	-	22
<15 undetermined	4	-	-	4
15-19.9	2	4	3	9
20-29.9	7	8	10	25
30-49.9	-	3	13	16
50+	4	3	8	15
>15 undetermined	28	4	9	41
Undetermined	8	-	-	8
TOTAL	141	22	43	**206**

2.4.4.9 Summary of the samples available for study

The deaths of the available population for analysis provided a demographic structure, which is summarised in Table 2.12.

Table 2.12. Summary data on individuals from each sample*.

Site	Total MNI	Subadult	Adults Sex unknown	Adult Males	Adult Females	Age and sex unknown
PCHN	75	9	46	14	6	0
VR47	23	7	7	5	4	0
VR38	23	11	4	3	4	1
PM01	18	3	3	7	5	0
Total Period 1	**139**	**30**	**60**	**29**	**19**	**1**
HLL	142	67	21	33	20	1
AR33	64	25	21	9	2	7
Total Period 2	**206**	**92**	**42**	**42**	**22**	**8**

* Codes: Period 1 = Punic period; Period 2 = Late Antiquity-Early Byzantine period.

2.5 Materials: representation of skeletal elements

Having established the MNI for each sample, it was possible to investigate the preservation and recovery of skeletal elements. Tables 2.13 and 2.14 display the frequency of skeletal elements that were present in a site, in relation to the number of elements expected if all the skeletons were completely (100%) preserved. Preservation frequencies for teeth are given in Chapter 6. Specific anatomical regions for each of the skeletal elements have been considered since they provide a more accurate count.

Table 2.13. Preservation of skeletal elements/landmarks in the Punic assemblages*.

Specific skeletal region	Site PCHN % recovered from an expected 75 complete skeletons	Site VR47 % recovered from an expected 23 complete skeletons	Site VR28 % recovered from an expected 23 complete skeletons	Site PM01 % recovered from an expected 18 complete skeletons
Glabella (*frontal bone*)	28% (21/75)	4.3%(1/23)	4.3% (1/23)	5.5% (1/18)
EAM (*temporal bone*)	30% (45/150)	15.2% (7/46)	28.2% (13/46)	8.3% (3/36)
Mastoid process (*temporal bone*)	36% (54/150)	19.5% (9/46)	15.2% (7/46)	2.7% (1/36)
Petrosa (*temporal bone*)	10% (15/150)	28.2% (13/46)	23.9% (11/46)	13.8% (5/36)
Ear ossicles	0% (0/450)	0% (0/138)	0% (0/138)	0% (0/108)
Nuchal crest area (*occipital bone*)	29.3% (22/75)	39.1% (9/23)	26% (6/23)	11.1% (2/18)
Zygomatic	15,3% (23/150)	15.2% (7/46)	8.6% (4/46)	5.5% (2/36)
Mental eminence (*mandible*)*	73.3% (55/75)	26% (6/23)	8.6% (2/23)	38.8% (7/18)
Ascending ramus (*mandible*)	18% (27/150)	21.7% (10/46)	4.3% (2/46)	27.7% (10/36)
Hyoid body (*hyoid*)	0% (0/75)	0% (0/23)	0% (0/23)	11.1% (2/18)
*Atlas**	28% (21/75)	0% (0/23)	8.6% (2/23)	33.3% (6/18)
Dens (*Axis*)	22.6% (17/75)	0% (0/23)	4.3% (1/23)	33.3% (6/18)
Sternal end (*clavicle*)	16.6% (25/150)	2.1% (1/46)	2.1% (1/46)	44.4% (16/36)
Acromial end (*clavicle*)	21.3% (32/150)	2.1% (1/46)	2.1% (1/46)	22.2% (8/36)
Glenoid fossa (*scapula*)	42.6% (64/150)	2.1% (1/46)	10.8% (5/46)	27.7% (10/36)
Manubrium (*sternum*)	9.3% (7/75)	0% (0/23)	0% (0/23)	16.6% (3/18)
PE (*humerus*)	32% (48/150)	0% (0/46)	0% (0/46)	50% (18/36)
P1/3 (deltoid tuberosity) (*humerus*)	34.6% (52/150)	15.2% (7/46)	32.6% (15/46)	36.1% (13/36)
D1/3 (olecranon fossa) (*humerus*)	54.6% (82/150)	23.9% (11/46)	30.4% (14/46)	58.3% (21/36)
DE (*humerus*)	76% (114/150)	0% (0/46)	4.3% (2/46)	41.6% (15/36)
PE (*radius*)	36.6% (55/150)	0% (0/46)	2.1% (1/46)	50% (18/36)
Radial tuberosity (P1/3) (*radius*)	41.3% (62/150)	4.3% (2/46)	10.8% (5/46)	50% (18/36)
M1/3 (nutrient foramen) (*radius*)	35.3% (53/150)	13% (6/46)	28.2% (13/46)	47.2% (18/360
D1/3 (*radius*)	21.3% (32/150)	13% (6/46)	23.9% (11/46)	47.2% (17/36)
DE (*radius*)	22% (33/150)	0% (0/46)	6.5% (3/46)	44.4% (16/36)
PE (*ulna*)	82% (123/150)	0% (0/46)	6.5% (3/46)	36.1% (13/36)
Radial notch or P1/3 (*ulna*)	84.6% (1278/150)	15.2% (7/46)	21.7% (10/46)	44.4% (16/36)
D1/3 (*ulna*)	18% (27/150)	8.6% (4/46)	19.5% (9/46)	36.1% (13/36)
DE (*ulna*)	16.6% (25/150)	0% (0/46)	0% (0/46)	27.7% (10/36)
Carpals	0.2% (3/1200)	0% (0/368)	2.9% (11/368)	20.4% (59/288)
*Metacarpals**	16.8% (126/750)	6% (14/230)	15.6% (36/230)	47.7% (86/180)
Phalanges (hands and feet)	2.7% (116/4200)	0.7% (10/1288)	3.4% (45/1288)	18.6% (188/1008)
Auricular surface (*ilium*)*	38% (57/150)	0% (0/46)	19.5% (9/46)	22.2% (8/36)
Pubis symphysis (*pubis*)*	22% (33/150)	0% (0/46)	0% (0/46)	13.8% (5/36)
Sciatic notch (*ilium*)	12% (18/150)	2.1% (1/46)	17.3% (8/46)	8.3% (3/36)
1st segment (*sacrum*)	24% (18/75)	0% (0/23)	17.3% (4/23)	16.6% (3/18)
PE (*femur*)	89.3% (134/150)	4.3% (2/46)	10.8% (5/46)	38.8% (14/36)
Lesser trochanter or P1/3 (*femur*)	58.6% (88/150)	30.4% (14/46)	30.4% (14/46)	27.7% (10/36)
M1/3 (linea aspera) (*femur*)	35.3% (53/150)	32.6% (15/46)	34.7% (16/46)	30.5% (11/36)
D1/3 (*femur*)	21.3% (32/150)	26% (12/46)	39.1% (18/46)	38.8% (14/36)
DE (*femur*)	37.3% (56/150)	0% (0/46)	6.5% (3/46)	27.7% (10/36)
Patella	35.3% (53/150)	0% (0/46)	6.5% (3/46)	69.4% (25/36)
PE (number of condyles) (*tibia*)	38% (114/300)	1% (1/92)	2.1% (2/92)	16.6% (12/72)
Nutrient foramen (*tibia*)	16% (24/150)	17.3% (8/46)	28.2% (13/46)	8.3% (3/36)
D1/3 (*tibia*)	19.3% (29/150)	13% (6/46)	34.7% (16/46)	16.6% (6/36)
DE (*tibia*)	36% (54/150)	0% (0/46)	10.8% (5/46)	41.6% (15/36)
PE (*fibula*)	7.3% (11/150)	0% (0/46)	0% (0/46)	25% (9/36)
M1/3 (nutrient foramen) (*fibula*)	13.3% (20/150)	10.8% (5/46)	36.9% (17/46)	41.6% (15/36)
DE (*fibula*)	14% (21/150)	0% (0/46)	4.3% (2/46)	50% (18/36)
*Tarsals**	26.4% (278/1050)	0% (0/322)	2.7% (9/322)	48.4% (122/252)
*Metatarsals**	28.4% (213/750)	1.7% (4/230)	5.6% (13/230)	75% (135/180)

*Codes: EAM = external auditory meatus; * = for a bone from this group to be counted, more than half the shaft or the bone had to be present to avoid duplicate counting. The numbers in brackets indicate the number of those elements preserved and the number of those elements that would be expected in 100% preservation and recovery. In paired elements, both left and right bones are considered. Because the proximal epiphyses of tibiae were mostly fragmented *post-mortem*, it was preferred to count individual facets in order to avoid duplicate when considering the isolated condyle fragments.

Variation in preservation frequencies was apparent between the samples. The poorest representation was given in the VR47 assemblage. If possible, this should be taken into account with regard to bias in palaeoepidemiological studies. Frequencies for the chronologically later sites are presented in Table 2.14. Overall preservation and recovery was most successful in site AR33.

Table 2.14. Preservation of skeletal regions in the Late Antiquity-Early Byzantine assemblages*.

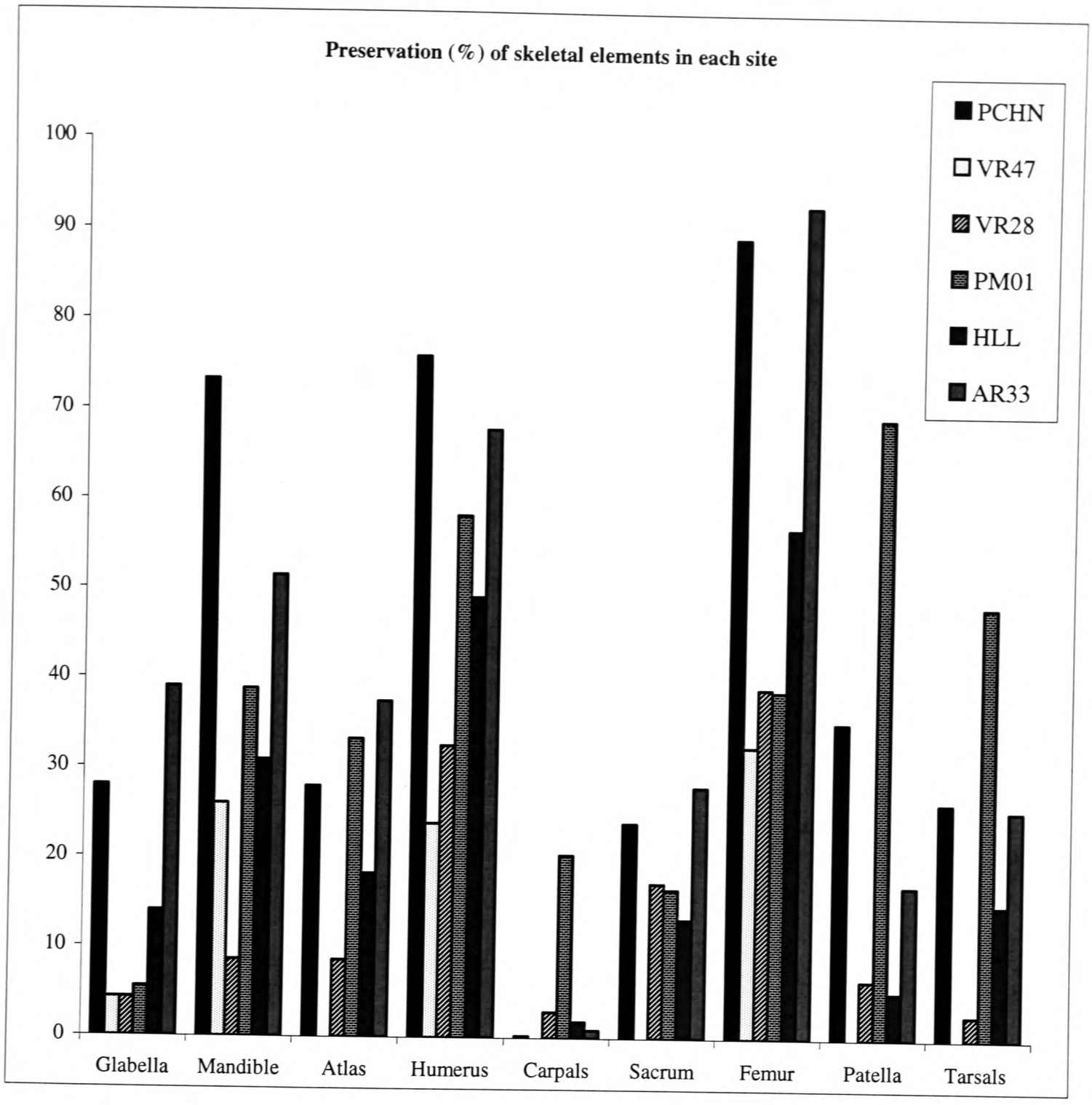
Specific skeletal region	Site HLL % recovered from an expected 142 complete skeletons	Site AR33 % recovered from an expected 64 complete skeletons
Glabella (*frontal bone*)	14% (20/142)	39% (25/64)
EAM (*temporal bone*)	19.7% (56/284)	47.6% (61/128)
Mastoid process (*temporal bone*)	19.7% (56/284)	45.3% (58/128)
Petrosa (*temporal bone*)	29.9% (85/284)	46.8% (60/128)
Ear ossicles	1.4% (12/852)	1.3% (5/384)
Nuchal crest area (*occipital bone*)	25.3% (36/142)	43.7% (28/64)
Zygomatic	19.7% (56/284)	23.4% (30/128)
Mental eminence (*mandible*)*	30.9% (44/142)	51.5% (33/128)
Ascending ramus (*mandible*)	22.1% (63/284)	46% (59/128)
Hyoid body (*hyoid*)	0.7% (1/142)	0% (0/64)
*Atlas**	18.3% (26/142)	37.5% (24/64)
Dens (*Axis*)	16.9% (24/142)	28.1% (18/64)
Sternal end (*clavicle*)	8.8% (25/284)	0.7% (1/128)
Acromial end (*clavicle*)	7% (20/284)	0.7% (1/128)
Glenoid fossa (*scapula*)	13% (37/284)	0.7% (1/128)
Manubrium (*sternum*)	2.1% (3/142)	9.3% (6/64)
PE (*humerus*)	8.4% (24/284)	20.3% (26/128)
P1/3 (deltoid tuberosity) (*humerus*)	35.5% (101/284)	57.8% (74/128)
D1/3 (olecranon fossa) (*humerus*)	49.2% (140/284)	67.9% (87/128)
DE (*humerus*)	14% (40/284)	28.9% (37/128)
PE (*radius*)	9.5% (27/284)	14% (18/128)
Radial tuberosity (P1/3) (*radius*)	31.3% (89/284)	47.6% (61/128)
M1/3 (nutrient foramen) (*radius*)	39% (111/284)	52.3% (67/128)
D1/3 (*radius*)	31.6% (90/284)	49.2% (63/128)
DE (*radius*)	9.8% (28/284)	16.4% (21/128)
PE (*ulna*)	13.3% (38/284)	25% (32/128)
Radial notch or P1/3 (*ulna*)	36.2% (103/284)	68.7% (88/128)
D1/3 (*ulna*)	26% (74/284)	45.3% (58/128)
DE (*ulna*)	3.8% (11/284)	13.2% (17/128)
Carpals	1.8% (42/2272)	0.9% (10/1024)
*Metacarpals**	13.8% (197/1420)	20.9% (134/640)
Phalanges (hands and feet)	3.9% (312/7952)	3.4% (124/3584)
Auricular surface (*ilium*)*	25% (71/284)	24.2% (31/128)
Pubis symphysis (*pubis*)*	8.4% (24/284)	7% (9/128)
Sciatic notch (*ilium*)	19.7% (56/284)	24.2% (31/128)
1st segment (*sacrum*)	13.3% (19/142)	28.1% (18/64)
PE (*femur*)	25.3% (72/284)	51.5% (66/128)
Lesser trochanter or P1/3 (*femur*)	55.6% (158/284)	92.9% (119/128)
M1/3 (linea aspera) (*femur*)	57% (162/284)	88.2% (113/128)
D1/3 (*femur*)	47.1% (137/284)	84.3% (108/128)
DE (*femur*)	18.3% (52/284)	35.1% (45/128)
Patella	5.2% (15/284)	17.1% (11/64)
PE (number of condyles) (*tibia*)	9.6% (55/568)	30.8% (79/256)
Nutrient foramen (*tibia*)	44.3% (126/284)	60.9% (78/129)
D1/3 (*tibia*)	47.1% (134/284)	75.7% (97/128)
DE (*tibia*)	11.9% (34/284)	26.5% (34/128)
PE (*fibula*)	1.4% (4/284)	6.2% (8/128)
M1/3 (nutrient foramen) (*fibula*)	33.4% (95/284)	70.3% (90/128)
DE (*fibula*)	4.2% (12/284)	13.2% (17/128)
*Tarsals**	4.4% (88/1988)	10.3% (93/896)
*Metatarsals**	15% (213/1420)	25.6% (164/640)

*Codes are provided in Table 2.13.

The percentages expressed above are only a close approximation to the real figures. In some cases there may be more bones actually present in the assemblage, but the frequencies have only counted those that are over than 50% complete in order to avoid overestimations by counting the same bone twice. In addition, a small proportion of bone fragments and segments could not be accurately identified and were omitted. Furthermore, all carpal bones are not present in younger subadult individuals since they appear at later stages in life. Due to the commingled nature of the assemblages, there could be no control as to the precise age of all the carpal bones. Moreover, if *represented bones* rather than *represented skeletal elements* would be counted, the preservation would be higher. For instance, two clearly different tombs could be present, one containing a complete skull and the other only a fragment of the frontal with no glabella. If bones were counted, then it can be said that two frontal bones were recovered. However, the number is reduced when specific regions (e.g. glabella) are considered. Finally, the expected number of bones in the population is correct but has not accounted for any extra bones such as extra ribs, vertebrae, tarsals or sesamoid bones that some individuals may have had.

Frequencies (%) for some skeletal elements are illustrated in Figure 2.1. Long bones were the most represented element, while carpals were the least. Out of all the sites, preservation was poorer in VR47 and VR28, while successful recovery rates for some bones were present particularly in AR33, PCHN and PM01.

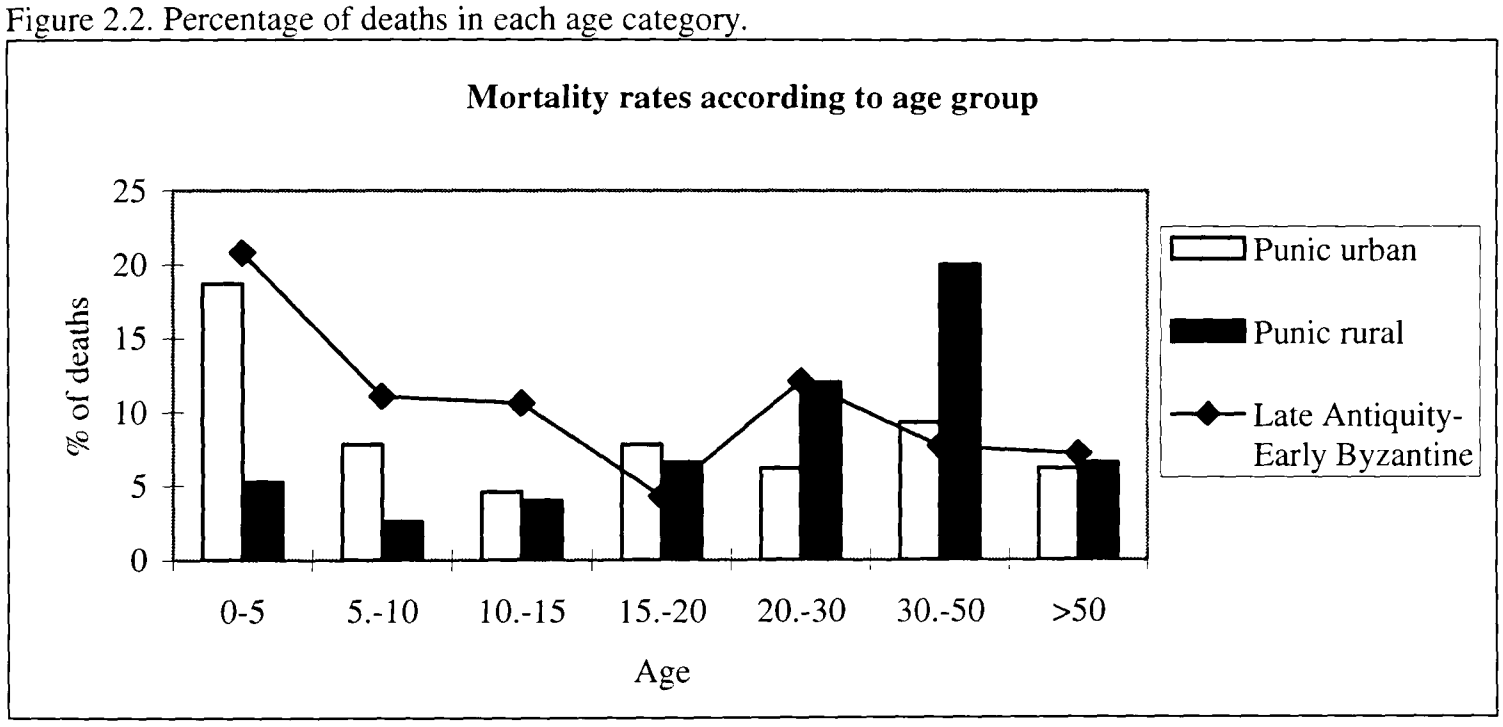
Figure 2.1. Examples of skeletal preservation in each site.



2.6 Materials: limited inferences about mortality

From the information in section 2.4, mortality rates were obtained for the Punic rural, the Punic urban and the Late Antiquity-Early Byzantine samples (Figure 2.2). Only individuals with known age-at-death were included. The profile assumes that age estimation is correct despite potential methodological problems. Differences in sex could not be accounted for due to reduced sample of sexed individuals.

Figure 2.2. Percentage of deaths in each age category.



Caution must be given when interpreting these profiles. Each sample, already small in itself, has a considerable amount of unaged individuals. If their true age were to be known, the diagrams might reveal a different picture. Nevertheless, mortality rates were lower in the Punic rural sample with regard to subadults. Rates in the rural sample were 5.3% (0-5 years), 2.6% (5-10 years) and 4% (10-15 years). Peaks in adult mortality in this context occurred in the 30-50 year age group. Peaks in mortality rates

in the Punic urban context appeared in the youngest age category and more or less equal in adults, although slightly higher in the 30-50 year age group. With regard to the Late Antiquity-Early Byzantine sample there was a contrasting picture, with mortality high in all subadult age categories compared to the Punic sites. The high mortality in the neonatal and post-neonatal age categories corresponded to what might be expected for pre-industrial societies (Saunders and Barrans, 1999). Usually, mortality rates are high during infancy, then decrease from the age of one year to about four years, reaching a minimum rate between the age of five and nine years old (Rousham and Humphrey, 2002: 124). Thus, the demographic profile of the Late Antiquity-Early Byzantine sample might be closer to the actual values. Peaks were present in the younger child and adult categories. A proportion of adults reached the age of 50 years and over, according to skeletal indicators rather than to chronological age. Nevertheless, Punic tombstones at Carthage reveal older individuals (Benichou-Safar, 1982). Roman gravestones from Ibiza reveal a wide variety of ages, ranging from young adults to a 90 year-old person (Juan, 1988). Byzantine documentary and epigraphic evidence indicates longevity reaching up to 80 years and over (Talbot, 1991: 1226). However, epigraphic evidence from tombstones can also be biased and problematic (Durand, 1960; Hopkins, 1987; Salmon, 1987)

The low subadult mortality rates at PCHN were noted. Interestingly, in the other three published Punic rural sites in Ibiza, subadult individuals were rarely present. Gómez (1989) found no individuals (0/28) at *Can Marines*. Likewise, no subadult individuals (0/15) were found at *Cas Jurat* (González-Martín and Lalueza, 1992). Only

at *Ca n'Eloi* was there one immature skeleton (1/17, 5.8%) aged about 3 years old (González-Martín and Lalueza, 2001). This frequency is similar to the 5.3% for the age group 1-5 years from PCHN.

Preservation and recovery bias might be a contributing factor for this low subadult representation. However, the same archaeologists have discovered infant bones in similar soil conditions. Differences between urban and rural soil environments can also be omitted. In rural cemeteries from Late Antiquity and excavated by the same site director as PCHN, the presence of subadult individuals is obvious. At *Ca na Martina* (subadult individuals comprised 22.2% (2/9) of the sample (Márquez-Grant, unpublished preliminary data). Likewise at *Can Fita*, a modest number of three tombs accounting for four individuals, revealed the presence of two immature skeletons (Márquez, 2002).

Therefore, excluding the possibility of lack of recovery or soil conditions, other alternative explanations are plausible. Firstly, the rural environment offered good health and little infant mortality. This would have the least weight. Secondly, there were actually no children in the rural areas. This may be logical if the farmsteads were only production centres where teenagers (that survived into adulthood), adolescent and adult slaves would have worked. Otherwise, rural-urban migrations may have been present. But, both sexes and age groups were present in the site, and these were likely to be family related. Moreover, immature skeletal remains were found at PCHN and there are reports of infant burials in other rural sites (see Gómez, 1986; Tarradell *et al.*, 2000).

Another possible factor is that children were buried elsewhere (see Scott, 1999: 126; Chapa, 2003: 120-121), receiving a different practice such as amphorae burial (see Gómez and Gómez, 1989), but at least in the urban areas infants were buried alongside adults (Gómez *et al.*, 1992). Different funerary practices for infants, usually under one year of age, have been present in Spain since the Bronze Age (Filloy, 1997). Evidence also exists in Punic contexts where infants were buried under house paving (Carrilero and López, 1994: 261). A site in Majorca, contemporary with Punic Ibiza, only includes infant burials (Guerrero, 1989). Although sacrifice is one possibility, the results are inconclusive in view that they may have died from natural causes (Guerrero, 1989). Possible child sacrifices in Punic and early Roman contexts in Spain may be present in Cadiz (Corzo, 1989; Belén, 1997: 121) but the evidence is not convincing in view of the interpretation given to the burial context and the anthropological analysis. A stele found in 1965 at *Can Rafalet* in Ibiza, similar to that found in the *tophet* ('sacrificial altar') of Carthage, contained an inscription read as an offering to a divinity associated with the sacrifice of children (Almagro, 1967). Some reference is made to a possible infant burial area in *Puig des Molins* in *Eivissa* (Mañá, 1948, 1953) but these issues need re-examination.

Finally, it may be that ploughing in rural areas has damaged subadult remains if buried elsewhere (the hypogeum would have provided protection). Whatever the reason, it seems that it might be the result of a combination of factors relating to early excavations, different burial treatment and/or less fertility in rural areas. These questions are set up here for future research.

Another interesting trend is the peak in young adult age (20-30 years) in the Late Antiquity-Early Byzantine samples. Out of 25 deaths in this category, at least 10 (40%) were males and 8 (32%) females. However, amongst all the adult female deaths, most (8/22, 36.3%) occur in this age category. Usually, deaths at this age result from accidents, social conflicts such as wars, natural catastrophes, epidemics and pregnancies. A peak in this age group is usually the result of demographic 'catastrophes' (Margerison and Knüsel, 2002). If this were true, then plagues for the period may have been present (see Section 1.9.7 and Chapter 4). Although some skeletons at AR33 may be seen as buried due to 'emergency situations'[59], without absolute and more precise dating of the bones, no inferences can be made about whether these died in the sixth century AD during the plague years. Skeleton HLL609, a possible 20-30 year-old female, had a foetus between her legs. The previous skeletons in that tomb seemed to have been shifted suddenly to make room for her. It is possible to think that such a case may be related to mortality related to pregnancy, although previous underlying factors such as infection or malnutrition would probably have played a role. Some social conflict was perhaps present in this period (see Chapter 5), although the healed cranial fractures indicate survival.

Nevertheless, some general conclusions could be obtained. These were simply the presence of many age groups and both sexes. High infant mortality was the norm

[59] The photos reveal 'stacks' of bodies in a tomb, probably interred close in time to each other as they were all articulated. An example of a possible emergency burial, or an urgent need for tombs, is a skeleton that had his or her legs bent possibly in order to fit into the tomb (Ill. 2.35). Unfortunately, all the data has now been lost as no bones can now be ascribed to a particular tomb.

but people also lived until old age. The situation in the rural environment has opened a new and exciting avenue for further research that deserves its own attention. Lastly, the peak in the young adult age category in the later period also raises questions to be answered in the future.

3 CHAPTER THREE – HEALTH STATUS DURING GROWTH

The present chapter assesses the health status of individuals during their growth. Apart from genetic and cultural factors, environmental conditions in the womb and in early infancy are crucial to the survival of young individuals. Growth can be affected by infection and malnutrition. Events leading to physiological stress in early childhood can have a major effect on adult morbidity and mortality (see Humphrey and King, 2000).

Data on mortality was presented in Chapter 2. In this chapter, the parameters employed to assess the health status during childhood were linear enamel hypoplasia, *cribra orbitalia* and stature. Other pathological lesions such as periostitis and dental caries are dealt with later in chapters 4 and 6 respectively[60].

The question regarding differences between Punic urban and rural contexts has been left aside when considering these three parameters. The reasons for this omission were twofold:

a) The limited sample size. For instance, with regard to *cribra orbitalia*, only one orbit in the urban sample was available for observation.

[60] Please note that, except for stature, all data is summarised in this thesis. Raw data for each tomb, each skeleton and each bone assemblage are available for consultation in the original archives and also in 'Microsoft Excel' documents. These are available on request. In addition, individual reports for each of these sites will be published in the near future.

b) Most of the dental and skeletal elements employed derive from individuals who died in adulthood. It was unknown whether the adult skeletons observed belonged to individuals who grew up in the same context (rural or urban) as the one in which they were buried. Individuals who grew up in rural areas may have later as adults, migrated to the urban centres where they died and were buried. Urban individuals may have shown an average shorter stature than the average of the rural population, but people from the former group could have grown up in the rural environment. Rural-urban migrations or vice versa could have been common. Thus, the results could not be accurately representative of urban and rural environments.

3.1 Linear enamel hypoplasia

3.1.1 Definition

Enamel hypoplasia (EH) is a dental enamel defect caused by generalised disruptions of enamel matrix formation (Hillson, 1996). Many types of enamel defects are found in teeth (see Hillson, 1996) and linear enamel hypoplasia (LEH) is one of those routinely studied in archaeological populations (Ill. 3.1, Ill. 3.2). The prevalence of LEH has been used to infer the level of physiological stress in a population (see Skinner and Goodman, 1992; Goodman *et al.*, 1988). Since these disruptions occur during tooth formation, roughly up to seven years of age or older if including third molars, these lesions provide an insight into the health of children.

3.1.2 Aetiology

The aetiology of LEH is multifactorial (Pindborg, 1982) and therefore LEH has been regarded as a non-specific indicator of stress. Amongst the factors contributing to the presence of LEH are malnutrition, infectious disease, genetic anomalies, diabetes, allergies, trauma, infections, neonatal disturbances, psychological stress and genetic background (see reviews in Pindborg, 1982; Rose *et al.*, 1985; King *et al.*, 2002). Generally speaking, presence of LEH in a population is more likely to occur due to a complex interaction of different factors. These factors are in turn influenced by the cultural, political, technological and economic systems of the time.

Despite their multifactorial aetiology, LEH in combination with other indicators of physiological stress can serve as a tool to understand the living conditions of past human populations (Goodman and Rose, 1991).

3.1.3 Methodological advantages and limitations

One of the advantages of employing LEH is that it provides a permanent record of developmental stress (Townsend *et al.*, 1994; King *et al.*, 2002). Also, since LEH records stress events that occur when the teeth are forming, if there is a lack of subadult remains in the skeletal sample, the defects observed in adult skeletons can be employed (Wright, 1997). Another advantage in using LEH is that teeth are well preserved in archaeological sites. This is because they are the most mineralised tissue, with 96% of its weight composed of inorganic matter (Trancho and Robledo, 1999: 269).

Some setbacks, which are later discussed, include problems of diagnosis of mild lines or grooves in teeth and sources of error attributed to tooth wear and dental calculus (Hillson, 1996; Trancho and Robledo, 1999; Palubeckaité *et al.*, 2002). With regard to estimating the age of hypoplasia several sources of variation such measurement error, population variation, and choice of developmental standard must be borne in mind (Goodman and Song, 1999). Caution when interpreting the results is required due to several problems highlighted in the literature (Goodman and

Armelagos, 1988; Wood *et al.*, 1992; Duray, 1996; Boldsen, 2005) and which are discussed below.

3.1.4 Materials and methods

Recording for presence or absence of LEH was scored for the buccal crown surfaces of permanent teeth. All formed crowns from all permanent maxillary and mandibular teeth were examined. Dental buds (crowns not complete formed) were not considered.

Data were introduced into a 'Microsoft Excel' spreadsheet. Site code, sex, age of the individual, position of the defect, age of formation of the lesion, tooth class (mandibular/maxillary, deciduous/permanent, side, tooth type), and whether the LEH was present/absent/unobservable was included alongside further observations such as caries, amount of dental wear and calculus.

The deciduous sample size was insufficient to allow comparisons between periods. The Punic rural site, for instance, did not yield any primary teeth at all. Defects in deciduous dentition were only considered during discussion of possible aetiological factors of LEH, although defects in these teeth might be difficult to interpret (Rose et al., 1985: 296). Moreover, enamel defects other than LEH might appear more commonly but have been less studied within archaeological contexts (see Lukacs and Walimbe, 1998; Lovell and Whyte, 1999).

Observation of defects took place once teeth were washed and dried. To ensure correct identification and standardisation, the definition and guidelines set up by the Fédération Dentaire Internationale (FDI, 1982) were followed. LEH identification corresponded with the type 4 category of dental defects listed by the Fédération Dentaire International (FDI, 1982).

Although histological studies have proved to be more precise (Hillson and Bond, 1997; see also King *et al.*, 2002) only macroscopic observations were possible, with strong oblique light and a dental probe. Linear hypoplasias were graded for severity based on width, depth, and definition. The lesions were scored as mild (very fine lines), moderate (clear lines) or very clear (usually grooves over 0.50 mm wide) (modified from Duray, 1996). For overall analysis all these classes were pooled. Moreover, separation between mild, moderate and severe forms must warrant caution due to the fact that not only might they depend on the severity of the stressor and the fitness of the individual, but also on the geometry of the tooth crown (Berti and Mahaney, 1995; Hillson and Bond, 1997).

In the literature it is suggested that a defect in one tooth can only be classified as caused by systemic stress, as opposed to local stress (e.g. trauma), if the antimere also presents hypoplasia. This procedure has been undertaken recently in several archaeological studies (e.g. Malville, 1997; Littleton, 2004; Šlaus *et al.*, 2004; King *et al.*, in press). Although the best effort was made to observe antimeres, unfortunately

most of the teeth were found loose and in the commingled assemblages matching was rarely possible. Moreover, even if mandibles were reconstructed, the antimere of a tooth was often lost *post-mortem*, or there was asymmetry in relation to calculus, wear, caries, *ante-mortem* tooth loss or *post-mortem* damage that restricted the observation of both teeth. At a population level, however, it is thought that the frequencies likely represent mostly systemic stress rather than local disturbances such as trauma caused to a tooth. Nevertheless, when antimeres were not available, attempts were made to match defects with concurrently forming teeth in order to ensure systemic stress (King *et al.*, 2002).

The number of hypoplasias per tooth was also recorded. Teeth were later grouped into those that had single lesions and those with multiple lesions, following the criteria established by the FDI (1982).

In addition, the position of the defect on the crown surface allowed for an assessment of the ages at which the physiological insults left their mark on enamel matrix formation. In order to record the position of the defect on the crown, measurements were taken from the cemento-enamel junction (CEJ) to the LEH. A sliding digital calliper with sharpened tips was employed recording to the nearest 0.01 mm. The initial margins of the lines were recorded. Crown heights from unworn teeth were also recorded according to normal standard procedures (see Buikstra and Ubelaker, 1994: 62-63). Measurements on the defect's location were converted to percentage of the crown height of the tooth. With that known percentage, the defect

was located on the charts devised by Reid and Dean (2002, and unpublished data) on their northern European data. These schemes have been recommended at least for British populations (Brickley and McKinley, 2004) and have also been used on Late Antiquity material from Spain (Zapata, 2004). The published charts refer to incisors and canines and the unpublished ones to molars. Studying the chronology of defects on posterior teeth as well as anterior rather than solely on anterior teeth allows recording of any earlier or later defects (King *et al.*, 2002: 36). The charts did not include data for premolar teeth so these had to be omitted from this age calculation.

Most of the analyses undertaken below were based on tooth counts due to the nature of the assemblages. Many teeth were found loose and could not always be associated with a particular skeleton. The sample was restricted for a variety of reasons to a smaller number of teeth than originally present. Firstly, dental crowns that were heavily worn (over one third of the crown) or had wear in the buccal crown surfaces were excluded from the analysis. Some dentitions from the Late Antiquity-Early Byzantine period (e.g. AR33-B) exhibited buccal wear probably due to occupational activity. Secondly, teeth with heavy calculus deposits restricting observation were excluded. Thirdly, teeth with gross caries or with *post-mortem* damage due to fracture or erosion were also omitted.

Separation into tooth categories was important. Intratooth variation exists with regard to the way in which defects are manifested and comparisons based on pooled data from different teeth are problematic (Goodman *et al.*, 1987: 17). Tooth classes

remained separate throughout the study although to allow comparison between samples, incisors and canines were later pooled as anterior teeth and premolars and molars were grouped as posterior teeth.

Although whole mouth or individual rates based on combination of teeth are difficult to interpret (Goodman *et al.*, 1987: 17), attempts were made to count mouth/individual affected with hypoplasia. However, since many teeth were lost *post-mortem*, this was a problem. To counteract this problem some authors have protocolled a minimum requirement for the number and type of teeth such as, for example, the presence of at least three anterior and three posterior teeth (Duray, 1996; Malville, 1997). However, the data gathered from Ibiza did not allow for any calculation of individuals with and without LEH or any comparisons between samples[61].

In summary, the analysis of LEH examined the number of teeth with the defect(s). Age groups and sexes were compared. In addition, the mean number of defects per tooth was calculated, as was the estimated age of formation.

3.1.4.1 A note on statistical analysis

The statistical tests employed throughout this thesis are worth pointing out here. Statistical analyses were performed with the SPSS 13.0 statistical package. Apart from stature (see relevant section), chi-square tests were performed to see whether any

[61] These minimum requirements were only met by one Punic dentition (VR28/710.B), which had LEH, and 25 Late Antiquity-Byzantine dentitions (23/25 dentitions with LEH).

differences between age groups, sexes and populations were significant. These statistical formulae compare the counts of categorical responses (yes/no) between two or more groups with discrete data from a counting process. Mathematical probability (p-value) between 0 and 1 was used; zero meaning no chance and one meaning certainty. By convention, when the alpha value (p) is under 0.05 the difference is said to be 'statistically significant'. That is, the difference found is likely to be real or, put in a different way, that there is only a 5% probability that the differences observed have occurred due to chance. In addition, by convention if $p<0.01$ the result was considered 'highly significant', and if $p<0.001$ it was considered 'extremely significant'.

A result that was not statistically significant just reflected that it was not strong enough to reject the null hypothesis. It can never be guaranteed, however, that a real difference will always show statistical significance because some samples may be too small or "underpowered". Thus, when a result proved not to be statistically significant, rather than indicating that the difference was not real, it meant, more appropriate, that it would have not been surprising if it were due to chance.

3.1.5 LEH results

A total of 194 teeth from the Punic period and 671 teeth from the Late Antiquity-Early Byzantine period provided information on presence or absence of LEH.

3.1.5.1 Punic sample: LEH frequencies

Although the total tooth sample observed was 457, only 194 could provide information on presence or absence of lesions. From the 263 teeth that could not be considered, 112 were not observed due to *post-mortem* (taphonomic) damage to the enamel surface, 110 due to heavy wear, 21 due to heavy calculus, nine due to gross caries and three due to a combination of both calculus and heavy wear. A total of eight teeth were excluded due to uncertainty in the diagnosis, in some cases reflecting poor preservation. From those unobservable teeth, 136 came from the site VR47 where dental as well as skeletal preservation was very poor. Teeth with crowns still forming, those unerupted and contained within the socket, those lost during life (*ante-mortem*) and those lost *post-mortem* were obviously not available for observation, thus decreasing the extent to which the sample is representative of the Ibizan Punic population[62].

Table 3.1.1 presents the incidence of LEH by tooth type, side and age category. Rather than employing the conventional numbering to identify a tooth as used in clinical dentistry, here simple abbreviations are indicated (e.g. first incisors as 'I1') to avoid confusion with numerical results. Both urban and rural samples were pooled. All the teeth from subadult individuals (<15 years) came from the urban sample. Those classified in the category of unknown age have complete formation (crown and roots)

[62] For these statistics see Chapter 6 on diet. With regard to incompletely formed crowns, representing those too frail to survive, the sample accounted for 55 Punic (urban) and 24 from Late Antiquity-Byzantine specimens.

but there is uncertainty as to whether they belonged to an individual under or over 15 years of age.

Table 3.1.1. LEH frequencies in the Punic sample*.

PERIOD 1		Subadult			Adult			Unknown age		
Maxilla		N	n	%	N	n	%	N	n	%
I1	L	1	1	100	2	0	0	-	-	-
	R	-	-	-	2	1	50.0	-	-	-
I2	L	-	-	-	-	-	-	2	2	100
	R	-	-	-	2	1	50.0	-	-	-
C	L	1	1	100	5	4	80.0	1	1	100
	R	-	-	-	3	2	66.6	-	-	-
P1	L	-	-	-	5	4	80.0	-	-	-
	R	-	-	-	1	1	100	-	-	-
P2	L	-	-	-	2	2	100	-	-	-
	R	-	-	-	2	2	100	1	1	100
M1	L	-	-	-	4	1	25.0	1	1	100
	R	-	-	-	3	0	0	1	1	100
M2	L	1	1	100	5	2	40.0	-	-	-
	R	2	2	100	3	1	33.3	-	-	-
M3	L	-	-	-	1	0	0	-	-	-
	R	-	-	-	-	-	-	-	-	-
Mandible		N	n	%	N	n	%	N	n	%
I1	L	1	1	100	-	-	-	1	0	0
	R	-	-	-	2	2	100	-	-	-
I2	L	-	-	-	2	2	100	3	1	33.3
	R	1	1	100	3	2	66.6	-	-	-
C	L	2	2	100	7	7	100	3	3	100
	R	-	-	-	6	5	83.3	-	-	-
P1	L	1	1	100	9	3	33.3	2	0	0
	R	-	-	-	6	2	33.3	2	1	50
P2	L	2	0	0	11	9	81.8	-	-	-
	R	1	1	100	10	7	70.0	-	-	-
M1	L	-	-	-	15	3	20.0	-	-	-
	R	2	2	100	14	1	7.1	1	1	100
M2	L	-	-	-	13	7	53.8	-	-	-
	R	-	-	-	11	2	18.1	-	-	-
M3	L	-	-	-	6	2	33.3	-	-	-
	R	-	-	-	6	1	16.6	-	-	-
SUBTOTAL		15	13	86.6	161	76	47.2	18	12	66.6
TOTAL SAMPLE = 52.0% (101/194)										

* Codes: N = number of teeth observed; n = number of teeth with LEH; % = percentage of teeth with LEH (n/N x 100); I1 = first (central) incisor; I2 = second (lateral) incisor; C = canine; P1 = first premolar; P2 = second premolar; M1 = first molar; M2 = second molar; M3 = third molar; L = left; R = right.

From all the teeth confirmed to have LEH (n = 101), only 20 could be compared with their antimeres to ensure they were caused by systemic stress. No available antimeres were available for 35 teeth with LEH, but these teeth were from mandibles or maxillae that had other hypoplastic teeth. Finally, 46 hypoplastic teeth, most of which were found loose, could not be confirmed at all as having lesions caused by systemic stress.

To increase the sample size, observed teeth were pooled from either side, from the upper and the lower jaw and grouped according to the following dental categories: incisors, canines, premolars and molars. The summary data are presented in Table 3.1.2.

Table 3.1.2. Punic sample: summary data on LEH*.

PERIOD 1	**Subadults**		**Adults**		**Unknown age**		**All age groups**		
	N	**n**	**N**	**n**	**N**	**n**	**N**	**n**	%
Incisors	3	3	13	8	6	3	22	14	63.6
Canines	3	3	21	18	4	4	28	25	89.2
Premolars	4	2	46	30	5	2	55	34	61.8
Molars	5	5	81	20	3	3	89	28	31.4
TOTAL	15	13	161	76	18	12	194	101	52.0

*Codes: N = number of teeth observed; n = number of teeth with LEH; % = percentage of teeth with LEH (n/N x 100).

The percentages reveal higher frequencies in canines and lower frequencies in molars. The overall frequency is 52.0%. Amongst the subadults, 86.6% of teeth had LEH. Amongst adults, 47.2% of teeth had defects. However, the subadult sample was limited in comparison to the adult group. In addition, the overall difference between these two age groups was not statistically significant ($x^2 = 2.32$; $p = 0.128$). Differences according to age and sex are later discussed in more detail.

The number of defects per tooth was also calculated. Table 3.1.3 indicates the number of teeth in each tooth class with single or multiple defects. It also includes how many teeth in each category have two, three, four or more defects. The maximum number of defects found in a single tooth in the Ibizan sample was five. A mean number of lesions per tooth category alongside its standard deviation were also calculated.

Table 3.1.3. Number of teeth with single and multiple lesions in each tooth class and age group*.

PERIOD 1	Teeth from subadult individuals								
	Single	**Multiple**	**2**	**3**	**4**	**5**	**Mean**	**SD**	**% multiple**
Incisors	0	3	3	0	0	0	2.00	0.00	100
Canines	0	3	3	0	0	0	2.00	0.00	100
Premolars	0	2	2	0	0	0	2.00	0.00	100
Molars	5	0	0	0	0	0	1.00	0.00	0
PERIOD 1	**Teeth from adult individuals**								
	Single	**Multiple**	**2**	**3**	**4**	**5**	**Mean**	**SD**	**% multiple**
Incisors	1	7	3	3	1	0	2.50	0.92	87.5
Canines	6	12	5	3	1	3	2.44	1.46	66.6
Premolars	17	13	10	2	1	0	1.56	0.77	43.3
Molars	18	1	1	0	0	0	1.05	0.22	5.2
PERIOD 1	**Teeth from individuals of unknown age**								
	Single	**Multiple**	**2**	**3**	**4**	**5**	**Mean**	**SD**	**% multiple**
Incisors	2	1	1	0	0	0	1.33	0.57	33.3
Canines	2	2	1	0	0	1	2.25	1.89	50.0
Premolars	2	0	0	0	0	0	1.00	0.00	0
Molars	3	0	0	0	0	0	1.00	0.00	0

*Single = number of teeth with one defect; Multiple = number of teeth with two or more defects; SD = standard deviation; % multiple = amongst the teeth with LEH, percentage of those with multiple lesions.

Teeth with multiple lesions were predominant, particularly in the canines and incisors. Molars had the least number of teeth with multiple defects. Despite the small sample size in subadults, except for premolars, teeth from individuals that died in adulthood presented more lesions than hose that died before the age of fifteen years. Nevertheless, while molar mean number of defects in each group was similar, a Mann-Whitney *U*-test was performed on the incisors, canines and premolars. No statistical significant results were produced ($p>0.05$).

3.1.5.2 Punic sample: LEH frequency per age group

Comparisons were made between teeth from subadults (<15 years) and adults. Statistical tests (chi-square) were performed to understand whether there were any significant differences between the samples[63]. The results are presented below in Table 3.1.5.

Table 3.1.5. Comparison of LEH between age groups.

PERIOD 1	Subadults			Adults			Statistical results	
	N	n	%	N	n	%	Chi-square	Significance
Incisors	3	3	100	13	8	61.5	0.274	n.s.
Canines	3	3	100	21	18	85.7	3.09	n.s.
Premolars	4	2	50.0	46	30	65.2	0.088	n.s.
Molars	5	5	100	81	20	24.6	4.76	<0.05

*Codes: N = number of teeth observed; n = number of teeth with LEH; n.s. = not statistically significant.

[63] In order to increase the sample size, left and right sides, maxillary and mandibular teeth from the same tooth class were pooled. Chi-square tests are employed for independent data. It is likely that many teeth relate to a same individual. With this regard, the samples might not be independent. This is a problem with other systemic conditions such as age-relate osteoarthritis, or in *cribra orbitalia* and periostitis where lesions might be bilateral, but this could not be detected in the commingled remains. Due to the disarticulated nature of the remains, whether the data was independent or whether it was dependent is unknown for most of the sample. However, the probability of having teeth from the same individual in a sample may not be independent but the same can apply to the sample it is being compared with. Therefore the null hypothesis would be that the prevalence of teeth with LEH is the same in both samples. One way to understand whether non-independence is a problem would be to calculate LEH in one tooth (e.g. upper left I1) and compare it to another group (e.g. lower right I1) before they are pooled. If differences are not significant then bias should not be a problem. However the samples are too small in these Ibizan populations in order to undertake these comparisons. It could only be assumed that the probability of presenting teeth of the same individual, either with LEH or without LEH, was equal in all the samples compared. Finally, frequencies per tooth rather than per individual were obtained. I thank Dr. L. Humphrey for pointing out this potential problem and I thank Luís Cabo for clarifying some of these statistical issues.

Samples sizes were insufficient for a reliable comparison. Only comparisons between molars showed statistical significance ($x^2 = 4.76$; $p = 0.029$). Thus, with this regard, subadult individuals had significantly higher frequencies of LEH in molars than adults.

A further breakdown was undertaken by adult age groups since it might provide some clues in relation to frailty (see Wood *et al.*, 1992). The adult age groups were divided into the following categories: 15-19.9 years, 20-29.9 years, >30 years (Table 3.1.6).

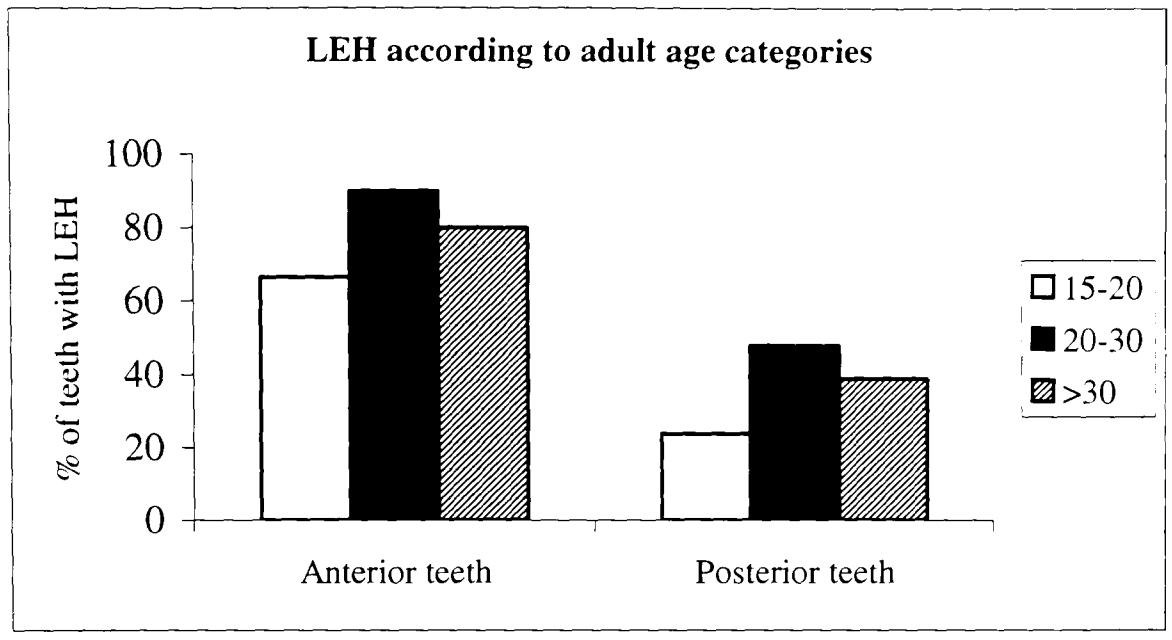
Table 3.1.6. LEH observation according to adult age groups*.

PERIOD 1	**15-20**		**20-30**		**>30**	
	N	**n**	**N**	**n**	**N**	**N**
Incisors	2	2	3	3	5	3
Canines	4	2	7	6	5	5
Premolars	6	4	14	11	24	14
Molars	15	1	32	11	30	7

*Codes: N = number of teeth observed; n = number of teeth with LEH.

To facilitate comparisons and increase the sample size, incisors and canines were pooled into a group of anterior teeth, while premolars and molars into a group of posterior teeth (Figure 3.1.1 and Table 3.1.7).

Figure 3.1.1 Percentage of teeth with LEH in the different adult age categories.



A peak of hypoplastic teeth in the 20-30 year age group was observed. The lowest frequencies were found in the youngest category (Table 3.1.7.).

Table 3.1.7. LEH comparison between adult age groups*.

PERIOD 1	15-20			20-30			>30		
	N	n	%	N	n	%	N	n	%
Is & Cs	6	4	66.6	10	9	90.0	10	8	80.0
Ps & Ms	21	5	23.8	46	22	47.8	54	21	38.8

*Codes: Is = incisors; Cs = canines; Ps = premolars; Ms = molars; N = number of teeth observed; n = number of teeth with LEH; n.s. = not statistically significant.

Statistical comparisons between all groups (six combinations) did not provide any significant values.

3.1.5.3 Punic sample: LEH frequency per sex

Most skeletons from the Punic urban sample and from the Late Antiquity-Early Byzantine population (site HLL) were sexed through a variety of skeletal indicators. Those dentitions from disarticulated assemblages such as the Punic rural sample, however, had to rely solely on mandibular morphology. Unfortunately, not all teeth could be assigned to a particular sex. In the Punic urban sample, teeth (n = 10) in the female sample came from at least two individuals, while teeth (n = 5) from the male sample derived from two males. Four mandibular portions from the rural population provided additional teeth (n = 8) for the female sample, while seven mandibular fragments (n = 24 teeth) likely to be from different individuals and one skull (n = 8 teeth) provided an additional 32 teeth for the male sample. Although samples were very limited (Table 3.1.8), chi-square tests were nevertheless performed. Apart from premolars, which showed an equal prevalence, differences between incisors, canines and molars were not significant.

Table 3.1.8. LEH frequency between female and male dentitions.

PERIOD 1	Females			Males			Statistical results	
	N	n	%	N	n	%	Chi-square	Significance
Incisors	3	2	66.6	2	1	50.0	3.56	n.s.
Canines	3	3	100	5	2	40.0	0.627	n.s.
Premolars	6	4	66.6	15	10	66.6	N/A	N/A
Molars	6	2	33.3	15	1	6.6	1.71	n.s.

*Codes: N = number of teeth observed; n = number of teeth with LEH; n.s. = not statistically significant; N/A = not applicable.

Therefore, no significant sexual differences were detected in the frequency of LEH with the samples considered, although these were limited because most dentitions could not be sexed.

3.1.5.4 Punic sample: age of formation of LEH

By measuring the position of the defect relative to the cemento-enamel junction (CEJ) of the tooth, the estimated age of the individual at the time the disruption left a mark on the tooth enamel could be inferred.

The location of the measured defect was transformed into the proportion of the tooth height. Because many tooth crowns were worn and on occasions the CEJ was obscured by factors like calculus or even caries, a mean height for this population was obtained from unworn teeth (Table 3.1.9). Mean crown heights for the Ibizan population were obtained from any available teeth from Punic and Late Antiquity-Early Byzantine samples. Most measurements came from unworn subadult teeth. Two upper second incisors came from unaged individuals. No unworn lower third molars were present, and only one upper third molar was available. The data are presented in Table 3.1.9. For those unworn teeth providing their own crown heights, the mean crown height was not necessary and therefore not employed.

Table 3.1.9. Average crown height for each tooth type, alongside the number of teeth measured, and the minimum and maximum measurements.

Tooth	Number	Minimum	Maximum	Mean crown height*
Upper I1	1	-	-	11.6
Upper I2	9	8.13	10.34	9.7
Upper C	6	8.98	13.06	11.1
Upper M1	3	7.40	8.73	8.2
Upper M2	5	6.73	10.64	8.3
Upper M3	1	-	-	6.7
Lower I1	4	10.61	11.06	10.8
Lower I2	13	8.86	10.43	10.0
Lower C	16	8.73	13.36	11.5
Lower M1	15	6.78	9.09	7.6
Lower M2	7	6.90	8.42	7.2
Lower M3	0	-	-	-

*Mean measurements have been rounded to the nearest 0.1 mm

Before interpreting the results several pointers had to be borne in mind. Firstly, variation in tooth crown exists, especially with regard to the third molar. Secondly, dental crown heights came mostly from subadult individual and early mortality might have resulted in smaller tooth dimensions (see comments in Mays, 1998; Molleson and Cruse, 1998). Finally, the charts for age estimation were not made specifically for the Ibizan populations.

Each defect was located within an age range illustrated in the charts created by Reid and Dean (2002, and unpublished material). These ages refer to the age of the individual when the disruption occurred. Several LEH were located at specific age boundaries (e.g. c.4.2 years) or within an age range. If the location of the LEH fell within an age range covering two different years (e.g. 2.9-3.4 years) then the average was estimated (=3.1) and the defect was classified in that year group (age 3-4 years old). The total number of teeth employed was 57, comprising a total of 107 defects.

Amongst these defects, four were mild, 66 moderate and 37 very clear. Seven additional hypoplastic teeth could not be measured and therefore no chronology was assigned to them.

To avoid double counting, antimeres were omitted. Excluding antimeres, the number of lesions considered was reduced from 107 to 94 defects. The distribution of age of occurrence of defects according to tooth class is summarised in Table 3.1.10. The table limits itself to the sixth year (5-6 years) of age because no lesions were identified as appearing after the age of six years. No upper third molars were present with hypoplastic lesions.

Table 3.1.10. Number of lesions occurring at different age ranges*.

Tooth	1-2 years	2-3 years	3-4 years	4-5 years	5–6 years
Upper I1	0	1	3	0	0
Upper I2	0	2	2	2	0
Upper C	0	1	8	6	0
Upper M1	0	2	0	N/A	N/A
Upper M2	N/A	N/A	N/A	0	6
Lower I1	0	6	1	N/A	N/A
Lower I2	0	4	6	0	N/A
Lower C	0	6	12	11	2
Lower M1	1	6	0	N/A	N/A
Lower M2	N/A	N/A	N/A	0	6
TOTAL	1	28	32	19	14

*N/A = not applicable as crown formation in this particular tooth according to the charts employed does not cover this age.

The earliest age of occurrence is documented at *circa* 1.8 years in a lower right M1 from individual VR28-1118, who died around three or fours year of age. The latest occurrence, between 5.6 and 5.9 years, was registered in second molars from four

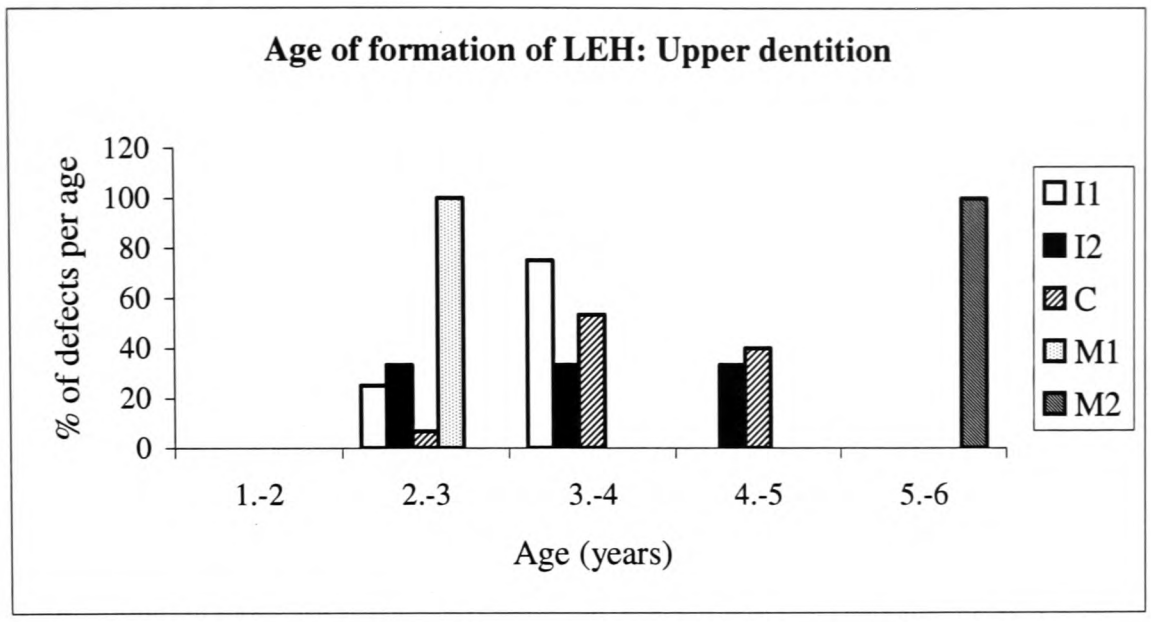
different individuals[64, 65]. With regard to the anterior teeth, overall the majority of defects occur between 3-4 years, although smaller peaks also occur in the 2-3 age range. Defects in the lower canine covered the widest age range. The earliest age of occurrence in the lower canines was around two years. This was documented in a 20-30 year old individual labelled PCHN-H7. The latest recorded age appeared on two canines, one found loose and labelled PCHN, and the other from an individual (VR28/312) about 10 years old. Here, the lesions were attributed to an age range between 4.9 and 5.6 years.

Percentages of defects per age were calculated per tooth class. The distribution for first and second incisors, canines, and first and second molars are shown in Figure 3.1.2 for the upper dentition, and Figure 3.1.3 for the lower.

[64]These were: lower left M2 from mandible PCHN-H10-M1 (adult, 20-30 years); lower left M2 from mandible PCHN-H10-M33 (adult, 20-30 years); upper right M2 from individual VR28/710.B (adult female, 20-30 years) and, from the same tomb, a lower right M2 from a younger individual around 10 or 11 years of age-at-death.

[65]Although no crown heights were available for lower third molars, five displayed LEH. These came from worn teeth belonging to 30-50 year old individuals. Although the formation of this tooth can be variable, the unpublished charts created by Reid and Dean reveal an age range between nine and eleven years for the occurrence of these defects. More precisely, all these lesions were within 2 mm distance from the CEJ, indicating approximately an age of occurrence of at least 10 years of age.

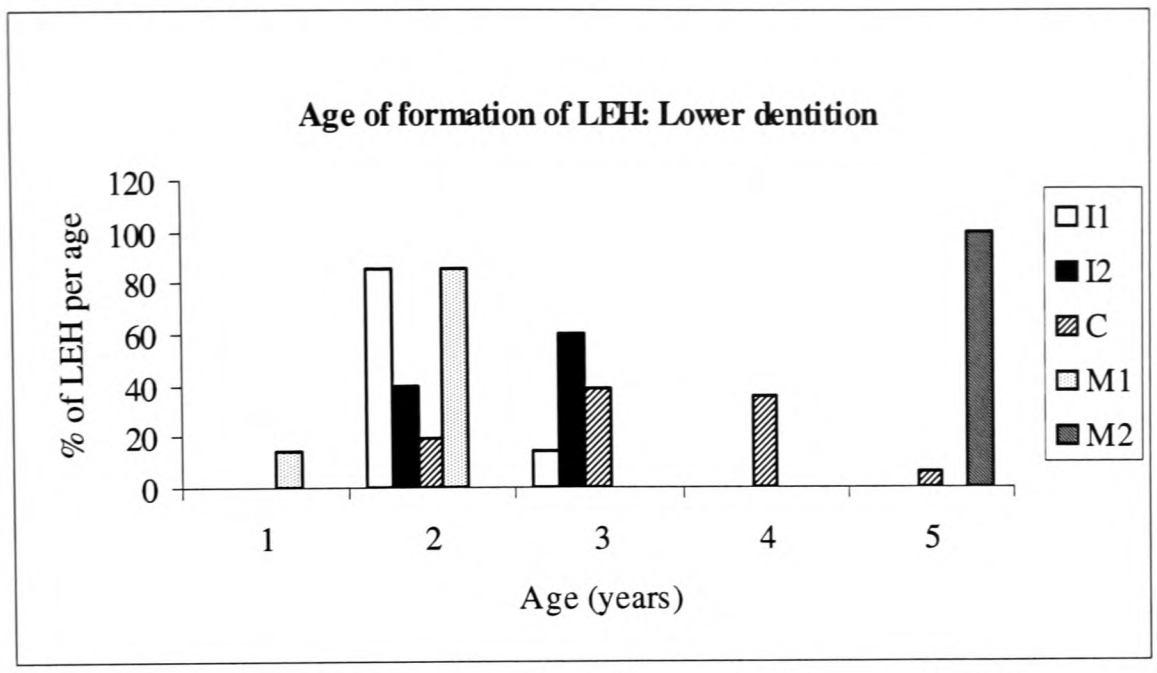
Figure 3.1.2. Punic sample: percentage of defects appearing at different ages in maxillary teeth.



For first incisors and canines the peak was located between 3 and 4 years of age three years of age. Second incisors had an equal distribution between 2 and 5 years. First molars lesions appear only between 2-3 years whilst it was between 5 and 6 years for second molars.

Figure 3.1.3 indicates the percentage of defects per age group in the lower dentition. Lower first incisors had a peak between 2-3 years. Lesions on first molars were also prevalent here. Most of the defects on second incisors and canines mostly occurred between 3-4 years of age. Second molars had lesions occurring later between 4-6 years of age.

Figure 3.1.3. Punic sample: percentage of defects appearing at different ages in mandibular teeth*.



*Codes: 1 = 1-2 years, 2 = 2-3 years, 3= 3-4 years; 4 = 4-5 years; 5 = 5-6 years.

From the point of view of later discussion, it is interesting to note that the lower canines with the highest number of defects, ranging between two and five years, belonged to two adult individuals. One of these had an age at death between 15-20 years (PCHN-H10-M14) and the other possibly between 20-30 years (PCHN-H10-26).

Overall, considering anterior teeth, no lesions were found in the first and second years of life (0-2 years). Peaks in LEH occurrence appeared during the third and fourth years of life (2-4 years). Defects on first molars showed a peak between 2-3 years.

3.1.5.5 The Late Antiquity-Early Byzantine sample: hypoplasia frequencies

The Late Antiquity-Early Byzantine sample provided 673 teeth for analysis, of which 345 had no LEH and 328 displayed LEH. Although the number of teeth was larger than that for Period 1, the sample was still reduced because a total of 488 teeth were unobservable. Reasons for this were as follows: 258 teeth were affected by taphonomic related factors or *post-mortem* damage, 73 teeth were too worn, 60 had heavy calculus, and 18 had gross caries. Other teeth (n = 79) exhibited a combination of these factors. Table 3.1.11 presents the summary data for LEH according to tooth type, side and age category.

Table 3.1.11. LEH frequencies in the Late Antiquity-Early Byzantine sample*.

PERIOD 2		Subadults			Adults			Unknown age		
Maxillary		N	n	%	N	n	%	N	n	%
I1	L	2	0	0	12	4	33.3	-	-	-
	R	3	1	33.3	9	3	33.3	-	-	-
I2	L	6	3	50.0	11	4	36.3	3	2	66.6
	R	7	5	71.4	6	3	50.0	2	1	50.0
C	L	7	6	85.7	11	8	72.7	5	4	80.0
	R	3	2	66.6	10	7	70.0	4	3	75.0
P1	L	4	2	50.0	7	3	42.8	5	4	80.0
	R	8	7	87.5	10	5	50.0	4	3	75.0
P2	L	4	3	75.0	9	3	33.3	2	2	100
	R	4	3	75.0	14	10	71.4	3	2	66.6
M1	L	6	1	16.6	11	1	9.0	2	1	50.0
	R	6	2	33.3	12	2	16.6	3	1	33.3
M2	L	2	1	50.0	12	4	33.3	2	2	100
	R	8	3	37.5	11	2	18.1	1	1	100
M3	L	1	0	0	12	1	8.3	-	-	-
	R	1	0	0	12	2	16.6	-	-	-
Mandibular		N	n	%	N	n	%	N	n	%
I1	L	5	3	60.0	8	4	50.0	2	1	50.0
	R	5	3	60.0	7	1	14.2	1	1	100
I2	L	7	6	85.7	8	4	50.0	2	2	100
	R	10	8	80.0	9	6	66.6	2	1	50.0
C	L	8	8	100	19	15	78.9	1	1	100
	R	9	8	88.8	23	22	95.6	2	2	100
P1	L	6	5	83.3	19	10	52.6	3	1	33.3
	R	8	6	75.0	20	14	70.0	4	4	100
P2	L	5	4	80.0	19	8	42.1	1	1	100
	R	4	3	75.0	19	9	47.3	-	-	-
M1	L	21	10	47.6	19	4	21.0	1	0	0
	R	17	6	35.2	18	2	11.1	2	0	0
M2	L	7	4	57.1	20	2	10.0	2	0	0
	R	10	5	50.0	20	5	25.0	1	0	0
M3	L	-	-	-	10	1	10.0	-	-	-
	R	-	-	-	12	1	8.3	-	-	-
SUBTOTAL		194	118	60.8	419	170	40.5	60	40	66.6
TOTAL SAMPLE = 48.7% (328/673)										

* Codes are provided in Table 3.1.1.

From all the teeth confirmed to have LEH (n = 328), 120 could be confirmed by their antimeres as caused by systemic stress. In 105 teeth LEHs could not be confirmed by their antimeres (unobservable) but these were associated with mandibles or maxillae where other hypoplastic teeth were present. In 87 teeth, most of which were loose, causes of LEH could not be confirmed at all by their opposites or by any other tooth. Finally, 15 hypoplastic teeth did not appear to be matched with their antimeres since, macroscopically, they did not display LEH. Therefore, it is possible that at least 4.3% of hypoplastic teeth (15/343) were caused by local stress such as trauma.

In order to increase the sample size and make it comparable with the Punic material, teeth from both sides were pooled as well as those from the upper and the lower jaw. The summary data according to tooth classes are presented below (Table 3.1.12).

Table 3.1.12. Late Antiquity-Early Byzantine sample: summary data on LEH*.

PERIOD 2	Subadults		Adults		Unknown age		All age groups		
	N	n	N	n	N	n	N	n	%
Incisors	45	29	70	29	12	8	127	66	51.9
Canines	27	24	63	52	12	10	102	86	84.3
Premolars	43	33	117	62	22	17	182	112	61.5
Molars	79	32	169	27	14	5	262	64	24.4
TOTAL	194	118	419	170	60	40	673	328	48.7

*Codes: N = number of teeth observed; n = number of teeth with LEH; % = percentage of teeth with LEH (n/N x 100).

Taking into account all age groups, canines show the highest percentage of hypoplastic defects, followed by premolars and incisors. All teeth, except molars, had over 50% prevalence of hypoplastic teeth. The total prevalence for this period was 48.7% of permanent teeth.

With regard to the number of defects per tooth, five was the maximum number observed. A summary of single, multiple and mean number of defects is presented in Table 3.1.13.

Table 3.1.3. Number of teeth with single and multiple lesions in each tooth class and age group*.

PERIOD 2	**Teeth from subadult individuals**								
	Single	**Multiple**	**2**	**3**	**4**	**5**	**Mean**	**SD**	**% multiple**
Incisors	9	20	11	6	2	0	2.03	0.92	68.9
Canines	8	16	5	6	4	1	2.37	1.24	66.6
Premolars	19	13	11	0	2	0	1.53	0.80	40.6
Molars	26	6	5	1	0	0	1.21	0.49	18.7
PERIOD 2	**Teeth from adult individuals**								
	Single	**Multiple**	**2**	**3**	**4**	**5**	**Mean**	**SD**	**% multiple**
Incisors	19	10	7	3	0	0	1.44	0.68	34.4
Canines	30	22	13	7	2	0	1.63	0.86	42.3
Premolars	44	18	13	4	1	0	1.38	0.86	29.0
Molars	26	1	1	0	0	0	1.02	0.19	3.7
PERIOD 2	**Teeth from individuals of unknown age**								
	Single	**Multiple**	**2**	**3**	**4**	**5**	**Mean**	**SD**	**% multiple**
Incisors	3	5	1	2	1	1	2.5	1.51	62.5
Canines	5	5	2	2	0	0	2	1.33	50.0
Premolars	13	4	1	1	2	0	1.52	1.06	23.5
Molars	5	0	0	0	0	0	1	0	0

* Single = number of teeth with one defect; Multiple = number of teeth with two or more defects; SD = standard deviation; % multiple = amongst the teeth with LEH, percentage of those with multiple lesions.

In both subadult and adult categories, canines had the highest mean number of defects. The proportion of teeth with multiple lesions rather than single lesions was higher in incisors and canines, while single lesions predominated in premolars and molars.

Because some studies report a higher number of lesions correlated with a lower age at death (e.g. Palubeckaité *et al.*, 2002), comparisons between subadults and adults was worth undertaking. The younger group had more defects per tooth than the adult group. Mann-Whitney *U*-tests found significant differences between incisors (U = 256.000; p = 0.009), canines (U = 410.500; p = 0.010), but not in molars (U = 366.500; p = 0.076). No significant difference was found when comparing premolars.

3.1.5.6 Late Antiquity-Early Byzantine sample: LEH frequency per age group

Amongst subadults, 60.8% of teeth had LEH. The prevalence was lower in adults with a rate of 40.5%. The difference between subadults and those that died in adulthood was significant ($x^2 = 7.53$; p = 0.006). Chi-square tests also compared the results between tooth classes from the subadult group and from the adult group (Table 3.1.15).

Table 3.1.15. Comparison of LEH between age groups.

PERIOD 2	Subadults			Adults			Statistical results	
	N	n	%	N	n	%	Chi-square	Significance
Incisors	45	29	64.4	70	29	41.4	1.86	n.s.
Canines	27	24	88.8	63	52	82.5	0.04	n.s.
Premolars	43	33	76.7	117	62	52.9	1.76	n.s.
Molars	79	32	40.5	169	27	15.9	10.3	<0.005

*Codes: N = number of teeth observed; n = number of teeth with LEH; n.s. = not statistically significant.

From the data above, there was an overall impression that teeth from subadult individuals yielded higher LEH frequencies than adults. However, only the difference between molars was significant ($x^2 = 10.3$; $p = 0.001$).

Additionally, a closer examination looked at possible differences in LEH prevalence rates between adult age groups (Table 3.1.16).

Table 3.1.16. Comparison between adult age groups*.

PERIOD 2	15-20		20-30		>30	
	N	n	N	n	N	n
Incisors	14	10	37	8	15	7
Canines	34	34	17	11	10	7
Premolars	23	18	57	22	28	15
Molars	51	9	95	12	29	6

*Codes: N = number of teeth observed; n = number of teeth with LEH.

In order to increase the sample and allow for ease of comparison with the Punic sample, teeth were grouped into anterior (incisors and canines) and posterior teeth (premolars and molars). This summary is presented in Table 3.1.1.7.

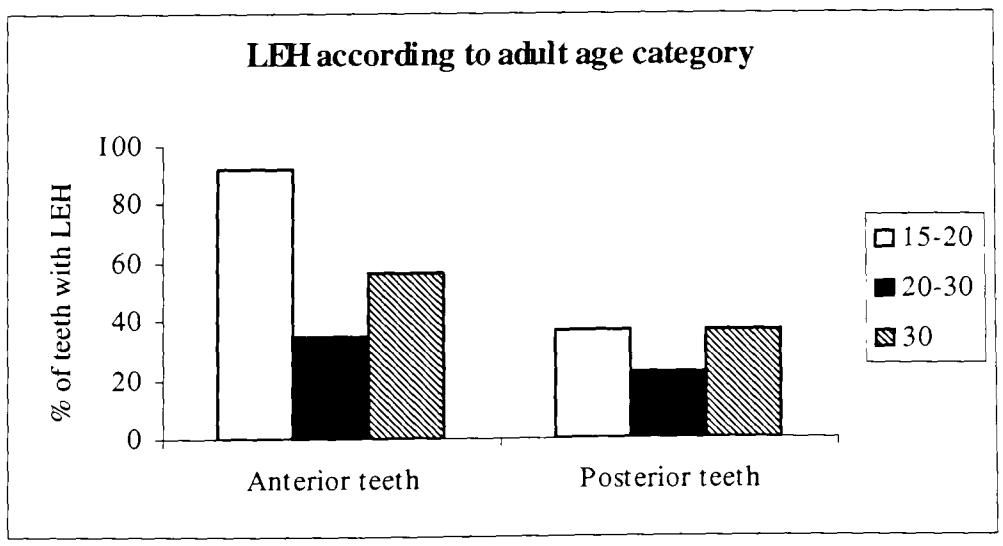
Table 3.1.18. Comparison between adult age groups*.

PERIOD 2	15-20			20-30			>30		
	N	n	%	N	n	%	N	n	%
Is & Cs	48	44	91.6	54	19	35.1	25	14	56
Ps & Ms	74	27	36.4	152	34	22.3	57	21	36.8

*Codes: Is = incisors; Cs = canines; Ps = premolars; Ms = molars; N = number of teeth observed; n = number of teeth with LEH; % = n/N x 100.

It is interesting to note that higher frequencies were present in the younger and older categories, with lower frequencies in the 20-30 year age group. Figure 3.1.4 illustrates this distinction. The younger adults had higher frequencies in anterior teeth, although similar rates to the older adults with regard to posterior teeth.

Figure 3.1.4. Percentage of teeth with LEH in the different adult age categories.



Bivariate chi-square tests were also carried out between two age groups, thus resulting in six different comparisons (15-20 *versus* 20-30 years; 15-20 *versus* >30 years for incisors and canines, etc.). The only significant result ($p<0.005$) was obtained when comparing anterior teeth between age groups 15-20 and 20-30 ($x^2 = 8.19$; $p = 0.004$).

3.1.5.7 Late Antiquity-Early Byzantine sample: LEH frequency per sex

Compared to Period 1, samples from Period 2 were larger when comparing LEH prevalence rates between females and males. However, like Period 1, significant differences between the sexes were not found.

Table 3.1.19. LEH comparison between female and male dentitions.

PERIOD 2	Females			Males			Statistical results	
	N	n	%	N	n	%	Chi-square	Significance
Incisors	20	3	15.0	38	19	50.0	3.38	n.s.
Canines	11	8	72.7	33	28	84.8	0.084	n.s.
Premolars	32	13	40.6	57	28	49.1	0.224	n.s.
Molars	54	9	16.6	70	8	11.4	0.534	n.s.
TOTAL	117	33	28.2	198	83	41.9	2.82	n.s.

*Codes: N = number of teeth observed; n = number of teeth with LEH; n.s. = not statistically significant.

Since no significant differences were observed in both periods, female and male samples could be pooled when comparing periods.

3.1.5.8 Late Antiquity-Early Byzantine sample: age of formation of LEH

A total of 153 teeth with LEH provided chronological ages for the formation of the defect. From these teeth, 246 defects could be aged. From these lesions, 24 were classified as mild, 139 as moderate and 83 as very clear (following Duray, 1996). The distribution of defects according to age is summarised in Table 3.1.20, after excluding antimeres as described earlier on during analysis of Punic teeth. For this period, information from upper third molars was available. Defects identified between five and six years of age were found in lower canines and second molars.

Table 3.1.20. Number of lesions occurring at different ages*.

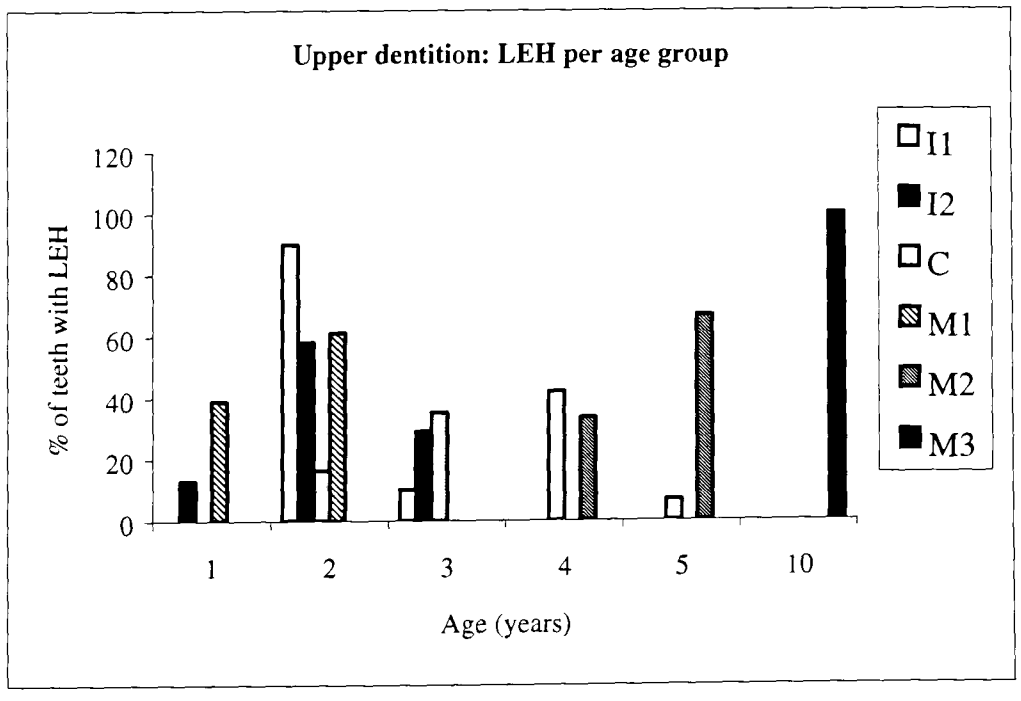
Tooth	1-2 years	2-3 years	3-4 years	4-5 years	5-6 years	10-11 years
Upper I1	0	5	6	4	N/A	N/A
Upper I2	0	4	19	0	0	N/A
Upper C	0	12	15	15	0	N/A
Upper M1	1	5	0	N/A	N/A	N/A
Upper M2	N/A	N/A	N/A	2	9	N/A
Upper M3	N/A	N/A	N/A	N/A	N/A	4
Lower I1	0	9	1	N/A	N/A	N/A
Lower I2	4	18	9	0	N/A	N/A
Lower C	0	12	26	31	5	N/A
Lower M1	7	11	0	N/A	N/A	N/A
Lower M2	N/A	N/A	N/A	4	8	N/A
TOTAL	12	76	76	56	22	4

*N/A = not applicable as crown formation in this particular tooth, according to the charts employed, does not occur at this age.

The earliest age of occurrence in the Late Antiquity-Early Byzantine sample occurred at 1.5-1.6, found in a lower right M1 from an individual (AR33-M-J/G-F) between 5 and 10 years old at the time of death. An age of 1.8 years was documented in a lower left M1 from a two year-old individual (HLL204). Similar ages, between 1.8 and 1.9 years, were found in first molars from a five year old child (AR33-J-P), a 15-20 year old individual (AR33-I-B) and a 20-30 year old male (HLL201.1). The latest occurrence, between 10.6 and 10.9 years, was provided by the upper third molar of a 20-30 year old individual (HLL402).

Percentages of defects per age group were calculated for each tooth class. Figure 3.1.5 illustrates the frequencies for the upper dentition.

Figure 3.1.5. Late Antiquity-Early Byzantine sample: percentage of defects appearing at different ages in maxillary teeth.

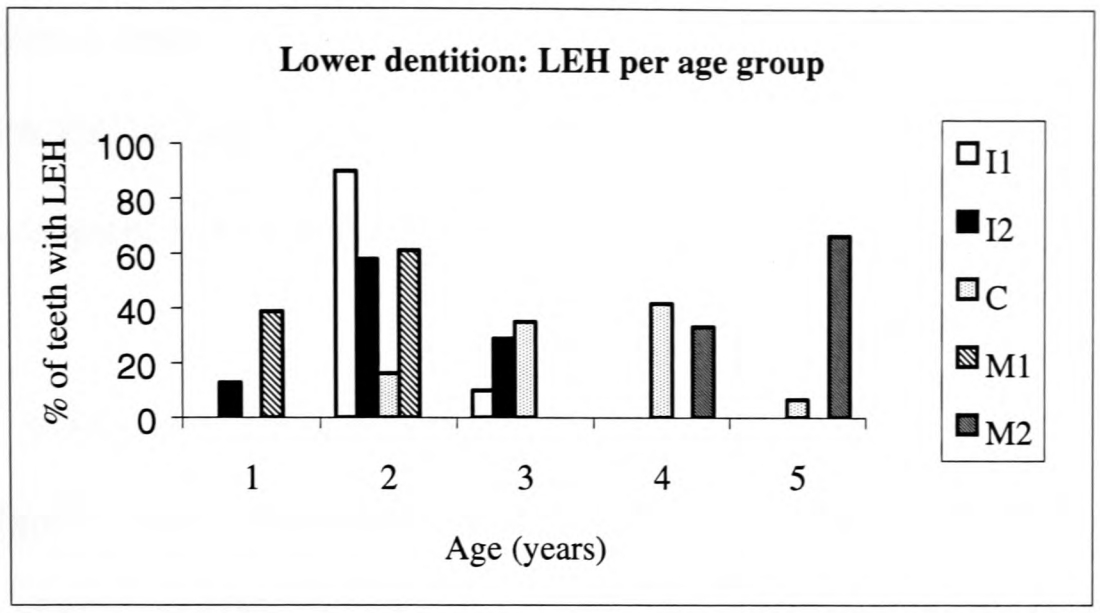


*Codes: 1 = 1-2 years, 2 = 2-3 years, 3= 3-4 years; 4 = 4-5 years; 5 = 5-6 years.

For first incisors, the peak was observed when individuals were between 3-4 years (40%); for second incisors at age 2-3 years (52.5%) and canines at age 3-4 years (35.7%) but equally between 4-5 years. First molars displayed lesions appearing during the third year of life (83.3%), while second molars had most occurring in the sixth year of life (81.8%). Defects in third molars appeared between 10-11 years of age, although high variability in this tooth must be taken into account.

Figure 3.1.6 illustrates the percentage of defects per age group in the lower dentition. First incisors have most defects (90%) during the second year of life; second incisors during the third year (58%) with some (12.9%) also occurring in the second year. Canine lesions ranged from the third year (16.2%) to the sixth year (6.7%), the peak being between 4-5 years (41.8%). While peaks in first molars were located in the third year (61.1%), peaks in second molars were located in the sixth year of life (66.6%).

Figure 3.1.6. Late Antiquity-Early Byzantine sample: percentage of defects appearing at different ages in mandibular teeth.



*Codes: 1 = 1-2 years, 2 = 2-3 years, 3= 3-4 years; 4 = 4-5 years; 5 = 5-6 years.

Overall, considering upper and lower incisors and canines, most frequencies tended to occur between 2 and 4 years, with the 2-3 year range predominating in the lower dentition. Defects in first molars cover a range between 1 and 3 years, with peaks in the 2-3 year age range. Physiological insults continued to occur in later years, as attested by second and third molars.

3.1.5.9 Comparisons between Period 1 and Period 2

Most comparisons between periods were undertaken with data from adult individuals. The Punic subadult sample was too limited to undertake reliable comparisons with Late Antiquity-Early Byzantine subadults.

In the Punic period, 100% (6/6) of anterior teeth (incisors, canines) and 77.7% (7/9) of posterior teeth (premolars, molars) had LEH in the subadult sample. Amongst adults, 76.4% (26/34) anterior teeth and 39.3% (50/127) posterior teeth were affected. The overall frequency of hypoplastic teeth for the Punic period was 52% (101/194).

The results from the Late Antiquity-Early Byzantine period were similar but revealed slightly lower frequencies. Amongst subadults, the incidence in anterior teeth was 73.6% (53/72) and 53.2% (65/122) in posterior teeth. Hypoplastic teeth in adults constituted 60.9% (81/133) of anterior teeth and 31.1% (89/286) of posterior teeth. The overall frequency for this period was 48.7% (328/673).

Although a trend towards higher frequency of hypoplastic teeth in Period 1 might have seemed apparent, the differences between Period 1 and Period 2 were not significant. This accounted for comparisons between subadult anterior teeth (x^2 = 0.258; p = 0.612) and posterior teeth (x^2 = 0.521; p = 0.471); adult anterior (x^2 = 0.592; p = 0.442) and posterior teeth (x^2 = 1.30; p = 0.254); and overall frequencies of hypoplastic teeth (x^2 = 0.221; p = 0.637).

When adult dentitions were considered, comparisons between periods were made with regard to age groups and sexes. In addition, mean number of defects per tooth was also compared. In order to increase the sample size, teeth were pooled according to tooth classes (anterior, posterior) and statistical tests were performed (Table 3.1.21).

Table 3.1.21. Period 1 *versus* Period 2: comparison between adult age groups*.

LEH	PERIOD 1			PERIOD 2			Statistical results	
	15-20			15-20				
	N	n	%	N	n	%	Chi-square	Significance
Is & Cs	6	4	66.6	48	44	91.6	0.222	n.s.
Ps & Ms	21	5	23.8	74	27	36.4	0.617	n.s.
	20-30			20-30			Chi-square	Significance
Is & Cs	10	9	90.0	54	19	35.1	3.24	n.s.
Ps & Ms	46	22	47.8	152	34	22.3	5.74	<0.05
	>30			>30			Chi-square	Significance
Is & Cs	10	8	80.0	25	14	56.0	0.380	n.s.
Ps & Ms	54	21	38.8	57	21	36.8	0.022	n.s.

*Codes: Is = incisors; Cs = canines; Ps = premolars; Ms = molars; N = number of teeth observed; n = number of teeth with LEH; n.s. = not statistically significant.

Apart from the younger age category (15-20 years), rates of hypoplastic teeth were higher in Period 1 than in Period 2. Differences were only significant ($p = 0.017$) between posterior teeth from the 20-30 year age group. Therefore, based on these teeth in this age category, there was a significant decrease in the prevalence of hypoplastic teeth in Period 2.

Samples of teeth from females and from males were also compared between periods. Different frequencies in females were not statistically significant, both for anterior teeth ($x^2 = 1.53$; $p = 0.215$) and posterior teeth ($x^2 = 1.50$; $p = 0.221$). The same applied when male anterior teeth ($x^2 = 0.374$; $p = 0.541$) and posterior teeth ($x^2 = 1.85$; $p = 0.174$) were compared.

Frequencies of teeth with multiple lesions were also compared (Table 3.1.22).

Table 3.1.22. Period 1 *versus* Period 2: percentage of teeth with multiple lesions*.

Teeth	PERIOD 1			PERIOD 2			Statistical results	
	N	N	%		N	%	Chi-square	Significance
Incisors	8	7	87.5	29	10	34.4	2.22	n.s.
Canines	18	12	66.6	52	22	42.3	1.02	n.s.
Premolars	30	13	43.3	62	18	29.0	0.887	n.s.
Molars	19	1	5.2	27	1	3.7	0.059	n.s.

*Codes: N = number of teeth with LEH; n = number of teeth with more than one lesion (multiple); % = percentage of teeth with multiple lesions; n.s. = not statistically significant.

There appeared to be more teeth with multiple lesions in adults from Period 1 than those from Period 2, but these differences were not significant.

Some significant differences were found when mean number of defects was compared between periods. Mann-Whitney *U*-test was performed on means from Period 1 and Period 2 incisors, canines and premolars. Means in molars were very similar between the earlier period (x = 1.05) and the later period (x = 1.02). The mean number of defects in incisors was significantly higher (U = 43.500; p = 0.003) in Period 1 (x = 2.50) than in Period 2 (x = 1.44). Mean number of defects in canine teeth was also higher in Period 1 (x = 2.44) compared to Period 2 (x = 1.63) and this difference was also significant (U = 317.000; p = 0.027). In premolars, means from Period 1 (x =

1.56) and Period 2 (x = 1.38) were compared but the difference was not significant (U = 801.500; p = 0.198).

With regard to the chronology of defects, apart from molar teeth, most lesions in the anterior dentition appear especially when individuals were between 2-4 years old. With regard to molar teeth, while most lesions were limited within one age group in Period 1, there appeared to be more widely distributed across a number of age ranges in Period 2.

3.1.5.10 Summary of findings

The Period 1 tooth sample (n = 194) was smaller[66] than the Period 2 sample (n = 673). The subadult sample was particularly small in the former period.

With the data available several conclusions were reached. Firstly, LEH frequency was relatively high, near 50% and over for both overall rates in each period as well as per tooth class. Secondly, in each period there were a higher proportion of hypoplastic teeth in the subadult group compared to the adult group. This trend also applied to the increase in the mean number of defects per tooth. Differences between

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[66] Unfortunately, in the published anthropological studies on Punic skeletons from Ibiza, no LEH frequencies or data are provided. At the site of *Cas Jurat*, the authors (González-Martín and Lalueza, 1992) merely indicate that some slight hypoplasias were observed in some individuals. The authors stated '*Algunos individuos tienen hipoplasias de tipo leve...*' (1992: 79). It was possible to count from the report that out of five individuals with some dentition present, at least one (Portmany IV) had LEH. With regard to the site of *Ca n'Eloi* (González-Martín and Lalueza, 2001) no comments were made on enamel defects. At the site of *Can Marines* (Gómez, 1989), only two mandibles with few teeth were found but no report was made on presence or absence of enamel hypoplasias.

subadults and adults however, were only statistically significant in the Period 2 samples. Significant differences in Period 1 were only present when comparing LEH frequencies among molars. Thirdly, within each period, no significant differences were found while comparing different adult age groups. In addition there were no significant differences between female and male frequencies of LEH in both periods.

In general, when results from Period 1 were compared with those from Period 2, an apparent higher frequency of LEH was present in the former period. However, these results were not statistically significant except for mean number of defects in incisors and canines, which proved to be significantly higher in Period 1. With regard to adult age groups, only results from the 20-30 age group revealed that frequencies were significantly higher in Period 1 than in Period 2. Differences were not significant between males and females from Period 1 and Period 2.

3.1.6 Discussion

All the frequencies recorded represent a minimum level. Microscopic methods (e.g. see Hillson and Bond, 1997; King *et al.*, 2002, and in press; Cunha *et al.*, 2004) would have probably revealed more defects than can be observed macroscopically. Even with this in mind, the prevalence of LEH was high in the Ibizan populations, in particular when compared to other populations. A lower frequency was found in a Neolithic site in Greece with only 8.3% (36/436) of teeth affected (Papathanasiou, 2005). In a relatively well-nourished sample from Mendes (Egypt), 17% of teeth had

hypoplasia (Lovell and Whyte, 1999). Closer to Ibiza, in the prehistoric population of *Es Càrritx*, in Majorca, 19.7% of teeth were affected (Rihuete, 2003). At *S'Illot des Porros*, also in Majorca and contemporary to Punic Ibiza, 34% of teeth displayed hypoplasias (Malgosa and Campillo, 1991). By contrast, higher frequencies (>70%) have been found in slave populations (Blakey *et al.*, 1994).

Results between both periods were similar, although the findings were suggestive of a slightly higher incidence of LEH in the Punic period. In view of the hypothesis and considering the potential aetiological factors of LEH, a difference between periods was expected.

In view of these two primary findings, discussion will concentrate on attempting to find any pre-eminent causes of LEH, despite its multifactorial aetiology, which might provide clues as to: a) why was there a high frequency in the Punic period; b) why were results similar between the two periods, perhaps with a slightly higher incidence of LEH in Period 1.

The teeth observed with a LEH belonged to individuals who survived the physiological insult, as the stress episode was recorded in the teeth. Simply stated in view of the hypothesis, physiological stress was not low in the Punic period, and was equal if not higher to the rates obtained for Period 2.

On reviewing the literature, the frequencies in Ibiza might well reflect a poor quality of life. Individuals with LEH lived in conditions that were poor (e.g. see May *et al.*, 1993; Moggi-Cecchi *et al.*, 1994; Saunders and Keenleyside, 1999; Littleton, 2005). Furthermore, it is possible that those with LEH were frailer, more susceptible to stress and may have died earlier (Rose *et al.*, 1985: 295; Suray, 1996: 282). This is illustrated in the higher number of defects in subadults compared to adults. This pattern is present in other studies too (e.g. Stodder, 1997; Šlaus *et al.*, 2004), although there are exceptions (e.g. see Rihuete, 2003). A number of archaeological examples have shown a correlation between presence of LEH and lower life expectancy although the mechanisms for this are unclear (Duray, 1996; Palubeckaité *et al.*, 2002; by contrast see Saunders and Keenleyside, 1999). Socio-economic status may influence LEH rates although this has not been strongly supported in the archaeological literature (e.g. Cucina and Işcan, 1997; Robb *et al.*, 2001).

Although the aetiology of LEH is multifactorial, it is of importance to attempt to examine what are the pre-eminent mechanisms resulting in these higher frequencies. Some can be discussed and others excluded. For instance, enamel defects occur more frequently in children born pre-maturely (Aine *et al.*, 2000). However, it is unlikely that the majority of cases derive from premature children.

Some anthropological studies have seen the presence of LEH correlated with nutritional stress (Goodman *et al.*, 1987; Larsen, 1997a; Dobney and Goodman, 1991; Zhou and Corruccini, 1998). Nevertheless, in an apparent economically prosperous

period such as the Punic, generally speaking malnutrition would be unexpected. Stable isotope analysis examined the protein intake in these populations (see Chapter 6). Meat or milk protein consumption was higher in the Period 1 population compared to Period 2 (B. Fuller, pers. comm.). Preliminary observations show that variation in nitrogen stable isotopic (meat/milk intake) in those with LEH varied, ranging from a low value ($\delta^{15}N$ = 8.3, skeleton HLL214-B) to one of the highest values ($\delta^{15}N$ = 12.1, skeleton 903). These two samples came from two 20-30 year-old female individuals. The range between these values in the population showed variation in presence and absence of LEH. Nutritional adequacy, however, needs to be investigated in subadult remains, as these enamel defects occur during growth. Presence of LEH did seem to indicate here that these were independent from protein intake. For instance, LEH was present in skeletons with $\delta^{15}N$ values of 9.4 (HLL408.2), 10.1 (HLL402), 11.9 (HLL210), and 12.9 (HLL803.2B)[67].

Nutrition cannot be the only contributing factor in the development of high frequencies in Ibiza. However, even if food resources were available, nutritional stress in children could have occurred in some instances due to post-partum maternal depression (Anoop *et al.*, 2004). Also illness would have likely played a significant role in the development of LEH. Incidence of these defects is high in individuals with

[67] There is some variation however in frequencies of LEH in a Prehistoric sample from *Ca na Costa* and an Islamic sample from *Es Soto,* with only one isolated case of hypoplastic tooth reported for the former (1/138) by Gómez (1989) and 24% (31/129) reported for the latter site (Márquez-Grant, 1999b). Interestingly, these have different diets to the Punic and Late Antiquity-Early Byzantine samples. At *Ca na Costa* there is a much higher meat consumption (B. Fuller, pers. comm.) whilst at *Es Soto* the diet appears to be more vegetarian and with a larger fish intake (Márquez-Grant *et al.*, 2003). While the isotopic results are preliminary, the LEH frequencies for these two sites need re-examination, separation between tooth classes, and analysis under a standardised methodology. At *Ca na Costa,* for example, Gómez (1989) does not provide any frequencies of affected teeth. He simply mentioned that a second incisor had at least five hypoplastic defects.

infectious lesions (see Stodder, 1997). Diarrhoea may have interfered with absorption of nutrients and with metabolic processes (May *et al.*, 1993: 47). Disease in subadults would, in turn, be related to the weaning process. Suggestions have been made with regard to a relationship between weaning and LEH (Goodman *et al.*, 1984; Moggi-Cecchi *et al.*, 1994), although this association has been doubted in other studies (Blakey *et al.*, 1994; Saunders and Keenleyside, 1999). However, three questionable assumptions have been made (Katzenberg *et al.*, 1996). Firstly, that there is a direct relationship between weaning and peak age of occurrence of defects[68]. Secondly, that the estimated age of defect occurrence is accurate. Thirdly, weaning and post-weaning periods are times of increased physiological stress for the child. Because of these assumptions and the non-specificity of the lesions, weaning should not be singled out as a major contributing factor (Katzenberg *et al.*, 1996: 186, 194).

Nevertheless, the weaning hypothesis has been an attractive one. This is especially true when the peaks of LEH appearance are ascribed to the age between one and three years (Goodman *et al.*, 1987). The human immune system matures at about 2 years of age and breastfeeding until that age provides immunity for the child (Lovell and Whyte, 1999: 75). Malnutrition, diarrhoeal diseases and higher infant mortality have been found to be more prevalent in infants artificially fed rather than breastfed (Gabr, 1987: 11). In a living Indian population, children who had been breastfed displayed lower LEH in their teeth (erupted deciduous teeth) than those receiving other animal or artificial milk, making them more susceptible to infectious agents (Agarwal

[68] It is possible that these peaks between 2-4 years of age are linked to tooth geometry and formation so that the observer is likely to score defects in this age range (Humphrey, pers. comm..).

et al., 2003). By contrast, however, if maternal feeding as the only nutritional source is prolonged over six months, this would result in a protein and calorie deficiency (Lovell and Whyte, 1999: 75).

Contaminated foodstuffs introduced during weaning may lead to gastrointestinal diseases, exacerbated by the loss of immunity after the cessation of breastfeeding. In addition, supplementary foods may be inappropriate for the young child. Ancient writers like Galen and Soranus wrote about supplementary foods including boiled honey and goat's milk, which were introduced at six months of age (Dupras *et al.*, 2001: 205)[69]. References to these foodstuffs have also been found in the Old Testament as well as in early medieval Europe (Greenberg, 1980). Sheep and goat remains have been predominant in Punic Ibizan faunal assemblages (Saña, 1994; Morales, 2003). Honey would be present too (see Bonet and Mata, 1997). Goat's milk is low in folate, which negatively affects the infant's ability to absorb iron, leading to iron-deficiency anaemia (Janssens, 1983). When honey, a source of *Clostridium botulinum*, is also fed to infants, botulism might occur and this could result in severe illness or be fatal (Fairgrieve and Molto, 2000).

[69] With this regard it is interesting to note the presence of 'feeding bottles' in archaeological contexts (see Bartsocas, 1978; Savona-Ventura, 1997), including Punic Ibiza (Ramon, 1996: 67, 77). Only one feeding bottle ('*vaso biberón*') from Ibiza has been reported alongside the anthropological study of its skeleton. In this case, the artefact dated to the sixth century BC was found in a tomb from *Puig des Molins* where the skeleton of a 2-3 year-old individual was interred (Gómez and Gómez, 1989). Further studies may provide clues as to the weaning process, although perhaps those that have died at a young age received different weaning practices to those that survived into adulthood.

Independent analysis of deciduous teeth[70] in this study has indicated that no LEH was present. When defects are present in teeth forming prenatally, these are often linked to malnutrition or deficiency of calcium in the mother, or even lactose intolerance (Lovell and Whyte, 1999: 75). Therefore, in this regard, no physiological insults related to linear defects occurred under one year of age, during deciduous crown formation. Therefore, up until this age it was likely that breast milk was being fed rather than milk from other animals, thus providing more protection with regard to immunity.

The weaning hypothesis cannot be argued for those defects showing age of occurrence at six or ten years of age, however. Genetics may have had some effect. Individuals with LEH may have had a genetic susceptibility to certain types of stressors (Duray, 1996). Whether genetic, environmental or cultural, the living conditions in the Punic period did not seem to have been favourable during growth, according to the LEH data. Individuals with defects clearly experienced episodes of physiological stress. Moreover, there is no apparent difference between Period 1 and Period 2. Surviving individuals without defects may have been better adapted to the stress or may have never been exposed to the stresses (Rose *et al.*, 1985: 290; Boldsen, 2005: 166).

Opposing views to this interpretation can be found. Population with high frequencies of LEH may indicate better health than those populations with lower rates

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[70] The Punic urban sample had 0% LEH incidence in deciduous teeth (0/10), six incisors and three molars from two individuals. Data from the site HLL from Late Antiquity-Early Byzantine period equally indicated 0% incidence in the number of individuals observed (0/36) and number of teeth (0/76) examined for LEH: 11 canines, 17 incisors, and 48 molars. No other types of enamel defects that were obvious were identified, although focus was primarily on LEH.

(Wood *et al.*, 1992). Individuals with defects were those able to adapt to stresses affecting their physiology. If lesion frequency increased and childhood mortality decreased, then health would be 'worse' with regard to disease frequency but 'better' in terms of greater childhood survival (Keita and Boyce, 2001: 741). Those too frail would not survive the stress episode to the point of it affecting enamel matrix formation since they died too quickly. Indeed, results do suggest that individuals who died in childhood had more lesions than adults. Individuals exposed to stress in infancy may have been biologically "damaged" by the stress and would find it difficult to cope with later insults in life (Duray, 1996). In the Punic period, the number of teeth with LEH was 89. From those 89 teeth, 76 (85.3%) belonged to individuals that survived childhood and reached adulthood. In Period 2, the number of hypoplastic teeth was 288, of which 170 (59.0%) belonged to individuals that died in adulthood. With this regard, more children in Period 1 were able to survive into adulthood, perhaps being fitter and better adapted than children in Period 2. These differences were statistically significant ($x^2 = 4.06$; $p = 0.044$).

With regards to sexual dimorphism in LEH frequency, samples were limited. Lower incidences of LEH in females may have been expected in relation to better buffering against environmental stress (Stinson, 1985) or, by contrast, lower frequencies could also be found in males in relation to culture if there was unequal access to food or different nursing preferences towards male children. However, no significant differences were found overall between the sexes, perhaps suggesting an

egalitarian society with regards to access to food resources and care between children of both sexes.

To sum up, one interesting finding from this analysis is that, generally speaking, frequencies were high in the Punic period. Furthermore, these frequencies were not different to those from Period 2. A slight increase in Period 1, though, might be indicative of better adaptation to reach adulthood. Higher frequencies in subadults provide clues as to the reflection of how these environmental circumstances resulting in LEH were risking the lives of children. Finally, the proportion of teeth with LEH came from contexts covering a time span of several centuries. With this regard, the negative environmental circumstances associated with LEH seem to have been a chronic problem.

The remaining parameters relating to stature and palaeopathology should provide further clues to this lifestyle, either confirming or rejecting the conclusions derived from the LEH analysis.

3.2 Porotic hyperostosis and *cribra orbitalia*

3.2.1 Definition

Porotic hyperostosis (PH) is a condition characterised by lesions involving the outer table of the cranial vault, particularly the frontal, the parietal and occipital bones (Angel, 1966; Stuart-Macadam, 1989a;). 'In the fully developed lesion the involved areas of the skull are thickened by the expanded diploic layer and the outer table overlying the lesions has been resorbed completely' (Aufderheide and Rodríguez-Martín, 1998: 348). *Cribra orbitalia* (CO) appears to be related to these vault lesions. CO (Ill. 3.3) is identified when the surface of the orbits, that are smooth and dense, present pits of varying size and density (Stuart-Macadam, 1998: 47). Similar lesions in the femur and humerus, known as *cribra femoralis* and *cribra humeralis* respectively, may also be related conditions (Miquel-Feucht *et al.*, 1999).

3.2.3 Aetiology

Anaemia seems a possible cause of these skeletal abnormalities (Angel, 1966; Stuart-Macadam, 1991, 1998). Recent clinical studies indicate that young children and pre-menopausal women in their reproductive years are more vulnerable to anaemia (Stuart-Macadam, 1998: 50, 53). When skeletal lesions are considered in children as opposed to adults, the space between the inner and the outer surface of the cranial bones is filled with red marrow and the increasing production of red cells leads to

expansion (Larsen, 1997b: 11). Thus, it is more likely for this condition to leave a trace in subadult skeletons.

Anaemia is a symptom and not a disease *per se* (Stuart-Macadam, 1998: 46). The condition is present when the number of red blood cells or the level of haemoglobin is below normal (Larsen, 1997b: 10). Although anaemia may not always leave a trace in the skeleton, PH and CO reflect a body's attempt to correct for iron deficiency through marrow hyperplasia (Blom *et al.*, 2005: 165).

Anaemia will negatively affect the work capacity and cognition of a person, as well as his or her immune system and thus will feel fatigued and weak (Stuart-Macadam, 1998: 46). This may affect industrial productivity. Anaemias can be genetic but they can also be acquired as a result of conditions leading to low iron availability (Larsen, 1997b). The presence of CO and PH in the Balearic Islands may be due partly to the high percentage of heterozygous individuals for thalassemia (Malgosa and Campillo, 1991). These lesions have also been used as indicators of 'nutritional stress'. Particular attention has been given to the possible role of iron deficiency anaemia on these lesions. Iron-deficiency anaemia may appear in relation to poor diet and inadequate nutrition, for example when there is reliance on a food staple that inhibits iron absorption (El-Najjar *et al.*, 1976; Blom *et al.*, 2005: 166).

A study of CO on Punic skulls from Carthage, together with chemical analysis, found that skulls with lesions, compared to those without, had lower iron content

(Fornaciari *et al.*, 1983). Experimental studies have concluded that the presence or absence of CO in rats was strongly linked to Mg and Fe proportions in the organism (Polo *et al.*, 1999).

Some other contributing factors with regard to nutrition may be a lack of folic acid due to goat milk consumption (Janssens, 1983). Excess nutrition such as hypervitaminosis or high meat intake may also be a contributing factor (Klepinger, 1992). Both too much and too little iron intake can affect the immune system and therefore make the individual more susceptible to infection (Stuart-Macadam, 1998: 58). Other data have suggested that a lack of vitamins (Grupe, 1995) and magnesium deficiency (Miquel-Feucht *et al.*, 2000) are associated with presence of CO.

More recently, histological examinations have been carried out on 333 Sudanese skulls dated between the second and sixth centuries AD (Wapler *et al.*, 2004). Out of the 93 skulls with CO only 43% were associated with anaemia. Other cases were likely associated with alterations such as sinusitis, oral infections, osteoporosis and vitamin C (Wapler *et al.*, 2004: 337-338). In fact, Subirà and colleagues (1992) undertook trace element analysis on a small skull sample from a site in Majorca and contemporary with Punic Ibiza. Since skulls with and without CO had similar diets, it was suggested that the lesions may not have been linked to nutritional deficiency (Subirà *et al.*, 1992; Subirà, 1993).

Nevertheless, iron deficiency anaemia is not about a dietary deficiency, but it depends on a wider ecological, immune, social, physiological, temporal, economic and political context (Stuart-Macadam, 1998: 59). Other contributing factors therefore must be considered. Pathogen load, the number of micro-organisms in the environment, could play a major role (Stuart-Macadam, 1992). A population may try to adapt to the pathogen load by lowering iron absorption (Stuart-Macadam, 1992). Other underlying causes are iron deficiency due to blood loss, chronic diarrhoea, or parasites accompanied by gastrointestinal bleeding. In turn, the risk of parasite infestation is associated with sedentism, eating raw meat and fish, sanitation, population aggregation, contaminated water, plagues, zoonoses, population movement and inefficient waste disposal amongst other factors (Kent, 1986; Larsen, 1997b: 10; Lovell, 1977a; Mittler and van Gerven, 1994: 293; Stuart-Macadam, 1998; Walker, 1986).

3.2.3 Methodological advantages and limitations

To summarize, PH and CO have a multifactorial aetiology (Campillo, 2001: 286-287). The presence of these lesions reflects some chronic health problem resulting in a complex combination of factors (Holland and O'Brien, 1997; Wapler *et al.*, 2004). These factors include living conditions, diet and disease. Hence, these lesions have been regarded as good indicators of the state of health, nutrition and hygiene of skeletal populations (Piontek and Kozlowski, 2002).

One potential problem associated with the use of *cribra orbitalia* is that porosity in the orbits does not necessarily represent pathology (Wapler *et al.*, 2004: 336). Moreover, because a reliable distinction between *ante-mortem* and *post-mortem* changes may not always be possible in macroscopic observations, histological analysis are of value in order to obtain a reliable diagnosis and aetiology of CO (Wapler *et al.*, 2004). However, there were no resources to undertake histological analysis on the Ibizan samples.

3.2.4 Materials and methods

From the skeletal areas affected by porotic hyperostosis, only those in the orbital areas (*cribra orbitalia*) were considered rather than the cranial vault. Lesions in the cranial vault were difficult to quantify for a palaeoepidemiological analysis because they were found very fragmented in the commingled assemblages. For instance, in the case of the Punic rural site of *Ses Païsses de Cala d'Hort* (PCHN), thousands of cranial fragments were washed and labelled, but only a few bones, let alone skulls, could be reconstructed.

In order to examine the incidence of CO in the Ibizan populations, orbits were examined macroscopically. Due to the commingled and fragmented nature of the skeletal remains, each orbit was classified independently. Data from published and unpublished sources were also employed to increase the sample size.

Each orbit was observed for presence or absence of CO. The lesions were identified when the surface of the orbits were pitting (Stuart-Macadam, 1998: 47). When a lesion was present, it was classified into one of four grades (after Stuart-Macadam, 1989, 1991): type 1) scattered fine foramina; type 2) large and small isolated foramina; type 3) foramina that have linked into a trabecular structure; and type 4) outgrowth in trabecular form from the outer table surface (see Ill. 3.3). This latter type was the most severe.

Data were introduced into a 'Microsoft Excel' spreadsheet including site code, bone (side), sex and presence or absence of CO. Lesions were coded for severity, location and state of healing. Data were imported from 'Excel' to SPSS 13.0 where statistical analyses were performed. Differences, both in terms of number of orbits and number of individuals affected, were compared between sexes and between periods.

3.2.5 Results

The Punic adult (> 15 years) sample consisted of 37 orbits, while the Late Antiquity-Early Byzantine group accounted for 33 orbits[71]. All the lesions were healed, presenting smooth lamellar bone.

[71] There was no possibility of comparing individuals less than 15 years of age at death because no observable subadult orbits were present in the Punic sample. In the Period 2 sample, 17 subadult orbits could be observed and 11 (64.7%) had CO.

3.2.5.1 The Punic sample

The Punic adult sample is presented in Table 3.2.1. The number of orbits observed, those affected and the degree of severity are presented. In the Punic period only the rural site PCHN and two orbits from PM01 (PM01/UE66) provided enough preservation for analysis of CO. Sex assessment of some individuals could only be based on the morphology of the glabella and the supraorbital margin, especially in the fragmented and commingled rural sample. Therefore, caution must be borne in mind when comparing sexes.

Table 3.2.1. Punic sample: number of orbits observed, number of those with CO and distribution according to severity.

PUNIC PERIOD						
Category	**Orbits observed**	**Orbits with CO**	**Type 1**	**Type 2**	**Type 3**	**Type 4**
Adult females	10	2	1	0	0	1
Adult males	17	8	3	3	2	0
Other adults (sex unknown)	10	2	0	0	2	0
TOTAL ADULT ORBITS	37	12	4	3	4	1

The total adult prevalence was 32.4% (12/37) orbits with CO. Amongst those affected, only one severe case (8.3%) was present.

Female orbits with CO accounted for 20.0% (2/10) compared to 47.0% (8/17) in males, but this difference was not statistically significant ($x^2 = 1.98$; $p = 0.160$).

In addition, it was possible to estimate the minimum number of individuals observed (Table 3.2.2). Only one individual from the urban sample was available for observation. With regard to the Punic rural sample, the maximum number of repeated orbits was taken into account. This was provided by the left orbit, which showed that 31.8% of individuals had CO. A total of 30.4% Punic individuals in the sample displayed the lesions.

Table 3.2.2. Punic sample: percentage of individuals with CO.

PUNIC PERIOD			
Site*	**Total Adults with CO**	**Males with CO**	**Females with CO**
PM01	0/1	0/1	0/0
PCHN	7/22[1]	4/11	2/5
TOTAL	30.4% (7/23)	33.3% (4/12)	40% (2/5)

*Site codes: PM01 = *Puig des Molins;* PCHN = *Ses Païsses de Cala d'Hort.*

[1] Only left orbits were considered since they provided the maximum count.

The difference between males and females was not statistically significant (x^2 = 0.068; p = 0.793).

3.2.5.2 Late Antiquity-Early Byzantine sample

The Late Antiquity-Early Byzantine adult sample is presented in Table 3.2.3. The total frequency of orbits with lesions was 45.4% (15/33).

Table 3.2.3. Late Antiquity-Early Byzantine sample: number of orbits observed, number of those with CO and distribution according to severity.

LATE ANTIQUITY-EARLY BYZANTINE PERIOD						
Category	**Orbits observed**	**Orbits with CO**	**Type 1**	**Type 2**	**Type 3**	**Type 4**
Adult females	5	1	0	1	0	0
Adult males	23	13	1	4	3	5
Other adults (sex unknown)	5	1	0	0	1	0
TOTAL ADULT ORBITS	33	15	1	5	4	5

Amongst the affected orbits, 33.3% (5/15) had severe (type 4) lesions. All these severe cases came from male individuals.

Adult female orbits with CO accounted for 20.0% (1/5) compared to 56.5% (13/23) of male orbits, although this differences was not significant ($x^2 = 2.19$; $p = 0.139$).

With regard to the minimum number of individuals affected (Table 3.2.4), a total 54.5% of individuals had CO. Since the assemblage AR33 was commingled, the individual prevalence rate was obtained from the count of repeated right orbits.

Table 3.2.4. Late Antiquity-Early Byzantine sample: percentage of individuals with CO.

LATE ANTIQUITY-EARLY BYZANTINE PERIOD			
Site*	**Total Adults with CO**	**Males with CO**	**Females with CO**
AR33	3/6[1]	2/4	0/0
HLL	9/16	9/12	0/2
TOTAL	54.5% (12/22)	68.7% (11/16)	0% (0/2)

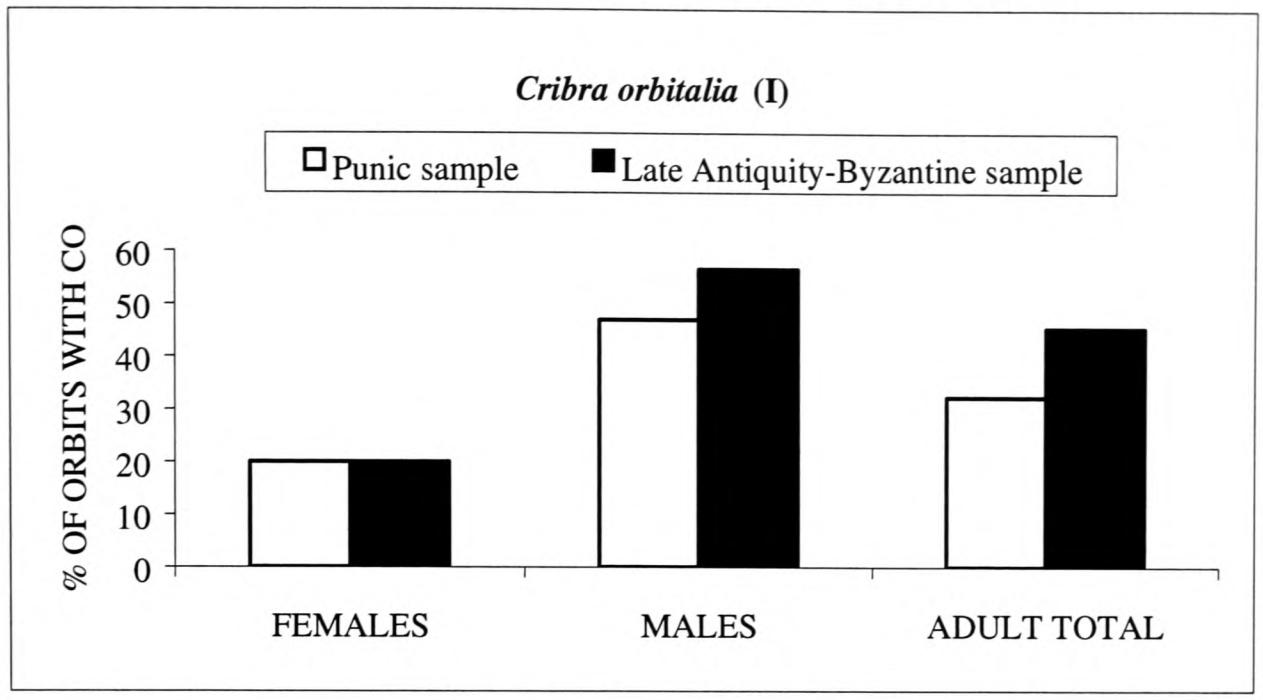
*Site codes: AR33 = *Carrer Aragó, 33*; HLL = *S'Hort des Llimoners*. [1] Only right orbits were considered since they provided the maximum count.

The female sample was too reduced to allow any reliable comparisons with the male sample. Nevertheless, statistical analysis was carried out, which revealed no significant differences ($x^2 = 3.54$; $p = 0.060$).

3.2.5.3 Comparisons between Period 1 and Period 2

From the above results, a trend was apparent when Period 1 was compared to Period 2. Figure 3.2.1 illustrates the percentage of affected orbits in the female, male and the overall adult groups.

Figure 3.2.1. Prevalence of CO in female and male orbits, and for the overall adult population. Period 1 (n = 37 orbits) and Period 2 (n = 33 orbits) are compared.



Overall, in Period 1 and Period 2 females have less CO than males. However, the female sample size was small and various orbits could not be sexed. The prevalence of lesions in the male and overall adult groups was lower in the Period 1 sample. The difference between male orbits from both periods was not significant ($x^2 = 0.351$; $p = 0.0554$), and neither were the differences between overall adult frequencies ($x^2 = 1.25$; $p = 0.264$). Although there were more severely affected orbits in Period 2 (5/15) than in Period 1 (1/12), the difference was also not significant ($x^2 = 2.41$; $p = 0.121$).

When frequencies among individuals affected rather than orbits were compared, Period 1 (30.4%) showed a lower incidence than Period 2 (54.5%). However, these differences were not statistically significant ($x^2 = 2.68$; $p = 0.102$). This non-significance equally applied to comparisons between the female groups from both

periods (x^2 = 1.12; p = 0.290), as well as between the male groups (x^2 = 3.46; p = 0.063).

3.2.5.4 Additional data: Comparisons between Period 1 and Period 2

In order to increase the sample size and to make it more representative of each period, especially the Punic, additional data from published and unpublished sources were employed. Punic data were obtained from the rural sites of *Cas Jurat* (González-Martín and Lalueza, 1992) and *Can Marines* (Gómez, 1989), located inland on the north-western and eastern parts of Ibiza respectively.

Caution must be given, however, as the skulls indicated with CO in these published studies were only reported as isolated cases. The authors did not provide any frequencies on the number of orbits affected from the number of those observed. Hence, a count for these sties was made here by carefully revising the descriptions provided by the authors. For example, in the sample from *Cas Jurat* (PORT), the authors indicated that there was no presence of CO[72]. It was assumed that all the well-preserved orbits were observed (n = 17). Where the description indicated poor preservation, the orbit was excluded from the count. In the case of *Can Marines* (Gómez, 1989), the estimated prevalence was 25% (4/16) based on the orbits with good preservation. The remaining published work on Punic Ibizan material, from the site of *Ca n'Eloi* (González-Martín and Lalueza, 2001), was not included in this analysis due to the fact that there was no indication in the report as to the presence or absence of CO.

[72] "No hay presencia de *cribra orbitalia*..." (González-Martín and Lalueza, 1992: 79).

The cranial remains were in a very bad state of preservation[73] and it was probably the case that no orbit was available for examination.

The only tombs from the Late Antiquity-Early Byzantine period that provided some orbits for observation came from the rural site of *Ca na Martina* (Márquez-Grant, unpublished data). Only two orbits were observed and none had CO.

This additional data for each period were added to the data from this thesis. The summary of the results is presented in Table 3.2.5. The sex determined on the skulls from the published sources was based on standard recommendations (e.g. Ferembach *et al.*, 1980).

Table 3.2.5 Prevalence of adult orbits with *cribra orbitalia* after adding additional data*.

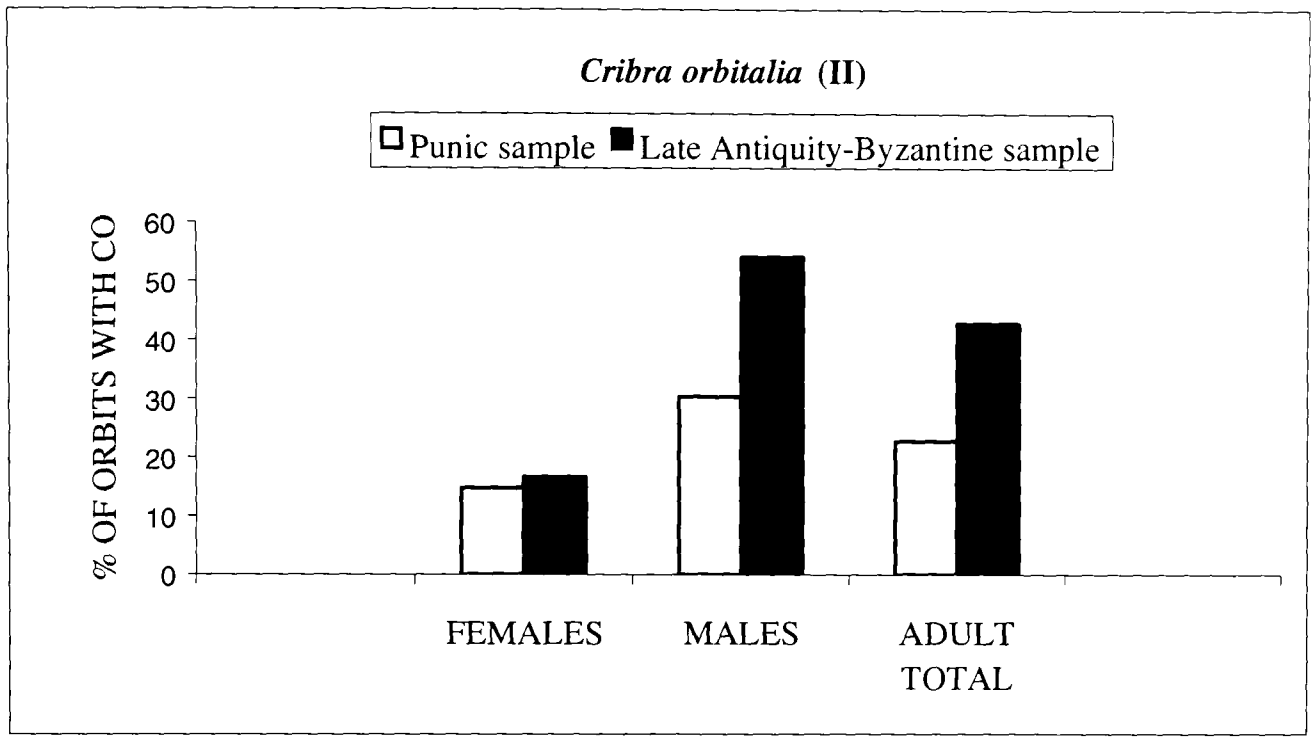
Period	**Total orbits with CO**	%	**Male orbits with CO**	%	**Female orbits with CO**	%
Period 1	16/70	22.8	10/23	43.4	4/27	14.8
Period 2	15/35	42.8	13/24	54.1	1/6	16.6

*Codes: Period 1 = Punic period; Period 2 = Late Antiquity-Early Byzantine period.

Cribra orbitalia was also less frequent in Period 1. Males and females were more affected in Period 2, although female frequencies were similar between periods. Overall, females had a lower incidence of CO than males. The percentage of affected orbits in each group is illustrated in Figure 3.2.2.

[73] "Los restos se hallaban en muy mal estado de conservación.... La degradación del tejido óseo ha afectado la tabla interna del hueso en muchos cráneos, haciendo desaparecer la mayoría de las caras..." (González-Martín y Lalueza, 2001: 103).

Figure 3.2.2. Percentage of orbits with CO after including additional data.



Period 1 displayed lower frequencies than Period 2. These differences were statistically significant ($x^2 = 4.49$; $p = 0.034$). When females and males were compared there were no significant differences in the Period 1 ($x^2 = 3.70$; $p = 0.055$) and the Period 2 samples ($x^2 = 2.71$; $p = 0.100$). Likewise, Period 1 females compared to Period 2 females did not show any significant differences ($x^2 = 0.001$; $p = 0.967$). This equally applied when comparing the male samples ($x^2 = 0.537$; $p = 0.464$).

Prevalence was also obtained for individuals. Individuals were identified according to the descriptions in the published sources. The pattern of low CO in Period 1 repeated itself (Table 3.2.6).

Table 3.2.6. Prevalence rate of individuals with CO after including additional data.

PUNIC PERIOD				
Site*	**Total adults with CO**	**Males with CO**	**Females with CO**	**Sources**
PM01/UE66	0/1	0/1	0/0	This study
PCHN	7/22	4/11	2/5	This study
PORT	0/10	0/5	0/5	González-Martín and Lalueza (1992)
CM	2/11	1/6	1/5	Gómez (1989)
TOTAL	**20.4% (9/44)**	**21.7% (5/23)**	**20.0% (3/15)**	-
LATE ANTIQUITY-EARLY BYZANTINE PERIOD				
Site*	**Total adults with CO**	**Males with CO**	**Females with CO**	**Sources**
AR33	3/6	2/4	0/0	This study
HLL	9/16	9/12	0/2	This study
CNM	0/2	0/1	0/1	Márquez-Grant (unpublished data)
TOTAL	**50.0% (12/24)**	**64.7% (11/17)**	**0% (0/3)**	-

*Site codes: PM01 = *Puig des Molins*; PCHN = *Ses Païsses de Cala d'Hort*; PORT = *Cas Jurat*; CM = *Can Marines*; AR33 = *Carrer Aragó, 33*; HLL = *S'Hort des Llimoners*; CNM = *Ca na Martina*.

CO lesions still remained less prevalent in Period 1. The overall results between Period 1 and Period 2 were statistically significant ($x^2 = 6.35$; $p = 0.012$). Females continued to have a lower incidence than males. The difference between the Punic males and females was not significant ($x^2 = 0.016$; $p = 0.898$), but it was significant between the Late Antiquity-Early Byzantine females and males ($x^2 = 4.31$; $p = 0.038$). Differences between Punic males and Late Antiquity-Early Byzantine males also proved to be significant ($x^2 = 7.52$; $p = 0.006$), but not between females ($x^2 = 0.720$; $p = 0.396$).

3.2.5.5 Summary of key findings

Frequencies in the Punic period were not low. A trend was apparent suggesting less CO in Period 1 than Period 2. Females revealed a lower incidence than males. Partly related to the limited sample size, significant differences ($p<0.05$) were only obtained, however, when additional data from other Ibizan sites were considered. From these samples several findings were obtained:

1) A lower proportion of orbits with CO in Period 1 compared to Period 2.
2) A lower number of individuals with CO in Period 1 compared to Period 2.
3) Period 1 males were less affected with CO than Period 2 males.
4) In Period 2, female individuals had a lower incidence of CO than male individuals.

A variety of issues are worth discussing in more detail: a) possible causes of CO in the Ibizan populations; b) sexual dimorphism in CO rates.

3.2.6 Discussion

The present analysis has only considered adult individuals, those that have survived childhood. Potential methodological bias in the observations of CO in the published studies must also be considered. Nevertheless, the difference of lower CO in Period 1 than in Period 2 was expected in view of the hypothesis. With this regard,

children in Period 1 were less 'stressed' than those in Period 2, inferring that living conditions were better in Period 1, although not as good as to provide low morbidity rates in relation to CO. In examples from Kulubnarti (Nubia), osteological as well as archaeological-historical information support the conclusion that the population with lower percentage of CO lived in better conditions than those showing a higher incidence of orbital lesions (Mittler and van Gerven, 1994).

The first contributing factor in relation to the appearance of these lesions relate to anaemia associated with iron-deficiency in the diet (Holland and O'Brien, 1997). Iron can be found in meat, fish, shellfish and poultry, in the form of heme iron, which is most easily and efficiently absorbed. Populations with a diet based primarily on seafood and fish rich in iron content exhibit an absence of CO (Lalueza *et al.*, 1993). In some plant foods, fruits and vegetables there is non-heme iron, which is less efficiently absorbed (Larsen, 1997b: 10).

Cereals have low iron content and inhibit iron absorption. Early supplementation of carbohydrate foods to children during and after weaning may result in anaemia. Populations, whose dietary staples are iron deficient or interfere with iron absorption, will be more iron deficient and will display more hyperplastic marrow responses than populations whose diets include sufficient meat (El-Najjar *et al.*, 1976: 485). Non-heme iron in maize when consumed together with fish or meat enhances iron absorption considerably (Larsen, 1997b: 10). An increase in dental caries in Period 2 (see Chapter 6) seems to indicate an increased reliance on carbohydrates. Individuals

from a contemporaneous sample (c. 600 AD) from Majorca appear to have had a diet relying more on plants than meat (García and Subirà, 2001). Byzantine documentary sources suggest that the food of ordinary people consisted mainly of bread, legumes, vegetables and perhaps some supplement of olives, fruit, fish and wine (Karpozilos and Kazhdan, 1991: 621-622). Moreover, stable isotope analysis (see Chapter 6) has revealed higher meat intake in Period 1. Interestingly, from four Period 2 subadult individuals (HLL302.1B, HLL402C, HLL815.1B, HLL901), the lowest nitrogen stable isotope value ($\delta^{15}N = 9.8$) was present in the only individual with CO (HLL302.1B), while the rest of individuals with higher meat intake did not present the lesions. From this, it may be that protein did have an influence, although further material needs to be obtained in the future to clarify this relationship.

Marine consumption was limited in past Ibizan populations (see Chapter 6), although *garum* (see Curtis, 1991), a type of fish sauce, was popular and would provide proteins, important vitamins and minerals. However, slightly more fish seems to have been eaten in Period 2 according to the stable isotope data and therefore this cannot be a contributing factor to lower levels of CO in Period 1. In addition, goat's milk consumption (Janssens, 1983; see also Fairgrieve and Molto, 2000) can also be ruled out because it was likely that children, if weaned with this milk, would have been weaned similarly in both periods.

Infectious disease would have resulted in a body response involving iron depletion. The emergence of new pathogens is facilitated by human migrations and

behaviour, technological and industrial innovations, economic development, land use, landscape change, international travel, microbial adaptation and change and these are, at times, combined with the effects of wars, natural disasters and economic collapse, (Mackerness, 1998: 2, 9). Overpopulation meant that wastes had to be catered for. Contamination of food or water could bring widespread illnesses such as typhoid or cholera (McElroy and Townsend, 2004: 156; Mackerness, 1998: 10-11; Howe, 1972: 39).

The Punic period offered those habitats: population density, land use, migration and trade, living and working with animals, and yet frequencies were lower. Population density was high in Punic *Eivissa* (Costa, 1994) and urban areas acted as magnets for pathogens, and merchants and sailors arriving at a place could have introduced diseases. 'One nation's familiar 'tamed' disease would be another's plague, as trade, travel and war detonated pathological explosions' (Porter, 1997: 22). Sea travel, which was quicker than road travel, played a significant role in the spread of diseases (McNeill, 1976: 107-108; Grmek, 1989: 89).

It might be that despite those factors in the Punic period, the prosperity would have contributed to better mechanisms of adaptation such as better sanitation and nutrition amongst other factors. By contrast, the social, economic and ecological circumstances during Late Antiquity-Early Byzantine times may have left many people homeless with inappropriate food and clothing (Miller, 1985: 70). It might be that this apparent malnourishment, poor personal hygiene and poor sanitation in this period lead

to increased CO frequencies. However, the Period 1 sample essentially derived from the rural cemetery. If the Period 1 sample would have included more observations from the urban context, perhaps the prevalence would have increased.

Nevertheless, farmers were also at increased exposure to pathogens, for instance, by living with animals (Ellis and Symington, 1994: 545). Animal zoonoses (see Horwitz and Smith, 2000) deteriorate human health. Cattle might have transmitted tuberculosis to humans, while pigs could have brought influenza; and cats, dogs, ducks, hens, mice and rats would be associated with *Salmonella* (Porter, 1997: 18). Farming also exposed people to infectious pathogens that were in the soil (Ortner, 1998: 79-80; Porter, 1997: 20). Many peasants could also be chronically undernourished and this would make them more vulnerable to infections (McNeill, 1976: 65; McElroy and Townsend, 2004: 190). Although a small part of CO present in the Punic orbits may be related to these factors, the overall population seemed to have been able to cope with these potential 'stressors'.

Other factors to consider might relate to intestinal parasites derived from eating raw fish or meat, since they are a common cause of chronic blood loss for entire communities (El-Najjar *et al.*, 1976: 484). Subsistence on raw or poorly cooked marine resources in Chinchorro Mummies from Chile exposed them to helminth parasites that absorbed nutrients from the body and increased the risk of acquiring anaemia (Arriaza, 1995). Marine consumption was not a primary subsistence in Punic or in Late Antiquity-Early Byzantine periods (see Chapter 6). However, tapeworms in meat would

probably be recognised. A taboo surrounded the consumption of pig in Phoenician-Punic times as it was considered an impure animal (see Ramon, 1994; Riquelme, 2001; Morales, 2003), although it was probably consumed to a certain extent (see Saña, 1994; Iborra *et al.*, 2003). Since Roman times, however, pork was more popular (King, 2001) although whether ordinary people regularly consumed it would be unlikely.

Finally, considering the geographical context of Ibiza, genetic factors affecting haemoglobin synthesis should not be ignored (Roberts and Manchester, 1995: 169-171; Malgosa and Campillo, 1991: 1415; Campillo, 2001: 288), especially with regard to the Balearic Islands (see Rihuete, 2003: 171). Genetically inherited forms of anaemia are thalassemia and sickle-cell anaemia. Some of the genetic variants related to these inherited disorders are frequently found in Spanish populations and their genetic origin might be traced back to the Phoenician and Greek influences (Campillo, 2001: 288). Although some anaemia in Ibiza may be related to this, if both populations had similar genetic background, then similar frequencies would probably have been expected between periods.

In relation to sexual dimorphism in CO prevalence, females overall appear to have had lower CO than males. Because the samples sizes were small, future data may be able confirm this pattern. Since stable isotopic values did not seem to show any real differences between males and females (B. Fuller, pers. comm.), the lower prevalence in females may respond to better immune system and buffering against any infections (Stini, 1985; Stodder, 1985; Ortner, 1998: 81-82, 86). These interpretations are limited

because the sex of the immature skeletons was unknown. There might be a bias in mortality for children of a certain sex or gender.

No clear specific synergistic factors were identified. A variety of factors could have caused anaemia in Ibiza. Nutritional inadequacy does not seem to be a convincing factor. Stable isotopic analysis has revealed a homogeneous diet in approximately 45 Punic rural individuals studied (Márquez-Grant *et al.*, 2003), both a similar diet for those with and without lesions. Some malnutrition might have taken place in Period 2 where agricultural surplus seems to have been non-existent. This malnutrition would be present within a wider context of poverty, poor sanitation, possible plagues, droughts and bad harvests. In addition, perhaps due to this poverty, iron reserves in the infant may have been depleted potentially as a result of poor health status of the mother during pregnancy.

In Period 2, could a 'catch 22' mechanism have worsened the economic situation? If CO can be regarded as reflecting anaemic conditions then a larger percentage of the population would experience fatigue, weakness, dizziness and cognitive problems, would this have affected economic productivity in Period 2 adversely? Only when larger samples can be studied and CO seems highly prevalent in the population, might it be possible to make any inferences relating to this issue.

Some factors such as working with animals, trade and population density might have accounted for frequencies of CO in the Punic period, but the better nutritional

status of the population would result in a better ability to resist disease (Gilbert, 1985: 342).

3.3 Stature

3.3.1 Factors influencing stature

Longitudinal growth can serve as an indicator of health and of the well being of a population, determined as a result of heredity, environmental and socio-economic factors influencing nutrition, illness, hygiene, housing conditions and psychological stress (Acheson, 1960; Comas, 1960; Gracey, 1987: 163-164; Bogin, 1988a, 1988b; Tanner, 1988; Eveleth and Tanner, 1990; Lampl and Johnston, 1996; King and Ulijaszek, 1999; Humphrey, 2000a, 2000b; Moffatt, 2003). Growth may also be affected by exercise and workload (Frary and Johnson, 2000), although not all studies support this (e.g. Yamanaka and Ashworth, 2002). Although typical growth studies of past populations evaluate long bone growth relative to dental development (Gracey, 1987; Humphrey, 2000a, 2000b), the state of preservation and disarticulated nature of the Ibizan assemblages only allows for examination of adult stature.

Stature can serve as a reasonable indicator of childhood health conditions. Even though stature has a strong genetic component, environmental factors such as nutrition and disease play a significant role. Changes in stature over time can be explained by environmental factors such as nutrition, health, climate, altitude, social and economic status, culture, and migrations (Shapiro, 1939; Comas, 1960; Angel, 1984; Ulijaszek, 1998, 2001). The ultimate size and shape that a child will attain in adulthood will be the

result of the interaction of these factors occurring during the growth period (Eveleth and Tanner, 1990).

3.3.2 The role of stature in inferring the health status of past populations

Stature can be a good indicator of nutritional status. Taller people tend to have had better nutrition than shorter individuals (Komlos, 1993). Where protein-energy malnutrition is present, stunting will occur (e.g. see Yamanaka and Ashworth, 2002; Adelakan, 2003). Not all individuals with short stature will be associated with impoverished living conditions during growth, but in archaeological populations the proportion of stunted individuals due to unfavourable environmental circumstances is more likely (Humphrey and King, 2000: 41).

Socio-economic circumstances do not have a direct effect on stature, but they do on disease and nutrition (e.g. food cost and supply) and this will affect growth (Komlos, 1993; Pádez. 2002). Although short-stature individuals may be better adapted in situations where food is scarce (Goodman, 1991), greater stature, however, seems to be associated with reduced coronary heart disease and longevity (Gunnell *et al.*, 2001, 2003; Davey Smith *et al.*, 2000; Pádez, 2002: 39; Kemkes-Grottenthaler, 2005).

With regards to the hypothesis, it was expected that average stature in Period 1 would be higher than that in Period 2, both for male and female individuals.

3.3.3 Methodological advantages and limitations

Stature estimation has the advantage that where subadult remains are not well preserved, adult long bones can be used to infer about health and nutritional status during growth. A setback is that complete long bone preservation is not always the case in many assemblages.

The stature estimated from long bones will only be an approximation of the real stature during life. Even in life, stature can vary according to age (Trotter and Gleser, 1951) and pathological conditions such as spinal deformities. The stature computed from long bones provided the maximum potential stature that an individual could have achieved with regard to his or her skeleton.

3.3.4 Materials and methods

Due to the state of preservation and the commingled and disarticulated nature of most of the Ibizan skeletal assemblages[74], the estimation of stature was based on long bone lengths rather than other skeletal elements[75].

Various long bones from Ibiza provided measurements for stature estimation. However, the sample was limited to a few bones due to a number of factors. Firstly,

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[74] In future excavations it would be worth documenting the length of an articulated skeleton *in situ*. At the same time, long bone lengths could also be documented in the field because they may fragment once lifted from the ground.

[75] For instance, the 'anatomical method' (Fully and Pineau, 1960) requires a mostly complete skeleton, taking into account other bones such as the vertebrae.

with regard to commingled tombs or contexts with various individuals, it was necessary to ensure, for statistical purposes, that each bone employed represented a different individual. This was achieved by taking the most repeated bone element (e.g. left humerii). When a similar number of different bone elements were available, for instance five left radii and five left tibiae, then the lower limb bones were selected. The femur and tibia appear to be the most accurate for computing stature (Trotter and Gleser, 1952). Secondly, although longitudinal growth ceases before epiphyseal union (Parfitt, 2002), only bones with complete epiphyseal fusion were selected. This ensured that the measurement represented the maximum longitudinal growth of the bone. The precise age of the adult skeleton was not required because age does not affect long bone length. Thirdly, only bones that could be positively sexed were employed. Except for the Punic site *Via Romana, 28-30* (VR28) and some skeletons from the Late Antiquity-Early Byzantine site *S'Hort des Llimoners* (HLL) which were sexed from pelvic and skull traits, the remainder of the disarticulated and commingled skeletal assemblages were sexed by employing sex discrimination functions for long bone dimensions. Only bones of known sex were employed[76]. In addition, complete fibulae could not be considered because the methods chosen for stature estimation did not include formulae applicable to this bone. This bone has also proved unreliable in some studies (see Constandse-Westermann *et al.*, 1985). Finally, only well-preserved bones were considered. Unfortunately, bone fragmentation and preservation dramatically reduced

[76] In some case the results were ambiguous. This ambiguity was the result of bones that provided some measurements that were characteristically female and others that were typically male. Also, ambiguity was present when there were discrepancies between the result from one sexing technique (Alemán *et al.*, 1997) and the other (*Fordisc 2.0* by Ousley and Jantz, 1996). This omission may have caused some bias in the results because it meant that only the gracile bones (female) and the robust bones (male) were included. Excluding the ambiguous bones may have meant excluding the tallest females and the shortest males.

the number of stature estimates. In the Punic site VR47 no complete bones were available. Elements with pathology such as trauma or severe joint abnormalities were also excluded since these pathologies are not related to longitudinal growth during childhood.

In total, the sample consisted of 45 long bones, representing 12 Punic individuals and 21 individuals from Late Antiquity-Early Byzantine period[77]. Each bone was measured with a standard osteometric board to the nearest millimetre. Maximum length was estimated for all bones. The tibia, however, was measured in two different ways when possible: a) from the intercondylar eminences (or tibial spine) to the distal malleolus (maximum length); and b) from the lateral condyle to the distal malleolus (total length). These two measurements were taken because they were required by different methods. For some individual skeletons, left and right sides of the same bone were available for stature estimation. When a bone was bilaterally present, a mean measurement was calculated. If a skeleton provided several complete bones (e.g. HLL.902), a stature for each bone was computed and then a mean stature was calculated. Although some investigators (e.g. Trotter and Gleser, 1952) may argue that in these cases only the femora and tibia should be used if available; others (e.g. Zakrzewski *et al.*, 2003) calculate the mean from all the long bones.

[77] The number of individuals employed for stature computation may vary according to the method used. For instance, in the method devised by Pearson (1898) there are no formulae applicable to the length of the ulna.

All the bones employed and their measurements are presented in Table 3.3.1 below. Bone measurements from the Punic rural sample of *Can Marines* were obtained from Gómez's (1989) published data. The tibia measurements included in Table 3.3.1 were calculated from the lateral condyle to the distal malleolus (total length). No maximum lengths for the tibia were possible due to *post-mortem* erosion of the tibial spine.

Table 3.3.1. Bones from Ibiza employed in the computation of stature.

PUNIC SAMPLE[1]				
Site/Skeleton	**Sex**	**Bone**	**Side**	**Length (cm)**
PM01/UE66	M	Humerus	L R	31.9 32.8
PM01/UE66	M	Humerus	R	31.0
PM01/UE66	M	Humerus	L R	33.1 34.1
PM01/UE66	M	Humerus	R	30.1
VR28/311	M	Femur	R	44.0
PCHN-H7	M	Tibia	L	36.5[+]
PCHN-H7	M	Tibia	L	35.3[+]
CM	M	Femur	R	45.6
CM	M	Femur	R	42.0
PM01/62	F	Tibia	R	31.8[+]
VR28/1108	F	Femur	L	43.8
CM	F	Radius	L	23.3
LATE ANTIQUITY-EARLY BYZANTINE SAMPLE				
Site/Skeleton	**Sex**	**Bone**	**Side**	**Length (cm)**
AR33-I-A	M	Humerus	L	31.0
AR33-I-A	M	Humerus	L	30.5
AR33-D	M	Humerus	R[*]	30.4
AR33-E	M	Humerus	L	28.9
AR33-L	M	Humerus	L	33.5
HLL201.2	M	Femur	L	46.0
HLL203.1	M	Femur Humerus	L L	46.5 32.1
HLL203.2	M	Femur	L	43.9
HLL809.5	M	Femur Femur Humerus Radius	R L R R	43.0 43.1 31.5 24.3
HLL817	M	Radius	L	22.3
HLL818.2	M	Radius	L	24.2
HLL902	M	Femur Femur Tibia Ulna	R L L R	39.1 39.0 32.3 23.7
HLL902.2	M	Humerus	L	27.4
AR33-I	F	Humerus	L	29.7
AR33-L	F	Humerus	L	29.6
HLL405.3	F	Tibia	L	37.4
HLL405.5	F	Femur	L	40.1
HLL609.5	F	Ulna	L	23.8
HLL801.3	F	Femur	L	40.2
HLL819	F	Femur Radius Humerus	R R R	43.0 23.0 30.3
HLL903	F	Femur Radius	R R	37.8 19.0

[1]The site codes are: PM01 = *Puig des Molins*, VR28 = *Via Romana, 28-30*, PCHN = *Ses Païsses de Cala d'Hort*, CM = *Can Marines* (data obtained from Gómez, 1989), HLL = *S'Hort des Llimoners*, AR33 = *Carrer Aragó, 33*. Sex codes: M = male, F = female; Side codes: L = left, R = right. * This right humerus represents a different individual to those represented by the left humerii, since it was already paired with a fragmented left humerus not included above. [+] = total length of tibia.

From the above table it can be observed that a variety of bones were considered. Some authors have argued that employing different types of bones may reduce accuracy. Trotter (1970: 82) indicated that when an inferior long bone is available, upper limb bones should not be used as they are less correlated with stature. Brothwell and Zakrzewski (2004: 33) also agreed that lower limbs bones should be preferred as they provide statures with smaller standard errors. Waldron (1998) suggests that only the femur should be used because it is the most accurate indicator of stature. However, the femur and the tibia provided similar stature estimates in a study of 60 European Neolithic skeletons (Formicola and Franceschi, 1996). In a Mesolithic sample, the proximal bones of upper and lower limbs, the humerus and the femur respectively, were better predictors of stature than forearm and leg bones (Constandse-Westermann *et al.*, 1985). In fact, a study of 686 subjects from various world populations found that there was no conclusive evidence to indicate that lower limb bones were better predictors of height than those of the upper limbs (Porter, 1999). Regardless of whether a bone belonged to the upper or lower limb, faced with a small sample size for Ibiza, as many bones as possible were employed in order to increase the sample size.

Moreover, whether one bone is more reliable than another depends on the physical constitution of the population. Limb proportions are influenced by the environment and, in particular, they are correlated with temperature (Freckleton *et al.*, 2003; Ruff, 2002: 11). Mammals adapted to the cold generally have smaller and shorter limbs than those in warmer climates. This is known as Allen's rule (1877). In humans, 'tropical groups' such as Africans and Australian aborigines have a longer tibia

relatively to the femur compared to Europeans and Eskimos, (Ruff, 1993). Food supply, however, may also exert a selective pressure on body size (Freckleton *et al.*, 2003: 824). As a result of these different body plans and variations in the ratio of long bone length to stature, population-specific formulae are necessary (Ubelaker, 1999: 61).

Unfortunately, the average body proportions in earlier populations from Ibiza are unknown, primarily because of the lack of completely preserved articulated skeletons. The only inferences that could be made on limb proportions were on a few Late Antiquity-Early Byzantine skeletons. The indices that could be calculated were the humero-femoral index, the brachial index and the crural index. The definitions and formulae of these different indices can be found in the relevant literature (e.g. Bass, 1995; Schwartz, 1995; also see du Souich, 2003). These indices respectively reflect the length of the humerus relative to the femur, the length of the radius relative to the humerus and the length of the tibia relative to the femur. The higher the index, the longer the upper limb compared to the lower limb, the longer the forearm compared to the upper arm and the longer the lower leg compared to the thigh. The only calculations available from the Ibizan material are presented in Table 3.3.2. These skeletons come from the site *S'Hort des Llimoners* (HLL) except for case CL13/CIII, a Roman skeleton from *Eivissa* studied by Gómez (1989) and for which indices were calculated here.

Table 3.3.2. The few indices obtained from Ibizan skeletons.

Skeleton	Sex	Humero-femoral	Brachial	Crural
HLL.203.1	M	69.0	-	-
HLL.809.5	M	73.1	77.1	-
HLL.902	M	-	-	82.7
HLL.819	F	70.4	75.9	-
CL-13/CIII	M	73.9	-	80.1

Although this is an extremely reduced sample, the values can, nevertheless, be compared with those computed by Robins and Shute (1986: 316, Table 1) on Egyptian Naqada skeletons and from the data of Trotter and Gleser (1952, 1958) on 'Blacks' (Afro-Americans). The humero-femoral index of HLL203.1 is similar but slightly lower than the 71.0 obtained from the Naqada sample and the 70.6 and 70.5 calculated from the male samples in the work of Trotter and Gleser published in 1952 and 1958 respectively. Skeleton HLL809.5 reveals a higher humero-femoral value indicating relatively longer humerus but a slightly lower value than that in Robins and Shute (1986: 317, Table 2). With regard to the radio-humeral or brachial index, 77.1 for this skeleton is a slightly lower index than the 78.8 from Naqada and the 78.3 and 78.0 from the Trotter and Gleser data of 1952 and 1958 respectively. Skeletons HLL902 and HLL819 provide identical results to the Egyptian indices and the American 'Black' indices. The crural index value of 82.7 in skeleton HLL902 is identical to that obtained from the Naqada male skeletons and slightly higher to the 81.7 given by Trotter and Gleser's (1952) data. The female skeleton HLL819 also has an identical humero-femoral index to the American sample (Trotter and Gleser, 1952) and very similar to the 70.1 of Naqada's female sample. The female skeleton HLL819, with a brachial

index of 75.9 is slightly lower too to the Naqada 78.1 and the 76.7 obtained from Trotter and Gleser (1952, 1977). The data derived from long bone measurements of CL-13/CIII provide higher humero-femoral values but lower crural values.

Although it is difficult to reach any obvious conclusion from the present data and the reference data employed, it does seem clear that some indexes are identical and similar to many of those provided by the Egyptian and the American sample of sub-Saharan ancestry. Body proportions may be similar, partly due to genetics and immigration, partly perhaps due to climate. Future studies and larger samples should contribute to this issue.

In reality, a computed stature is unlikely to be identical to the real height of the individual during life. With this in mind and for the purpose of comparing the health status and growth of two populations, raw long bone lengths alone could be employed instead. In this study, only male humerii and male femora raw long bone lengths were available for comparisons between periods. The number of repeated female bones was insufficient for any comparisons to be made. Because of this insufficient sample size, computed statures from any available bones had to be used in order to compare between sexes and between periods.

Difficulties were encountered when deciding what formulae to use in the computation of stature from long bones. No opportunities have yet been present to devise a method for past Ibizan populations. In the European literature, there are

discrepancies between authors. Pearson's (1898) formulae are often used in southern Europe (Formicola, 1993: 352). Formicola (1993) estimated stature from several European Neolithic samples and concluded that the formulae of Pearson (1898), Olivier *et al.* (1978) as well as Trotter and Gleser's (1952, 1958) equations for 'Blacks' were reliable for a range between 154 cm and 179 cm. Olivier's formulae provided the most acceptable estimates for very tall individuals. Other authors have provided stature estimations for specific populations, such as those for Portugal by Mendonça (2000) although only the humerus and the femur are considered.

Lalueza (1998) tested three methods of stature estimation employing data from Spanish populations. He concluded that the method devised by Pearson was the most accurate indicator, followed by the formulae of Manouvrier (1893). His analysis demonstrated that the most unreliable results were given by the methods of Trotter and Gleser (1952, 1958) for 'Whites'. Du Souich (2003: 15), however, has commented that Pearson's method provides underestimations. This underestimation may be a result of the French sample of short to medium stature individuals employed by Pearson. Therefore, it would not be adequate when applied to taller individuals (Dupertius and Hadden, 1951). It would be incorrect to assume *a priori* that the Ibizan population was short on average. In addition, the data on limb proportions might suggest a body plan similar to 'tropical' human groups.

With these considerations and suggestions in mind, the most appropriate methods were selected. Pearson (1898) himself indicated that his formulae must not be

taken as final. He also stated that the sample he had used might have a socio-economic bias and that caution must be given if applying his formulae to other populations. Despite these remarks, several authors (e.g. Formicola, 1993; Lalueza, 1998) in southern Europe have concluded that Pearson's method is suitable. It has also been widely used in Spain and therefore it is a standardised method in which comparisons can be made with other Spanish populations.

In addition, a second method was employed bearing in mind that Africans or people with sub-Saharan ancestry might have been present in Ibiza. Although Pearson's method was appropriate, it was thought worthy to explore Robins and Shute's (1986) formulae in view of the body proportions obtained from the Late Antiquity-Early Byzantine samples. This method was based on modifications of Trotter and Gleser's (1952, 1958) equations for 'Black' individuals, which were found to have errors especially with regard to the tibia formulae (see also Jantz *et al.*, 1994). These modified formulae have been applied to Egyptian populations because these populations seem to have an average body proportion typical of a tropical climate (Robins and Shute, 1983; Zakrzewski, 2003; Zakrzewski *et al.*, 2003). This 'tropical' body plan has long forearms compared to the upper arms, and long legs compared to the thighs.

Estimated long bone lengths from fragmentary remains (e.g. Steele and McKern, 1969; Steele, 1970; Jacobs, 1992) were not employed because the measurements involve a certain degree of subjectivity with regard to different landmarks in the bone, and therefore there is increased potential for error.

Data were introduced into a 'Microsoft Excel' spreadsheet, which included site code, bone, sex, length in centimetres and stature as estimated from the selected methods. Data were imported from 'Excel' to SPSS 13.0 where statistical analyses were performed. The differences between periods in average statures were tested to see if they were statistically significant. A non-parametric Mann-Whitney *U*-test was employed for these analyses.

Differences in average stature between males and females were tested for statistical significance since there might be differences between the sexes with regard to nutritional stresses (Gray and Wolfe, 1980; Neves and Costa, 1998: 279). When the difference between the sexes was significant, the percentage of dimorphism was calculated by subtracting the male mean stature from the female stature, the result multiplied by 100 and then divided by the male mean stature (see Zakrzewski, 2003: 225).

3.3.5 Results

The computed adult statures are show in Table 3.3.3 after applying the formulae of Pearson (1898) and Robins and Shute (1986). Overall, the former provides lower estimates than the latter. The heights are given in centimetres and are shown to the nearest 0.1 cm.

Table 3.3.3. Computed statures for the Ibizan material*.

PUNIC SAMPLE						
Site/Skeleton	**Sex**	**Bone**	**Side**	**Length (cm)**	**Pearson**	**Robins and Shute**
PM01/UE66	M	Humerus	L R	31.9 32.8	162.9 165.5 X = 164.2	167.3 168.9 X = 168.1
PM01/UE66	M	Humerus	R	31.0	160.3	164.7
PM01/UE66	M	Humerus	L R	33.1 34.1	166.4 169.3 X = 167.8	170.8 173.6 X = 172.2
PM01/UE66	M	Humerus	R	30.1	157.7	162.1
VR28/311	M	Femur	R	44.0	164.0	164.6
PCHN-H7	M	Tibia	L	36.5+	165.3	-
PCHN-H7	M	Tibia	L	35.3+	162.5	-
CM	M	Femur	R	45.6	167.0	167.9
CM	M	Femur	R	42.0	160.2	160.4
PM01/62	F	Tibia	R	31.8+	149.5	150.4
VR28/1108	F	Femur	L	43.8	158.0	159.6
CM	F	Radius	L	23.3	158.1	158.4
LATE ANTIQUITY-EARLY BYZANTINE SAMPLE						
Site/Skeleton	**Sex**	**Bone**	**Side**	**Length (cm)**	**Pearson**	**Robins and Shute**
AR33-I-A	M	Humerus	L	31.0	160.3	164.7
AR33-I-A	M	Humerus	L	30.5	158.9	163.3
AR33-D	M	Humerus	R*	30.4	158.6	163.0
AR33-E	M	Humerus	L	28.9	154.2	158.7
AR33-L	M	Humerus	L	33.5	167.5	171.9
HLL.201.2	M	Femur	L	46.0	167.7	168.8
HLL.203.1	M	Femur Humerus	L L	46.5 32.1	168.7 163.5 X = 166.1	169.8 167.9 X = 168.8
HLL.203.2	M	Femur	L	43.9	163.8	164.4
HLL.809.5	M	Femur Femur Humerus Radius	R L R R	43.0 43.1 31.5 24.3	162.1 162.3 161.8 165.4 X = 162.9	162.5 162.7 166.1 166.1 X = 164.3
HLL.817	M	Radius	L	22.3	158.8	159.4
HLL.818.2	M	Radius	L	24.2	165.0	165.7
HLL.902	M	Femur Femur Tibia Ulna	R L L R	39.1 39.0 32.3+ 23.7	154.8 154.6 155.4 - X = 154.9	154.3 154.1 - 158.6 X = 155.6
HLL.902.2	M	Humerus	L	27.4	149.9	154.3
AR33-I	F	Humerus	L	29.7	153.2	156.1
AR33-L	F	Humerus	L	29.6	152.9	155.8
HLL.405.3	F	Tibia	L	37.4+	162.7	164.3
HLL.405.5	F	Femur	L	40.1	150.8	151.0
HLL.609.5	F	Ulna	L	23.8	-	154.2
HLL.801.3	F	Femur	L	40.2	151.0	151.2
HLL.819	F	Femur Radius Humerus	R R R	43.0 23.0 30.3	156.4 158.1 154.9 X = 156.4	157.7 157.3 157.9 X = 157.6
HLL.903	F	Femur Radius	R R	37.8 19.0	146.3 144.7 X = 145.5	145.7 142.6 X = 144.1

*Codes: X = average. Remaining codes are provided in Table 3.3.1.

The data presented for each period above could be summarised into an average stature, a range, the number of individuals employed and the standard deviation (Table 3.3.4).

Table 3.3.4. Summary data for stature*.

Period	Sex	N	Method	Average stature	Minimum	Maximum	S.D.
Punic	M	9	Pearson	163.2	157.7	167.0	3.35
	F	3	Pearson	155.2	149.5	158.1	4.93
	M	7	R & S	165.7	160.4	172.2	4.00
	F	3	R & S	156.1	150.4	159.6	5.00
Late Antiquity-Early Byzantine	M	13	Pearson	160.6	149.9	167.7	5.48
	F	7	Pearson	153.2	145.5	162.7	5.33
	M	13	R & S	163.3	154.3	171.9	5.17
	F	8	R & S	154.2	144.1	164.3	5.86

* Codes: M = male, F = female; N = number of individuals in the sample; Pearson = Pearson (1898); R & S = Robins and Shute (1986); N = number of individuals; S.D. = standard deviation.

These results are discussed in more detail below. Firstly, the results from the Punic period are explained and sexual dimorphism is explored. The same process is undertaken for the data from Late Antiquity-Early Byzantine period. Finally, both periods are compared.

3.3.5.1 The Punic sample

Punic female stature ranged from 149.5 cm to 158.1 cm according to Pearson's (1898) method, and from 150.4 to 159.6 cm according to the formulae of Robins and

Shute (1986). The former method revealed an average stature of 155.2 cm, while the second method, an average of 156.1 cm.

According to Pearson's method, Punic male stature ranged from 157.7 cm to 167 cm with an average of 163.2 cm. The statures after applying Robins and Shute's (1986) method ranged from 160.4 to 172.2 with an average of 165.7 cm.

Overall males were larger than females. The results obtained from the first method (Pearson, 1898) showed that Punic males were 8 cm taller than Punic females. With the second method (Robins and Shute, 1986), the difference between the sexes was 9.6 cm. A Mann-Whitney *U*-test revealed that the differences were statistically significant. The results obtained with Pearson's method were significant at the 0.05 probability level ($U = 2$; $p = 0.033$). The results from the second method were also significant ($U = 0$; $p = 0.017$). Since these differences between the sexes were significant, the degree of sexual dimorphism was calculated. Overall, men were 4.9% larger than females according to the results obtained from the first method, and 5.7% according to the results from the second method. Therefore, taking the results from each method, females accounted for 95.1% and 94.3% of male stature respectively.

3.3.5.2 The Late Antiquity-Early Byzantine sample

In the sample from Period 2, female stature ranged from 145.5 cm to 162.7 cm according to Pearson's (1898) method, and from 144.1 to 164.3 cm according to the

formulae of Robins and Shute (1986). The former method revealed an average female stature of 153.2 cm, while the second method provided an average of 154.2 cm.

According to Pearson's method, Late Antiquity-Early Byzantine males had a stature that ranged from 149.9 cm to 167.7 cm, with an average of 160.6 cm. The statures after applying Robins and Shute's (1986) method ranged from 154.3 to 171.9 cm, with an average stature of 163.3 cm.

Overall, males were larger than females. The results obtained from the first method (Pearson, 1898) showed that Period 2 males were 7.4 cm taller than Period 2 females. With the second method (Robins and Shute, 1986), the difference between the sexes was 9.1 cm. The results obtained with Pearson's method were significant ($U = 14$; $p = 0.013$), and with regard to the second method, highly significant ($U = 12.5$; $p = 0.004$). Since these differences between the sexes were statistically significant, the degree of sexual dimorphism was calculated. Overall, men were 4.6% larger than females according to the results obtained from the first method, and 5.5% according to the results from the second method. Therefore, taking the results from each method, females accounted for 95.4% and 94.5% of male stature respectively.

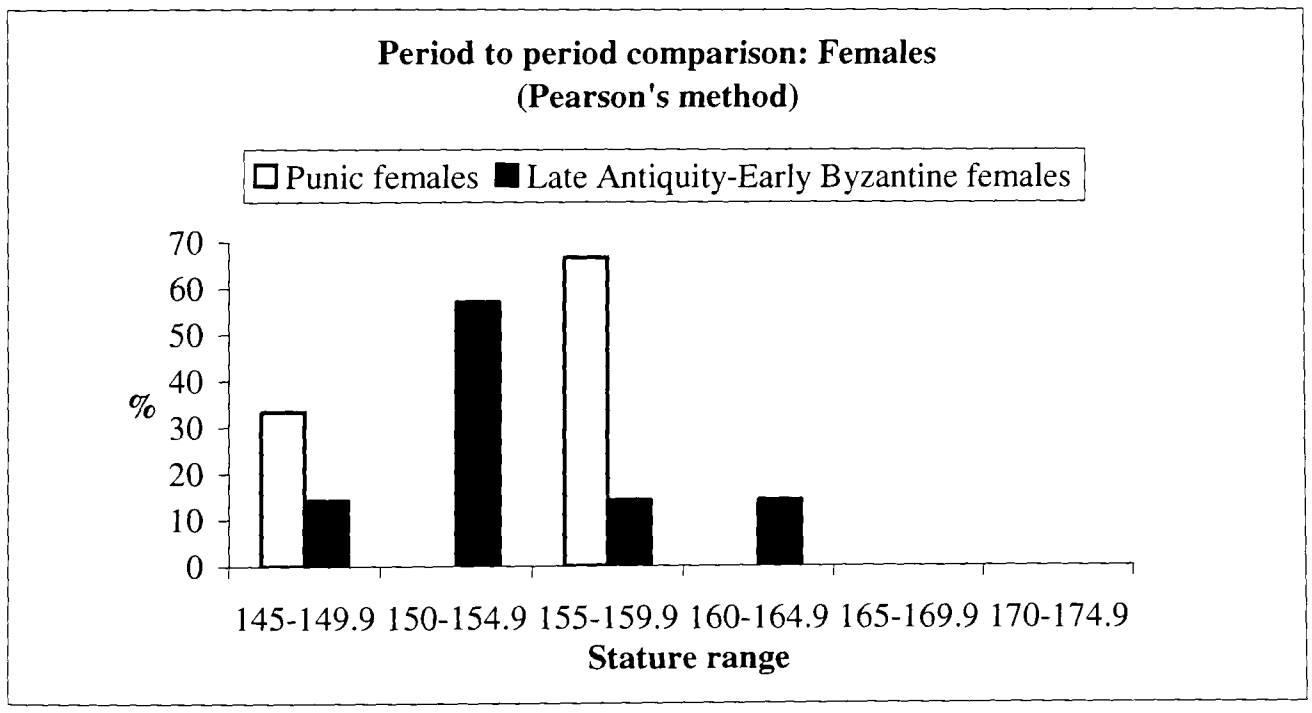
3.3.5.3 Comparisons between Period 1 and Period 2

From the summary information in table 3.3.4, both sexes show smaller average statures in Period 2. The shortest females and the shortest males also appear in Period 2.

However, at the same time the tallest female also appears in Period 2. Both periods have similar statures for the tallest individuals.

In general, there does seem to be a trend of taller individuals in Period 1 than in Period 2. In addition, as shown in figures 3.3.1 and 3.3.2 there is a higher percentage of taller individuals in Period 1 than in Period 2, according to the computations undertaken with the Pearson (1898) method. The first figure illustrates the data from the female sample, and the second figure that of the male sample.

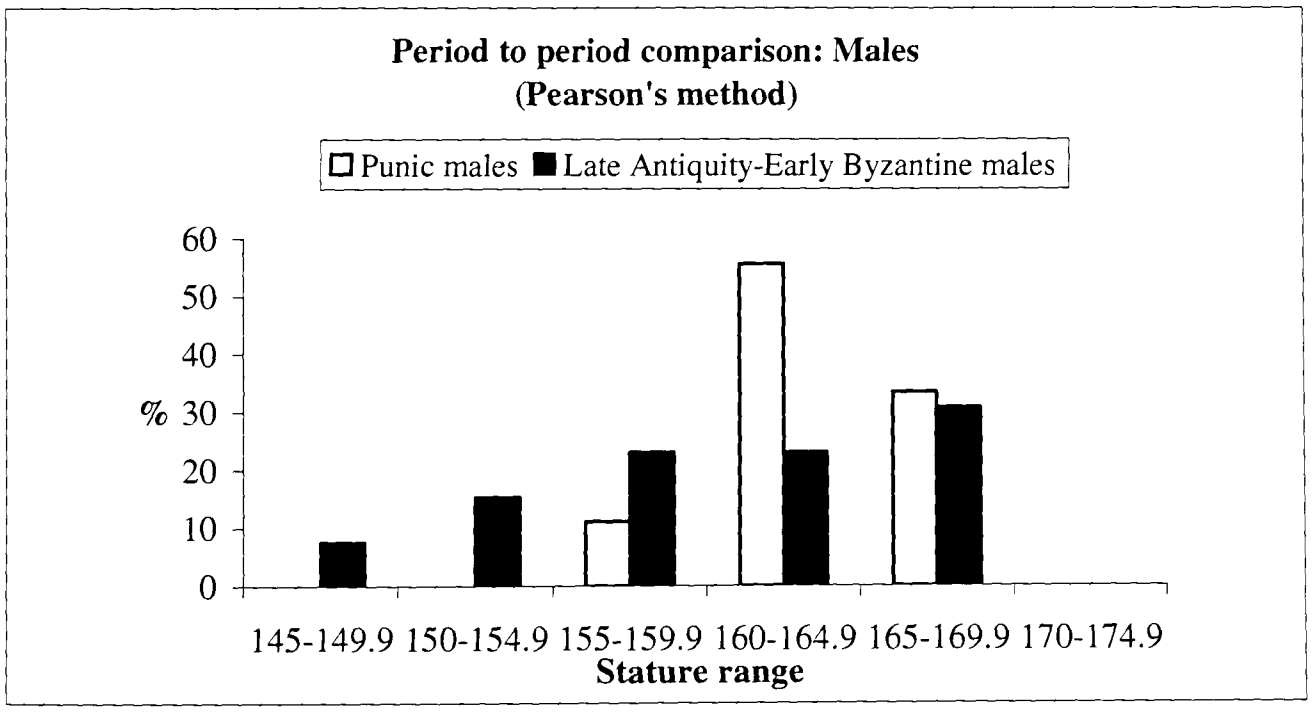
Figure 3.3.1. Period 1 (n = 3) compared to Period 2 (n = 7). Percentage of female individuals in each stature category.



Although the average female was taller in Period 1 than in Period 2 the sample size for Period 1 was too small (n = 3) to make any inferences. Furthermore, the difference was not statistically significant on examination of the results obtained by Pearson's method (U = 8; p = 0.569) or by Robins and Shute's method (U = 9; p = 0.540).

More clearly, the male sample seems to show a larger percentage of taller males in Period 1 than in Period 2 (Figure 3.3.2).

Figure 3.3.2. Period 1 (n = 9) compared to Period 2 (n = 13). Percentage of male individuals in each stature category.



However, the results were neither significant with the data obtained from the methods by Pearson (U = 42.5; p = 0.285) or by Robins and Shute (U = 33.5; p = 0.341).

Maximum raw bone lengths of male humerii and femora (Tables 3.3.5 and 3.3.6) were also tested for statistical significance. Lengths are given in millimetres. When left and right bones were present, a mean was calculated from both.

Table 3.3.5. Raw humerii lengths*.

HUMERII					
PUNIC SAMPLE			**LATE ANTIQUITY-EARLY BYZANTINE SAMPLE**		
Site/skeleton	**Side**	**Length (mm)**	**Site/skeleton**	**Side**	**Length (mm)**
PM01/UE66	L + R	323.5	AR33-I-A	L	310
PM01/UE66	R	310	AR33-I-A	L	305
PM01/UE66	L + R	336	AR33-D	R	304
PM01/UE66	R	301	AR33-E	L	289
CM[1]	L + R	338.5	AR33-L	L	335
-	-	-	HLL203.1	L	321
-	-	-	HLL809.5	R	315
-	-	-	HLL902.2	L	274
AVERAGE	321.8		AVERAGE	306.6	
S.D.	16.24		S.D.	18.81	

*Site and side codes were given earlier in Table 3.3.1; S.D. = standard deviation. [1]It was unclear from the report whether these two bones (L = 343 mm; R = 334 mm) belonged to the same individual or to different individuals, but the mean from both was calculated.

The average provides longer bone lengths for males in Period 1 than in Period 2. However, a Mann-Whitney *U*-test proved that these differences were not significant ($U = 10.5$; $p = 0.164$).

Femora lengths (Table 3.3.6) also produced a longer average length in Period 1 but the results were not significant either ($U = 17$; $p = 0.661$).

Table 3.3.6. Raw femora lengths*.

FEMORA					
PUNIC SAMPLE			LATE ANTIQUITY-EARLY BYZANTINE SAMPLE		
Site/skeleton	**Side**	**Length (mm)**	**Site/skeleton**	**Side**	**Length (mm)**
PM01/UE62	L	463	AR33-H	L + R	407
VR28/311	R	440	AR33-K	L	406.5
CM	R	456	AR33-M	R	477
CM	R	420	HLL201.2	L	460
PCHN-H7[1]	L + R	435	HLL203.1	L	465
-			HLL2032	L	439
-	-	-	HLL809.5	L + R	430.5
-	-	-	HLL902.2	L + R	390.5
AVERAGE	442.8		AVERAGE	434.4	
S.D.	17.10		S.D.	31.39	

*Site and side codes were given earlier in Table 3.3.1; S.D. = standard deviation. [1]It was unclear from the report whether these two bones (L = 426 mm; R = 444 mm) belonged to the same individual or to different individuals, the mean from both was calculated.

The average estimated humerus and femur length was markedly longer in the Punic sample. The absence of statistically significant differences was not conclusive. Power analysis[78] revealed that sample size alone could account for the lack of any statistically significant results. These analyses revealed that a minimum sample size of 19 humerii and 115 femora per group would be necessary to detect significant differences at the 0.05 fixed level, with an 80% of probability.

3.3.5.4 Summary of key findings

Period 1 displayed higher mean statures than Period 2. This applied to both male and female stature data, as well as the male raw long bone lengths. The shortest

[78] I would like to thank Luís Cabo, Director, Forensic Anthropology Laboratory (Mercyhurst College, PA, USA) for his guidance with this analysis. Software employed: Piface v 1.61, by Russell V. Lenth. http://www.stat.uiowa.edu/~rlenth/Power/index.html

individuals came from Period 2. This increased stature in Period 1 would be expected in view of the hypothesis. However, these differences were not statistically significant.

Overall, males were larger than females. Differences between the sexes were statistically significant. Sexual dimorphism in stature was similar, although just slightly greater in Period 1 than in Period 2. Both periods showed similar proportion in height of females relative to their male counterparts.

3.3.6 Discussion

No statistical differences were found between average stature in Period 1 and that of Period 2. These results are surprising because diet and nutrition were different between periods (Chapter 6) and socio-economic circumstances were too. Two possible explanations are presented. The first is that the sample sizes were too small to reveal any significant differences. Unfortunately, stature could only be estimated for 12% (13/108) of the adult Punic assemblage, while in the Late Antiquity-Early Byzantine sample, only 20.7% (22/106) of adult individuals were measured. The second explanation is that living conditions and nutrition during growth were similar in both periods due to similar socio-economic circumstances.

It is also possible that this similarity is due to a common ancestry or genetic background. There seems to be a strong association between body stature dimorphism and phylogeny (Holden and Mace, 1999; Gustafsson and Lindenfors, 2004). Until

larger samples are obtained from Ibiza, these results must remain provisional. Whether similar health was present in both periods will be investigated when all data are pooled in Chapter 7.

The sex differences in Ibiza were lower, compared to the 12-13 cm difference in the modern populations considered by Bogin (1999) (Zakrzewski, 2003: 226). Gray and Wolfe (1980) found that nutritional status could influence sexual dimorphism. In her study on Egyptian populations, Zakrzewski (2003) interprets lower sexual dimorphism due to an egalitarian society, where both sexes have equal access to food.

It is possible that lower sexual dimorphism was due to nutritional stress where males, who are more susceptible to nutritional stress (see Stini, 1985), did not reach their maximum potential stature. Differences in diet, nutrition, food production and different access to food between boys and girls could also explain this difference (see Holden and Mace, 1999).

4 CHAPTER FOUR – NON-SPECIFIC INFECTIONS (PERIOSTITIS)

According to Roberts and colleagues (1998: 94), 'the presence of lesions associated with infectious diseases provides useful data on how people adapted to the environments in which they lived'. Infectious diseases that affect the skeleton are relatively uncommon (Ortner, 1998: 89). In general, these bone lesions are a result of bacterial rather than viral infection (Roberts and Manchester, 1995: 125). The former would involve a chronic invasive process; the latter would be acute and resolve rapidly or be fatal before any skeletal response has taken place (Roberts and Manchester, 1995: 125; Roberts et al., 1998: 94). A variety of factors determine whether the infection leads to death or not. These include the individual's age of onset, nutritional status, immune response, treatment efficacy, biocultural conditions and the point of entry of the infection (Ortner, 1998: 79-80).

Periostitis, a non-specific infection, is often employed in studies of past population health (e.g. Steckel *et al.*, 2002). This chapter assesses the incidence of periostitis in the Ibizan skeletal remains[79], which is appropriate in view of the commingled bone assemblages[80].

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[79] Dental caries was studied in this thesis. This is also a pathological process related to infection. However, because this pathology was used here in an attempt to reconstruct dietary patterns, the results of such analysis have been included in Chapter 6, which deals with dietary reconstruction.

[80] Generally, fairly complete preservation of an individual skeleton is necessary in order to identify specific infections such as leprosy or syphilis (see Roberts and Manchester, 1995).

4.1 Definition

Periostitis is a non-specific lesion characterised by inflammation of the periosteum. This basic inflammatory response may be caused by bacterial infection via the blood stream or even by direct traumatic injury to the bone (Ortner and Putschar, 1981). Periostitis is uncommon as a disease in itself, usually forming part of a disease syndrome such as syphilis (Ortner and Putschar, 1981: 129, 131). The condition can be primary, which is localised or unevenly distributed and caused by infection or trauma; and it can also be secondary, appearing alongside with or as part of another disease (Schwartz, 1995: 231).

4.2 Aetiology

Apart from direct trauma, the point of entry of bacterial infection may be via the skin, the respiratory system or the digestive tract (Campillo, 2001: 141). The presence of periostitis can be associated with malnutrition, poor sanitation and general living conditions. Keenleyside (1998) indicates that Eskimos and Aleuts would be at risk of acquiring zoonitic and parasitic infections through contact with animals and their waste. Human migrations and high population density can facilitate the spread of infections. Individuals with an inadequate diet, poor sanitation and who lived in unfavourable environmental circumstances would be more vulnerable to infection and early death than others (Larsen, 1997a).

4.3 Methodological advantages and limitations

As stated above, contributing factors for the presence of these lesions are unfavourable environmental conditions such as malnutrition and poor sanitation. Therefore, when comparing populations, the sample with the lowest frequency of periostitis can be regarded as having had better health.

However, interpreting the presence as well as the absence of periostitis is complex and not straightforward (see Wood *et al.*, 1992; Ortner, 1998). Abnormal periosteal lesions in bones appear as a result of chronic conditions, indicating that the person survived the condition long enough for it to reach the bone. The absence of periostitis in a skeleton could mean at least three possibilities: a) the individual was healthy, living in an adequate environment without being threatened or exposed to noxious bacteria; b) the individual had an infection but was healthy enough to cope with it before it reached the bone stage of involvement; c) the individual was infected but he or she died rapidly due to frailty or lower immunity before any bone involvement had taken place.

Differentiating active from inactive (healed) lesions is important (Wood *et al.*, 1992: 352-353). The frailest individuals that have acquired an infection are likely to die immediately, revealing no lesion on the bone. Frail individuals may show a bone response to the infection but die while the disease was active. Lastly, a healed (inactive)

lesion indicating survival of a disease process earlier in life would reflect individuals whose frailty is low (Wood *et al.*, 1992: 352).

Another potential problem is that not all periosteal bone formation is restricted to infections (Ortner and Putschar, 1981: 129). In addition, active and fit people such as athletes commonly suffer from 'shin pain' or medial tibia stress syndrome, which can result in periostitis when the usual bone remodelling process becomes maladaptive (e.g. see Couture and Karlson, 2002). Large chronic skin ulcers, in particular those caused by venous stasis may also produce periostitis (Ortner and Putschar, 1981: 131; Pinheiro *et al.*, 2004).

4.4 Materials and methods

Although all bones were examined in the Ibizan material, only the tibia was analysed here. The tibia is the bone most commonly affected in archaeological assemblages (Ortner and Putschar, 1981: 132). Although the reason for this predominance is unclear, it is probably related to its position in the body, its closeness to the skin and to the physiological characteristics of the leg (Steinbock, 1976; Larsen, 1997a). Additionally, the tibia is surrounded by less muscle mass and fat compared to other bones and is less protected and more susceptible to direct trauma (Ortner and Putschar, 1981: 132).

Observations of tibiae diaphyses were made macroscopically under normal light conditions. Roberts and Manchester (1995: 129-130) state that periostitis is characterised by fine pitting, longitudinal striation and plaque-like new bone formation on the original cortical surface (Ill. 4.1). Subadult and adult bones were examined, although individuals under one year of age were excluded because of the difficulties in differentiating pathological changes from normal growth remodelling in this age group.

Pathological conditions were recorded as absent, present or unobservable. Where a lesion was observed or suspected, it was described in detail: state of healing, location, severity and extent, alongside the age and sex of the individual if possible. Lesions were also classified as active (woven bone), healed (lamellar bone) or having a 'mixed' reaction (woven and lamellar). All lesions were photographed. Attempts were made to identify whether lesions belonged to primary or secondary periostitis, for instance by noting any trauma on the bone.

Prevalence of periostitis was calculated by dividing the number of tibiae with the lesions by the number of tibiae observed. In order to quantify for count frequency in the Ibizan group, at least 75% of the bone surface had to be available for observation. Additionally, examination had to make allowance for the fragmentary and incomplete nature of most tibiae in the skeletal assemblages. It would have been unreliable, for instance, to record absence of periostitis in an individual if only the proximal third of the tibia was present. Thus, a more reliable and conservative way of calculating the incidence of periostitis was by segment count rather than by bone count. Thus, the

diaphysis was considered as having three segments: proximal, middle and distal thirds. In order to include a segment in the count, over 75% completeness and bone surface preservation was required.

Individual tibia count was also available in more a reduced sample. In this case, for a reliable representation of a tibia and to ensure that different tibiae were being counted, at least two thirds of the bone had to be present and available for observation.

4.5 Results

Punic (Period 1) samples were first examined in relation to their rural and urban context. These were later pooled together and compared to the Late Antiquity-Early Byzantine (Period 2) data.

4.5.1 The Punic sample

The overall Period 1 sample consisted of a limited number (n = 13) of subadult tibial segments and a total of 166 adult segments. Punic rural and urban periostitis frequencies are summarised in Table 4.1. Unfortunately, no bones surfaces from VR47 were sufficiently well preserved to allow pathological examination and therefore this site was not represented in the summary table. When possible, divisions were made between male and female tibiae[81], although more specific divisions according to adult

[81] Long bones in this disarticulated sample were sexed according to long bone dimensions as stated in Chapter 2. Apart from some urban articulated material, the isolated tibiae in disarticulated contexts were

age were not possible due to the disarticulated nature of most assemblages. Differences were compared for statistical significance.

Table 4.1. Frequencies of segments with periostitis in the Punic sample*.

PERIOD 1	Punic rural		Punic urban		Statistical results	
	n/N	%	n/N	%	Chi-square	Significance
<15	1/4	25.0	0/9	0	1.94	n.s.
>15 Women	12/15	80.0	3/13	23.0	2.92	n.s.
>15 Men	6/13	46.1	0/9	0	3.62	n.s.
Total ADULTS[1]	28/136	20.5	6/30	20.0	-	-

*Codes: n = segments with periostitis; N = segments observed; % = percentage of segments with periostitis (n/N x 100); [1] = total adult count includes those female and male segments but also those unsexed; n.s. = not statistically significant.

Between rural and urban contexts the overall results were similar with 20% of adult segments having periostitis. Between the sexes, no significant differences were found between the female groups and between the male groups, although frequencies were higher in the rural series. No significant differences were found between rural females and rural males ($x^2 = 0.775$; $p = 0.379$) and between urban females and males ($x^2 = 1.92$; $p = 0.166$).

The overall Punic subadult sample with periostitis accounted for 7.6% (1/13) of the observed segments, while in the total adult sample 20.4% (34/166) segments were affected. Amongst the total adult sample, 53.5% (15/28) segments with periostitis belonged to females compared to 27.2% (6/22) in the male sample. The remaining

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sexed by employing as many of the following measurements as possible: proximal and distal epiphyseal breadths, antero-posterior and medio-lateral measurements at the level of the nutrient foramen. Observations were also made on general robusticity.

11.2% (13/116) could not be assigned a sex. Differences between subadults and adults were not significant ($x^2 = 0.929$; $p = 0.335$) and neither were the overall frequencies for Punic males compared to Punic females ($x^2 = 1.47$; $p = 0.225$).

The percentage of segments with active, inactive or 'mixed' periostitis was also calculated (Table 4.2).

Table 4.2. Active and inactive lesions in the Punic sample*.

PERIOD 1	N	n	Non-survivors			Survivors
			Active	Mixed	Total Active + Mixed	Healed
Subadult	13	1	1	0	1	0
Subadult total	13	1	100%	0%	100%	0%
Rural female	15	12	3	3	6	6
Rural male	13	6	0	0	0	6
Rural adult (sex unknown)	108	10	0	1	1	9
Total rural adults	136	28	3	4	7	21
Urban female	13	3	0	3	3	0
Urban male	9	0	-	-	-	-
Urban adult (sex unknown)	8	3	0	0	-	3
Total urban adults	30	6	0	3	3	3
Adult total	166	34	3	7	10	24
			8.8%	20.5%	29.4%	70.5%

*Codes: N = segments observed; n = segments with periostitis.

Due to the reduced sample, only the proportion of active and inactive lesions in rural and urban adults was compared. Rural adults had a lower frequency (25%) of active lesions than urban adults (50%). These differences were significant ($x^2 = 5.70$; $p = 0.017$).

Frequencies of periostitis were also calculated for complete (>two thirds) tibiae (Table 4.3). The number of affected tibiae in rural areas was compared to that from the urban area. Right and left sides were pooled. A higher frequency was found in the rural sample but the difference was not significant ($x^2 = 1.27$; $p = 0.260$) when compared to the urban.

Table 4.3. Tibiae affected in the Punic period.

PUNIC RURAL	**Right**	**Left**
Subadult	-	-
Adult male	2/2	0/2
Adult female	2/2	2/3
Adult sex unknown	0/2	0/1
Total adult rural tibiae	50% (6/12)	
PUNIC URBAN	**Right**	**Left**
Subadult	0/2	0/2
Adult male	0/2	0/2
Adult female	0/3	1/1
Adult sex unknown	1/1	0/2
Total adult urban tibiae	18.1% (2/11)	
Total adult Punic tibiae	**34.7% (8/23)**	

Out of the six tibiae affected in the rural area, four displayed healed lesions (two male, two female) and only two (female tibiae) displayed active periostitis. A female tibiae displayed active periostitis in the urban context, while the tibia with healed lesions could not be ascribed to a sex. The overall frequency of healed lesions in tibiae in the Punic sample was 63.5% (5/8).

4.5.2 The Late Antiquity-Early Byzantine period

The results obtained from the Period 2 sample are summarised in Table 4.4. Overall 147 subadult and 245 adult tibia segments were analysed.

Table 4.4. Frequencies of segments with periostitis in the Late Antiquity-Early Byzantine sample*.

PERIOD 2	n/N	%
<15	23/147	15.6
Unknown age	7/21	33.3
>15 Women	0/46	0
>15 Men	35/109	32.1
Total ADULTS[1]	62/245	25.3

*Codes: n = segments with periostitis; N = segments observed; % = percentage of segments with periostitis (n/N x 100); [1] = total adult count includes those female and male segments but also those unsexed.

In the subadult sample, 15.6% (23/147) of segments displayed periostitis. The prevalence in the total adult sample accounted for 25.3% (62/245). Differences between subadult and adult prevalence rates were not significant ($x^2 = 3.32$; $p = 0.068$). There was a striking absence of periostitis in female bones (0/46). In the male sample, 32.1% (35/109) of segments displayed periosteal lesions. The difference between the sexes was extremely significant ($x^2 = 13.7$; $p = 0.000$).

The percentage of segments with active, inactive or 'mixed' periostitis was also calculated (Table 4.5). Subadults had more active lesions than adults, although this

difference was not significant ($x^2 = 1.18$; $p = 0.278$). In the total adult count, active and inactive lesions were equally distributed.

Table 4.5. Active and inactive lesions in the Late Antiquity-Early Byzantine sample*.

PERIOD 2	N	n	Non-survivors			Survivors
			Active	Mixed	Total Active + Mixed	Healed
Subadult	147	23	17	6	23	0
Subadult total	147	23	73.9%	26.0%	100%	0%
Unknown age	21	7	1	0	1	6
Female	46	0	-	-	-	-
Male	109	35	9	5	14	21
Adult (sex unknown)	90	27	17	0	17	10
Adult total	245	62	26	5	31	31
			41.9%	8%	50%	50%

*Codes: N = segments observed; n = segments with periostitis.

Subadult and adult rates were also compared pooling all left and right tibiae (Table 4.6.). The difference was not significant ($x^2 = 1.95$; $p = 0.163$). Female and male results were also compared and a significantly lower level of periostitis was found in females ($x^2 = 5.18$; $p = 0.023$).

Table 4.6. Tibia affected in the Late Antiquity-Early Byzantine period.

PERIOD 2	Right	Left
Subadult	3/20	4/26
Total subadult tibiae	**15.2% (7/46)**	
Age unknown	1/3	1/4
Adult male	6/17	7/20
Adult female	0/5	0/11
Adult sex unknown	6/13	4/13
Total adult tibiae	**29.1% (23/79)**	

All the affected subadult tibiae (n = 7) presented active lesions. In the two tibiae from individuals of unknown age, only healed lesions were present. In adults, active lesions were present in 12 tibiae. Amongst male tibiae, five exhibited active lesions and eight exhibited healed lesions. The remaining sample (n = 10), individuals of unknown sex, comprised seven tibiae with active and three with healed lesions.

4.5.3 Comparison between Period 1 and Period 2

The Punic rural and urban samples were pooled into one group (Period 1) and compared to data from Period 2. Figure 4.1 illustrates the percentage of segments with periostitis in each period.

Figure 4.1. Periostitis in Period 1 and Period 2 according to segment count.

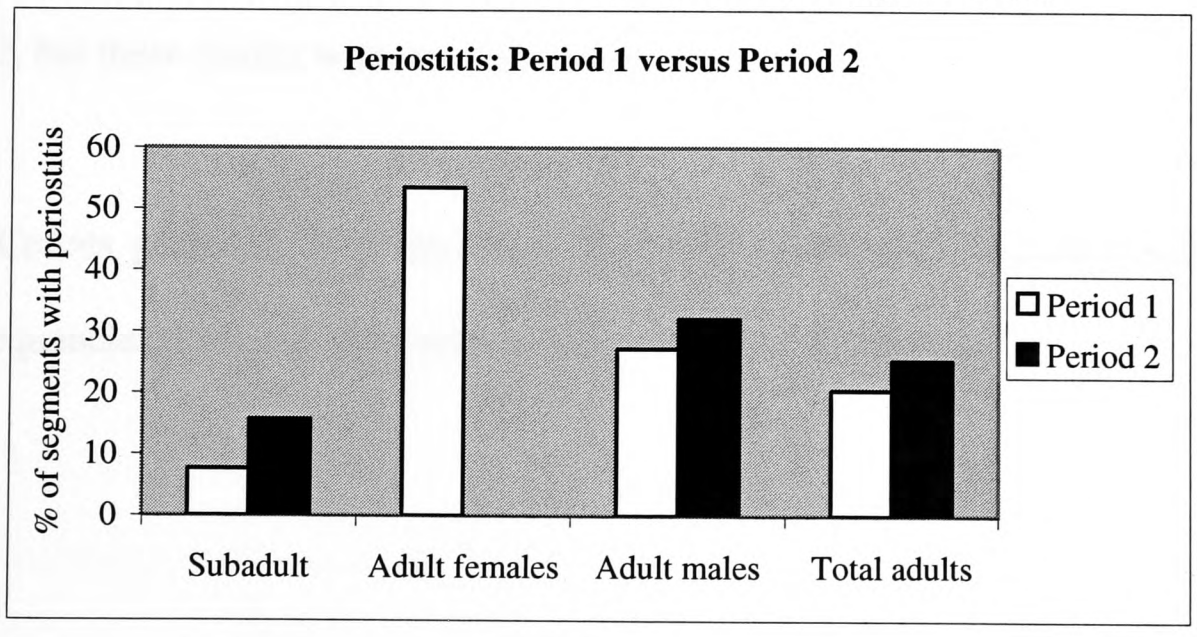

Table 4.7 includes the statistical results. With regard to active lesions, all subadult segments displayed active periostitis.

Table 4.7. Overall frequencies of periostitis in each period according to segment count*.

Group	Period 1		Period 2		Statistical results	
	n/N	%	n/N	%	Chi-square	Significance
Total SUBADULTS	1/13	7.6	23/147	15.6	0.465	n.s.
Total ADULTS[1]	34/166	20.4	62/245	25.3	0.806	n.s.
>15 Women	15/28	53.5	0/46	0	19.3	P<0.001
>15 Men	6/22	27.2	35/109	32.1	0.107	n.s.
Active lesions (adults)	10/34	29.4	31/62	50	1.60	n.s.

*Codes: n = segments with periostitis; N = segments observed; % = percentage of segments with periostitis (n/N x 100); [1] = total adult count includes female and male segments and also those unsexed; n.s. = not statistically significant;

There were no significant differences between Period 1 and Period 2 except between the female groups where periostitis was more prevalent in Period 1. Apart from the female group, presence of periostitis in adults and subadults was higher in Period 2, but these results were not significant.

Counts per adult tibia were also compared (Table 4.7), including female and male frequencies. Left and right sides were pooled for this analysis.

Table 4.7. Overall frequencies of periostitis according to number of tibia observed*.

Group	Period 1		Period 2		Statistical results	
	n/N	%	n/N	%	Chi-square	Significance
Total ADULTS[1]	8/23	34.7	23/79	29.1	0.141	n.s.
>15 Women	5/9	55.5	0/16	0	6.86	$p<0.05$
>15 Men	2/8	25.0	13/37	35.1	0.160	n.s.
Active lesions	5/8	63.5	12/23	52.1	0.072	n.s.

*Codes: n = segments with periostitis; N = segments observed; % = percentage of segments with periostitis (n/N x 100); n.s. = not statistically significant; [1] = total adult count includes female, male and also those unsexed tibiae.

The frequencies in Period 1, by contrast, were higher when tibiae counts were considered. Significant differences were only revealed when the female groups were compared.

4.5.4 Summary of key findings

Sample size for the Punic period was limited. Nevertheless, rates were low in adults (c.20%) with regard to segment count and higher when complete tibia counts were considered. There were no significant differences between rural and urban contexts.

The subadult series displayed more lesions than the adult, and the adult males had lower frequencies than females, but these differences were not statistically significant. When active and inactive lesions were compared, the urban sample displayed a significantly higher number of active lesions than the rural one.

When the Period 1 segment data were compared to the Period 2 data, all groups except the female samples were lower in the former period although differences did not appear to be significant. Females in Period 1 had significantly higher rates of periostitis than Period 2 females where there was a striking absence of lesions.

When complete tibiae counts were considered, significant differences were also observed between the female groups from both periods. Lastly, there were more adult tibiae in Period 1 with periostitis (except males) and more tibiae with active lesions when compared to Period 2, but no statistically significant differences were found.

From these findings it was difficult to observe clear trends. The general impression was that periostitis was present in high frequencies in some groups (e.g. Punic females) but that differences in rural and urban contexts were not significant. In general, the majority of comparisons, except for females, indicated a lower frequency of periostitis in Period 1 than in Period 2 but these differences were not significant.

4.5.5 A note on primary and secondary periostitis

Largely due to the commingled characteristic of the assemblages, it was not possible to determine whether periostitis was primary or secondary in the samples studied. A total of four tibiae (10 infected segments) had possible signs of trauma[82].

[82] These were not obvious fractures, but possible cases of trauma inferred from areas in the diaphysis with a 'bulge' or abnormal bone formation. The tibiae affected were: VR28/402 (Period 1) tibia of unknown age with active periostitis and possible healed fracture in the middle third of the shaft; HLL801.1 (Period 2), right tibia with active periostitis and possible healed fracture in the middle third of

One Punic bone had ostemyelitis (for a definition see Ortner and Putschar, 1981; Roberts and Manchester, 1995). This case was present in the left tibia of an urban female skeleton, VR28/1108, with an age-at-death between 30-50 years. The complete diaphysis was affected and the state of healing was incomplete at the time of death, with a mix of active and inactive bone lesions[83].

No further information was available to indicate the type of periostitis or to demonstrate whether it was focal, generalised or systemic (see Campillo, 2001: 182-184). No evidence was found of any specific infections such as tuberculosis, leprosy or syphilis in the Ibizan example although a quantifiable study should be undertaken in future. No changes such as *caries sicca* or nasal resorption were found in any of the skulls examined.

Interestingly, the AR33 assemblage included several cases of rib periostitis. Amongst all the rib fragments observed from Ibiza, these active lesions found on the visceral surface of the ribs are at present the only cases that have been reported. Such lesions appear with high probability in individuals that suffered from pulmonary tuberculosis or from other chronic pulmonary infections (Kelley and Micozzi, 1984; Pfeiffer, 1991; Roberts *et al.*, 1994; Lambert, 2002). No clear association between these

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the shaft; AR33-B (Period 2) adult male right tibia showing possible trauma also in the middle third; AR33-L (Period 2) complete left tibia diaphysis with active periostitis and showing possible trauma also in the middle third of the shaft.

[83] The right tibia was not available for observation. No other bones from this skeleton had any periosteal reaction, including ribs and other long bones. This is the only case of ostemyelitis reported among the published and unpublished works in Ibiza.

lesions and any tibial periostitis could be undertaken due to the disarticulated nature of the sample.

4.6 Discussion

In view of these findings, a number of points are briefly discussed in association with periostitis.

4.6.1 Discussion: the Punic period

Similar frequencies (c.20%) of segments with periostitis from Punic rural and urban environments suggest that both contexts were exposed to similar levels of pathogens. Equal frequencies may indicate similar lifestyles, but could also reflect different living conditions that resulted in similar rates of periostitis.

As a general rule, city walls abruptly separated town and country (Foss, 2002: 73). The literature on Ibiza suggests that a pattern of craft and industrial activity in the town was present, with free men devoted to commercial and maritime activity, compared to agricultural production in the rural environment perhaps undertaken by slaves (Julbe and Pascuet, 2001).

Both rural and urban Punic populations possibly worked and lived alongside other animals. Animals can pass diseases onto humans (a process called zoonoses).

Animals can also act as intermediaries acting as part of a pathogenic cycle whereby the pathogen hosted is transmitted to humans but the animal is not affected by illness (Campillo, 2001: 142). While animals in rural areas would be reared and fed, in urban contexts they would have been slaughtered and skinned (Schofield and Vince, 2003). A study from a prehistoric site in Majorca found evidence for herding of goats and/or sheep, pigs and cows (Castro-Martínez *et al.*, 2003). Similar fauna has been found in Punic contexts from Ibiza (Saña, 1994; Morales, 2003).

The Punic rural site may have been associated with a higher level of pathogens, linked with land use and cultivation. The Punic urban context, however, may have also been exposed to a high level of pathogens because of high population density, immigration and the introduction of animal stock via the harbour. Traders, merchants, sailors and armies might have brought their own diseases into the urban environment (McNeill, 1976: 107-108; Grmek, 1989: 89; Kiple, 1996: 25).

4.6.2 Discussion: Comparisons between Period 1 and Period 2

Apart from the female group, no significant differences in the overall incidence of periostitis were found between the Period 1 and the Period 2 samples. Interestingly, similarities were also found in the other palaeopathological parameters employed such as LEH and stature (Chapter 3). This was unexpected in view of the hypothesis.

With regard to physiological stress, the present picture might suggest that social, economic, cultural and ecological conditions in both periods were not significantly different. Archaeological and documentary evidence, however, does suggest that differences were present in a number of contexts such as the social, environmental and economic ones.

Females had lower frequencies than males, a difference proved significant at least in the Period 2 sample. Females in Period 1 had a higher prevalence of periostitis than females in Period 2. With regard to the first premise that females were less affected than males, it is possible that a more effective immune system (Stini, 1985) came into play. Division of labour according to gender may have also played a role, so that one group might have been involved in activities posing a high risk of zoonoses (e.g. butchers).

There is no straightforward interpretation of the absence of periostitis (Wood *et al.*, 1992; see Section 1.8.5.2). The absence of periostitis in Period 2 females may indicate either that no infection was present or that the females examined died before the disease resulted in a bone response. Furthermore, comparisons between periods were complex because it was unknown how many individuals had infections. Among those infected in the once living population, it was also unknown how many would have succumbed to earlier death and how many were able to survive before the disease affected the skeleton. Certainly in cases with active lesions, the individuals survived

long enough for that disease to reach the chronic stage, but were not fit enough to survive the stress.

The non-specificity of these lesions does not allow a more precise interpretation of their aetiology. However, in the samples considered, the presence of periostitis does indicate that environmental circumstances did affect the health and physiology of individuals.

A number of factors could explain the presence of periostitis in Period 1, including a combination of high population density and overcrowding (see Manchester, 1992), intensified trade, animal domestication, and landscape transformation. Fortified urban centres are often associated with overcrowding (Grmek, 1989: 90). Horden and Purcell (2000: 382) have pointed out that due to the mobility of people it is theoretically impossible to talk about the population of a city: some will only live there for a few days such as slaves or pilgrims. Nevertheless, the estimated presence of thousands of Punic tombs at *Puig des Molins* and the evidence for tomb reuse likely reflects an overpopulated town with over a thousand inhabitants (Mañá, 1948: 206; Tarradell and Font; 1975: 246-248; Costa, 1994). Even in areas where density was low, however, overcrowding could still have been present if a large family shared the same household, thus facilitating the spread of infections (Polunin, 1967).

In addition, industrial activity would have involved the active participation of potters and probably glassmakers who would have had particular diseases related to

these occupations. For instance, those involved in activities associated with the inhalation of gases or working in closed confinements would have suffered from lung problems (Thackrah, 1832; Oliver, 1908; see also Kilpatrick, 2001), while butchers would have been at an increase risk of zoonoses (Ellis and Symington, 1994: 545).

Contaminated water may have also been a contributing factor in spreading infection. Although water systems are known from the Punic and Late Antiquity-Early Byzantine periods (Ramon, 1995a, 2002), there is no current knowledge as to the quality of the water at that time.

The key finding of this analysis with regards to periostitis is that economic development was not enough to ensure the health of the population. Chapter 7 integrates this data with the remaining pathological indicators and a more precise picture of the health of the inhabitants and its relation to prosperity is considered.

5 CHAPTER FIVE - PATTERNS OF ACTIVITY

In order to further investigate the lifestyles of past peoples of Ibiza, two pathological conditions were examined: trauma and joint disease. In conjunction with other parameters, analysis of trauma and osteoarthritis has been employed to reconstruct the health status of past populations (Goodman *et al.*, 1988; Steckel *et al.*, 2002). Added to these were two skeletal modifications that are environmentally, rather than genetically, induced: *torus auditivus* and squatting facets. These indicators may provide clues as to the activity patterns of the Ibizan populations.

5.1 Trauma

Trauma is one of the most common pathological conditions that exist in skeletal assemblages (Ortner and Putschar, 1981: 55). Trauma may be defined as an injury to living tissue caused by a force or mechanism extrinsic to the body (Lovell, 1997b). In general, trauma can affect the bone by partial or complete break, abnormal displacement or dislocation, a disruption in the nerve and/or blood supply, and an artificially induced abnormal bone shape (Ortner and Putschar, 1981: 55). The various types of trauma include fractures, dislocations, amputations and weapon wounds (Ortner and Putschar, 1981; Lovell, 1997b). Amongst the different kinds, fractures are the most easily diagnosed and the most common among the different kinds of skeletal trauma (Jurmain, 2001: 13). This thesis focused on analysis of fractures (Ill. 5.1).

5.1.1 Definition

A fracture is characterised by a disruption of the normal bone structure, either representing a complete or incomplete break in the continuity of the bone (Grauer and Roberts, 1996: 532). These lesions are usually accompanied by lacerations that have affected soft tissues and blood vessels (Ubelaker, 1999: 109). The process of repair or healing and the complications involved with fractures (e.g. infections) can be found in the relevant palaeopathological literature (e.g. Ortner and Putschar, 1981; Roberts and Manchester, 1995; Ubelaker, 1999: 109). Basically, during repair a callus forms around the site of the injury. Between 16 days and 30 days after the fracture, bone callus

bridges the separate fragments, while permanent bone is slowly replaced in a process that might last years (Ubelaker, 1999: 109).

Fractures can also be grouped into different types, such as transverse or oblique. These can inform about the type and direction of the force and whether they acted directly or indirectly on the fractures site. The anatomical position of lesions can add further clues as to possible aetiologies (e.g. see Berger and Trinkaus, 1995).

5.1.2 Fracture analysis in skeletal populations

Patterns in fracture analysis (see Lovejoy and Heiple, 1981) have provided insights into a society's general level of social tension (e.g. Alvrus, 1999; Lessa and Mendonça de Souza, 2004) and even the type of subsistence economy (Neves *et al.*, 1999). For instance, a period of political and economic change in historic Nubia was correlated with an increase in fracture rates amongst the population (Van Gerven *et al.*, 1995). Further information obtained from fracture analysis relates to knowledge on medical care and treatment (Grauer and Roberts, 1996), interpersonal violence (Judd, 2004), aspects of warfare including fighting styles and weapons used (Strouhal and Jungwirth, 1980), and even behavioural patterns among archaic *Homo* species (Berger and Trinkaus, 1995).

Rather than merely reporting isolated cases of trauma in palaeopathology, the interest lies in investigating how the pattern of trauma has changed over time (Roberts

and Manchester, 1995: 65). The types and distribution of trauma can provide some clues about the lifestyle of the population, their socio-cultural environment and their adaptation to that environment. A high incidence of fractures in the distal forearm, for example, may be a result of frequent falls or even a result of parrying a blow to the head in an act of violence (Ubelaker, 1999: 109; see also Judd, 2004). Spiral fractures in the lower leg may be caused by accidents during ploughing and, therefore, may be more common in rural populations rather than in urban contexts (Molleson, 1992; Farwell and Molleson, 1993).

Although fracture prevalence is greatly influenced by culture, other factors cannot be ignored such as physiological ones (e.g. senile osteoporosis) that could make a person more vulnerable to fractures (Ortner and Putschar, 1981: 55).

5.1.3 Methodological advantages and limitations

Several potential problems are present when analysing trauma. With regard to *peri-mortem* injuries, these may not be easily distinguished from *post-mortem* fractures (see Etxeberria and Carnicero, 1998). With regard to healed fractures, it is usually not possible to identify the age the individual had when that trauma occurred. Childhood fractures may completely remodel and are thus not clearly evident in adult skeletons. Nevertheless, Glencross and Stuart-Macadam (2000) have stated that every age group has a 'typical' type of injury.

A further problem with regard particularly to subadult skeletons is that trauma recognition may pass unnoticed due to *post-mortem* fragmentation and preservation (Glencross and Stuart-Macadam, 2000; Grauer and Roberts, 1996: 532). In addition, only bone involvement is observed and many individuals may have suffered soft-tissue wounds, but the prevalence of these injuries cannot be accurately estimated (Jurmain, 2001: 20).

Finally, when two populations are compared, the frequency of trauma may be higher in one sample as opposed to the other. A high prevalence might not necessarily indicate a negative or unfavourable environment. Indeed, higher frequencies may be a result of higher life expectancy in one population, which in turn provides a higher probability of acquiring injury. Therefore, mortality profiles should be taken into account whenever possible. The longer a person lives the higher the probability of acquiring more skeletal lesions (Wood *et al.*, 1992). Injury recidivists must also be taken into account (Judd, 2002a).

5.1.4 Materials and methods

Amongst all the possible types of trauma, the present study was only confined to healed or partially healed (*ante-mortem*) fractures. In clinical studies, fractures occur more frequently than other types of bone trauma such as dislocations (Judd, 2004: 48). Other types of trauma, however, such as *peri-mortem* trauma, dislocations, *osteochondritis dissecans* (reflecting trauma to the blood supply) or *myositis ossificans*

(resulting from muscle trauma) were only recorded anecdotally. Since these other types are not common in archaeological samples, reports tend to be anecdotal (Jurmain, 2001: 14). These other cases of trauma were stated here if they provided further useful information regarding the hypothesis set up in this thesis.

The diagnosis of a healed fracture was based on the observation of a callus, as well as angular deformity and overlapping. Each case was closely examined macroscopically. No radiological equipment was available but a note was made of those cases that would benefit from this examination in the future.

With every observation, there was an indication to the type of bone, side, age and sex if possible. When a fracture was present, the type of fracture, stage of healing, angulation, overlapping, rotation and other modifications and associated pathologies were recorded (after Ortner and Putschar, 1981; Buikstra and Ubelaker, 1994; Roberts and Manchester, 1995; Lovell, 1997b; Roberts, 2000; Judd, 2002b).

For the present palaeoepidemiological analysis, the following bone elements were examined: humerus, radius, ulna, femur, tibia and fibula. Frequencies were later given for clavicles, metacarpals, metatarsals and phalanges.

Fractures in other skeletal regions such as the skull or the ribs were only reported anecdotally rather than being quantified. The reason for this was the state of fragmentation. With the thousands of cranial fragments available, it was not easy to

establish a calculation between the numbers of cases observed and the number of cases with trauma. In addition, nasal bones, which are susceptible to trauma from violent episodes, were very rarely preserved. Likewise, rib fractures were difficult to quantify because, as a result of the hundreds of incomplete shaft fragments, it was difficult to calculate the number of different ribs that were represented.

Only long bone shafts (diaphyses) were quantifiable since, compared to other skeletal regions (e.g. epiphyses), they were the area of the bone where preservation was better. However, these bones were very often fragmented. This incomplete preservation implied that it would be unwise, for instance, to conclude that from a preserved proximal radius with no trauma, the *whole* bone was unaffected. Trauma might have been present in the distal end of the radius since fractures are susceptible in this area (e.g. Colles' fracture) but this part would have been missing. Thus, comparing *whole* radii count between populations would be misleading. The right approach would be to state that no trauma was present in the proximal third, rather than saying it was absent in the whole bone.

Therefore, following Judd (2002b, 2004), the pathological frequencies were calculated considering each bone as divided into segments: proximal third, middle third and distal third. These segment counts have been successfully applied to archaeological populations (e.g. Judd, 2004). This method is similar to that documented in clinical medicine and serves to locate the position of a fracture (Judd, 2002a: 1257). In order to count a segment as a valid observation, more than 75% of its surface had to be

preserved. This provided a conservative and safe approach and provided more reliability when making comparisons between samples.

The advantages of undertaking such analysis by segment count are many (Judd, 2002a: 1263): it provides an estimate of the bones that are present and their preserved parts; certain segments can be compared (e.g. distal third of the forearm where specific trauma occurs); and it is an appropriate method for the majority of archaeological assemblages including those that have cremated human bone. In addition, it directly illustrates the location of the fracture so that further interpretations can be made. Furthermore, it minimizes any bias that may be present if only complete long bones shafts were considered.

One minor criticism to this method could be that the division between one segment and another or the classification of one fragment into a segment is subjective and based on personal judgement. To resolve this and minimize the error, each segment in incomplete shafts was determined by taking a complete bone of similar dimensions as a comparative reference.

With regard to clavicles, metatarsals, metacarpals and phalanges, an observation (absence, presence) was scored if over 75% of the shaft was available for examination.

Long bone fractures in which the initial trauma was obscured in gross examination by degenerative joint disease or infection were not included in this study

unless there was clear visual evidence for fracture. The number of diaphyseal segments with *ante-mortem* fractures (n), divided by the number of observed segments (N) and multiplied by 100, provided the prevalence rates.

Only individuals over the age of 15 years were considered in detail, an age boundary that is common in other studies of trauma (e.g. Jurmain, 2001). Compared to children, those individuals older than 15 years represent the most active population, which were the main bulk of the working and fighting force. Frequencies of trauma in subadult bones were briefly reported.

5.1.5 Results

Results are first presented for the Punic period, including rural and urban contexts, and later for the Late Antiquity-Early Byzantine period.

5.1.5.1 The Punic rural sample

The total number of segments observed were 666, of which six (0.9%) had evidence of trauma. Table 5.1.1 indicates the prevalence according to each long bone segment (proximal, middle, distal) in the Punic rural sample. Left and right sides were pooled. The side of the bone was irrelevant to the hypothesis. Laterality would only be considered in any relevant discussions with regard to trauma patterns.

Table 5.1.1. Trauma in the Punic rural context*.

PUNIC RURAL	P1/3	P1/3	P1/3	M1/3	M1/3	M1/3	D1/3	D1/3	D1/3	TOTAL		
	n	N	%	n	N	%	n	N	%	n	N	%
Humerus	1	25	4	0	34	0	0	59	0	1	118	0.8
Radius	0	40	0	0	42	0	1	20	5	1	102	0.9
Ulna	0	118	0	0	24	0	1	22	4.5	1	164	0.6
Femur	0	71	0	0	37	0	0	18	0	0	126	0
Tibia	0	13	0	0	97	0	0	19	0	0	129	0
Fibula	0	2	0	0	14	0	3	11	27.2	3	27	11.1

*Codes: P1/3 = proximal third; M1/3 = middle third; D1/3 = distal third; n = number of segments with trauma; N = number of segments observed; % = percentage of segments affected (n/N x 100).

The six cases of trauma in this sample were located in a number of bones. The fracture in the humerus (PCHN-H4) was present in the proximal third and on gross examination appeared to be a spiral fracture. The fractured right radius (PCHN-H10) belonged to a male individual and was a typical case of Colles' fracture (see Galloway, 1999b). A right ulna (PCHN-H10) also had a fracture in the distal third. The remaining three bones, all fibulae, had fractures in the distal third of the shaft: one possibly from a male (PCHN-H7) individual and probably from the left side; another from a right male fibula (PCHN-H7) and the remaining from a left fibula (PCHN-H4) possibly belonging to a male individual (Ill. 5.2). All of these cases had some slight evidence of overlapping of the two fractured ends, as well as some angulation of one end in relation to the normal outline of the bone.

All these fractures had healed. Secondary complications, such as infection or arthritis, were only apparent in two fibulae (PCHN-H7) where some evidence for considerable osteoarthritis seems to have been associated with the fracture.

No femora or tibiae displayed fractures. The highest frequency was found in the distal fibula, followed by the forearm bones (radius and ulna) and finally the humerus. Comparisons between fibulae prevalence rates and the results from these bones were not statistically significant (humerii and fibulae, $x^2 = 3.13$; $p = 0.077$; radii and fibulae, $x^2 = 2.31$; $p = 0.129$; ulnae and fibulae, $x^2 = 2.63$; $p = 0.105$).

5.1.5.2 The Punic urban sample

The Punic urban sample provided only slightly different patterns (Table 5.1.2). The total number of segments observed was 307, five (1.6%) of which displayed traumatic lesions.

Table 5.1.2. Trauma in the Punic urban context*.

PUNIC URBAN	P1/3	P1/3	P1/3	M1/3	M1/3	M1/3	D1/3	D1/3	D1/3	TOTAL		
	n	N	%	n	N	%	n	N	%	n	N	%
Humerus	0	18	0	1	21	4.7	0	30	0	1	69	1.4
Radius	0	18	0	0	21	0	2	19	10.5	2	58	3.4
Ulna	0	19	0	0	12	0	0	16	0	0	47	0
Femur	0	14	0	0	14	0	0	17	0	0	45	0
Tibia	0	9	0	1	10	10	0	9	0	1	28	3.5
Fibula	0	17	0	0	21	0	1	22	4.5	1	60	1.6

*Codes: P1/3 = proximal third; M1/3 = middle third; D1/3 = distal third; n = number of segments with trauma; N = number of segments observed; % = percentage of segments affected (n/N x 100).

Four traumatic lesions were present in the same adult male skeleton (VR28/308). In this individual the lesions seemed to be greenstick fractures, probably occurring during childhood. These lesions were evident in the left humerus, the left radius, the left tibia and the left fibula. All the lesions had been healed, with no overlapping but with some angulation. No further complications (e.g. periostitis) were observed as a result of these lesions.

The remaining fracture came from a left radius belonging to a 30-50 year old male (VR47/U29). The lesion was observed in the distal third, with a 'bulge' occurring medially. The lesion was well healed. No periostitis could be observed due to taphonomic factors. The lesion was oblique, unilateral, with no fracture present on the right radius. It was not typical of a Colles' fracture (see Galloway, 1999b).

No trauma was present in ulnae or in femora. The highest frequency was found in the distal third of the radius (10.5%), followed by the middle third of the tibia (10%), the middle third of the humerus (4.7%) and the distal third of the fibula (4.5%). The radius and tibia showed similar frequencies, as well as the humerus in relation to the fibula. With regard to these rates, no significant differences were found between radii and humerii ($x^2 = 0.410$; $p = 0.522$), radii and fibulae ($x^2 = 0.463$; $p = 0.496$), humerii and tibiae ($x^2 = 0.266$; $p = 0.606$), and tibiae with fibulae ($x^2 = 0.302$; $p = 0.582$).

5.1.5.3 Rural and urban comparisons

No significant differences were found between rural and urban settings. Pooling all segments, differences were not statistically significant ($x^2 = 0.971$; $p = 0.324$) between the rural (0.9%) and the urban (1.6%) context. Comparisons were made in more detail for the ulna, the radius and the fibula since they provided the highest frequencies. With regard to the ulna, frequencies in the rural sample (4.5%) were not significantly ($x^2 = 0.714$; $p = 0.398$) different to the urban (0%). Neither were the differences significant in the distal radius ($x^2 = 0.359$; $p = 0.549$) although the rural sample (5%) showed a lower rate than the urban (10.5%) series. Fracture prevalence rates in the distal fibula, 27.2% in the rural and 4.5% in the urban, were not significantly different either ($x^2 = 2.63$; $p = 0.105$).

5.1.5.4 The total Punic sample

All the Punic data were pooled and later compared to the Late Antiquity-Early Byzantine data. A total of 973 segments were observed and 1.1% of these (n = 11) had fractures (Table 5.1.3.).

Table 5.1.3. Overall trauma results for the Punic period*.

PERIOD 1	P1/3	P1/3	P1/3	M1/3	M1/3	M1/3	D1/3	D1/3	D1/3	TOTAL		
	N	N	%	n	N	%	n	N	%	n	N	%
Humerus	1	43	2.3	1	55	1.8	0	89	0	2	187	1
Radius	0	58	0	0	63	0	3	39	7.6	3	160	1.8
Ulna	0	137	0	0	36	0	1	38	2.6	1	211	0.4
Femur	0	85	0	0	51	0	0	35	0	0	171	0
Tibia	0	22	0	1	107	0.9	0	28	0	1	157	0.6
Fibula	0	19	0	0	35	0	4	33	12.1	4	87	4.5

*Codes: P1/3 = proximal third; M1/3 = middle third; D1/3 = distal third; n = number of segments with trauma; N = number of segments observed; % = percentage of segments affected (n/N x 100).

Only the femur was exempt from any *ante-mortem* fractures. The most affected segments were the distal thirds of the fibula (12.1%), the radius (7.6%) and the ulna (2.6%). When comparing all the segments displaying trauma in the different bones, only the following differences were found to be statistically significant: the distal fibula had significantly higher rates than the middle third of the humerus ($x^2 = 11.4$; $p = 0.001$) and than the middle third of the tibia ($x^2 = 8.09$; $p = 0.004$); and the distal radius had higher rates than the middle third of the tibia ($x^2 = 4.50$; $p = 0.034$). Differences between the distal fibula and the distal ulna ($x^2 = 2.10$; $p = 0.147$), the distal fibula and the distal radius ($x^2 = 0.326$; $p = 0.567$), the distal fibula and the proximal humerus ($x^2 = 2.53$; $p = 0.112$), and the distal radius compared to the distal ulna ($x^2 = 0.903$; $p = 0.342$). Hence, only fibulae had significantly higher frequencies than humerii and tibiae, while radii had more trauma than tibiae. Fractures in upper limb bones in Period 1 (6/549, 1.0%) were similar to the injuries in the lower limb bones (5/415, 1.2%).

Differences between the sexes could be investigated. Sex estimation was based on long bone measurements (see Chapter 2). Many isolated bones, in particular ulnae, did not provide a sex diagnosis. Since samples were small when treated separately according to rural and urban contexts, only overall Punic frequencies were used to compare male bones with female bones (Table 5.1.5). Sexual differences were only present in the humerus, radius, tibia and fibula. Males had more trauma than females who had no trauma. The differences were essentially minimal bearing in mind that the male sample was greater than the female sample and that the number of lesions was not great.

Table 5.1.4. Sexual dimorphism in Punic trauma*.

PERIOD 1	**P1/3 (n/N)**	**M1/3 (n/N)**	**D1/3 (n/N)**	**TOTAL (n/N)**	**(%)**
FEMALE HUMERUS	0/10	0/6	0/18	0/34	0
MALE HUMERUS	0/19	1/15	0/31	1/65	1.5
FEMALE RADIUS	0/2	0/3	0/3	0/8	0
MALE RADIUS	0/9	0/9	2/10	2/28	7.1
FEMALE ULNA	0/3	0/2	0/1	0/6	0
MALE ULNA	0/4	0/3	0/2	0/9	0
FEMALE FEMUR	0/15	0/15	0/11	0/41	0
MALE FEMUR	0/18	0/11	0/11	0/40	0
FEMALE TIBIA	0/4	0/4	0/3	0/11	0
MALE TIBIA	0/10	1/10	0/10	1/30	3.3
FEMALE FIBULA	0/4	0/4	0/9	0/17	0
MALE FIBULA	0/7	0/7	3/13	3/27	11.1

*Codes: P1/3 = proximal third; M1/3 = middle third; D1/3 = distal third; n = number of segments with trauma; N = number of segments observed; % = percentage of segments affected (n/N x 100).

Considering the overall frequencies from counting all segments, no statistical differences were found between the humerii ($x^2 = 0.520$; $p = 0.471$), the radii ($x^2 =$

0.563; p = 0.453), the tibiae (x^2 = 0.363; p = 0.547) and the fibulae (x^2 = 2.77; p = 0.096).

5.1.5.5 The Late Antiquity-Early Byzantine sample

The overall prevalence rate for trauma according to segment count was 1.0% (17/1647) in this period (Table 5.1.5.). The results revealed some different locations compared to the pattern in Period 1.

Table 5.1.5. Overall trauma results for the Late Antiquity-Early Byzantine period*.

PERIOD 2	P1/3	P1/3	P1/3	M1/3	M1/3	M1/3	D1/3	D1/3	D1/3	TOTAL		
	n	N	%	n	N	%	n	N	%	n	N	%
Humerus	0	87	0	1	110	0.9	0	125	0	1	322	0.3
Radius	0	74	0	1	81	1.2	6	79	7.5	7	234	2.9
Ulna	0	77	0	0	77	0	5	63	7.9	5	217	2.3
Femur	0	136	0	0	147	0	0	121	0	0	404	0
Tibia	1	91	1.0	1	108	0.9	0	89	0	2	288	0.6
Fibula	1	55	1.8	1	89	1.1	0	65	0	2	209	0.9

*Codes: P1/3 = proximal third; M1/3 = middle third; D1/3 = distal third; n = number of segments with trauma; N = number of segments observed; % = percentage of segments affected (n/N x 100).

All bones suffered from trauma except for the femur. Variation existed with regard to the distribution of lesions. The most affected segments were the distal ulna and the distal radius, with a prevalence rate of 7.9% and 7.5% respectively. The remaining frequencies were low. One traumatic lesion was present among the humerii, two among the tibiae and fibulae, five among the ulnae and six among the radii.

Affected upper limb bone segments in Period 2 accounted for 1.6% (13/773) compared to the frequency (0.4%) obtained from the lower limb bones (4/901). The difference between upper and lower limb bones in Period 2 was significant ($x^2 = 6.21$; $p = 0.013$).

One male (AR33-F-B) had an injury in the middle third of the right humerus. All fractures in the radii came from five individuals from the site of *S'Hort des LLimoners*: a right element from HLL409 (adult, sex unknown), the left and right elements from HLL815.2 (>50 years, female), the left and right bones from HLL807 (>50 years, sex unknown), and two left radius from tomb HLL801, one clearly ascribed to a possible 30-50 year-old female (HLL801.1) and the other from the disarticulated context in the same tomb. It was noted that at least four of these fractured radii belonged to individuals over 50 years of age.

The original field notes include drawings, further descriptions and photographs. Here, a brief summary of the type of fracture is provided. The radius HLL409 had an oblique well-healed fracture in the distal third, with slight malalignment but no overlapping and no periostitis. The bilateral lesions from skeleton HLL815.2 occurred in the distal third segments and slight posterior angulation was observed. The lesions in HLL807 showed no overlapping and only slight angulation. A distal left radius from HLL801.1 had an oblique healed fracture with posterior angulation, while the remaining left radius revealed a fracture in the middle third, possibly a greenstick fracture resulting in some malalignment towards the mesial side. None of these cases were typical Colles' fractures near the distal epiphysis because they were located higher

up in the shaft (see Ortner and Putschar, 1981; Galloway, 199b). All these fractures were completely healed.

Five ulnae segments had signs of healed *ante-mortem* fractures. The distal third of the left and right ulnae from HLL407 (adult, sex unknown) displayed oblique fractures. A right ulna belonging to HLL202 (20-50 years, male) presented an oblique fracture in the upper part of the distal third. In this case, there was little angulation but evident malalignment and overlapping associated with some shortening of the length of the bone (see Ill. 5.1). No differences in laterality could be observed because the distal third of the left ulna was missing *post-mortem.* None of the radii from this individual had any injuries. A distal third injury was also present in a right ulna (AR33-H) and also in a left ulna (AR33-D). In this latter case, some active periostitis was present in the proximal third, although the association with the traumatic event was unclear.

With regard to adult tibiae, two adult segments were affected. The first case (AR33-B) had a lesion in the middle shaft (Ill. 5.3), characterised by a 'bulge' accompanied by mixed periosteal reaction (active and inactive). The second reported case (AR33-C) appeared to be a well-healed fracture at the proximal third characterised by some abnormal alignment and angulation.

Finally, two fractured fibulae were present: a right fibula (HLL409) with a healed spiral fracture in the middle shaft displaying some malalignment, and a left

fibula (AR33-K) with an injury in the proximal third accompanied with periostitis in that area.

Statistical tests were performed to learn whether the highest rates in the distal ulna (7.9%) and distal radius (7.5%) were significantly different to the rates obtained by other affected segments: the proximal fibula (1.8%), the middle fibula (1.1%) and the proximal tibia (1.0%). While no significant differences were observed between the ulna and the fibula ($x^2 = 2.07$; $p = 0.151$) and the radius and the fibula ($x^2 = 1.99$; $p = 0.158$), significant differences were observed in the remaining comparisons. The higher prevalence in the distal ulna was significantly different to the trauma rates for the middle fibula ($x^2 = 4.13$; $p = 0.042$) and the proximal tibia ($x^2 = 4.25$; $p = 0.039$). The distal radius also had significantly higher rates than the middle fibula ($x^2 = 4.03$; $p = 0.045$) and the proximal tibia ($x^2 = 4.15$; $p = 0.042$).

Differences between the sexes were also calculated (Table 5.1.6).

Table 5.1.6. Sexual dimorphism in Late Antiquity-Early Byzantine trauma*.

PERIOD 1	P1/3 (n/N)	M1/3 (n/N)	D1/3 (n/N)	TOTAL (n/N)	(%)
FEMALE HUMERUS	0/15	0/17	0/21	0/53	0
MALE HUMERUS	1/32	0/39	0/40	1/111	0.9
FEMALE RADIUS	0/15	0/17	3/18	3/50	6.0
MALE RADIUS	0/25	0/27	0/31	0/83	0
FEMALE ULNA	0/12	0/7	0/5	0/24	0
MALE ULNA	0/13	0/10	1/12	1/35	2.8
FEMALE FEMUR	0/33	0/30	0/28	0/91	0
MALE FEMUR	0/60	0/60	0/52	0/172	0
FEMALE TIBIA	0/23	0/26	0/25	0/74	0
MALE TIBIA	0/41	1/48	0/38	1/127	0.7
FEMALE FIBULA	0/12	0/14	0/16	0/42	0
MALE FIBULA	0/17	0/17	0/17	0/51	0

*Codes: P1/3 = proximal third; M1/3 = middle third; D1/3 = distal third; n = number of segments with trauma; N = number of segments observed; % = percentage of segments affected (n/N x 100).

Notable differences between females and males were observed in the radius and ulna. Females had a significantly higher trauma rate in the radius compared to males (x^2 = 3.50; p = 0.029), although in the case of the ulna the difference between sex groups was not significant (x^2 = 0.678; p = 0.410). Thus, similarities were found overall among the sexes except for the radius where females showed a higher prevalence (6%) than males. It is worth noting that at least two fractured radii came from old aged female individuals. This will be taken into account in the discussion.

5.1.5.6 Comparison between Period 1 and Period 2

Overall rates between Period 1 and Period 2 were identical (c.1%) according to segment count. Rates were also similar in upper limb bones (1%). Although Punic

lower limb bones exhibited slightly higher rates of trauma (1.2%) than lower limb from the Late Antiquity-Early Byzantine sample (0.4%), the difference was not significant ($x^2 = 2.07$; $p = 0.150$).

A more detailed breakdown is shown in Table 5.1.7 where frequencies (%) of *ante-mortem* fractures are given.

Table 5.1.7. Percentages of affected bone segments: Period 1 *versus* Period 2*.

%	P1/3		M1/3		D1/3		TOTAL	
	P1	P2	P1	P2	P1	P2	P1	P2
Humerus	2.3	0	1.8	0.9	0	0	1.0	0.3
Radius	0	0	0	1.2	7.6	7.5	1.8	2.9
Ulna	0	0	0	0	2.6	7.9	0.4	2.3
Femur	0	0	0	0	0	0	0	0
Tibia	0	1.0	0.9	0.9	0	0	0.6	0.6
Fibula	0	1.8	0	1.1	12.1	0	4.5	0.9

*Codes: P1/3 = proximal third; M1/3 = middle third; D1/3 = distal third; P1 = Period 1 (Punic); P2 = Period 2 (Late Antiquity-Early Byzantine).

No trauma was identified in femora, in proximal radius, proximal ulna, middle ulna, middle tibia, distal humerus and distal tibia. Overall rates for the femora and tibiae were also identical. The distal third of the radius had essentially the same rates. Although only slight differences were observed among the remaining bone segments, statistical tests were nevertheless performed (Table 5.1.8).

Table 5.1.8. Differences in trauma between Punic and Late Antiquity-Early Byzantine bones*.

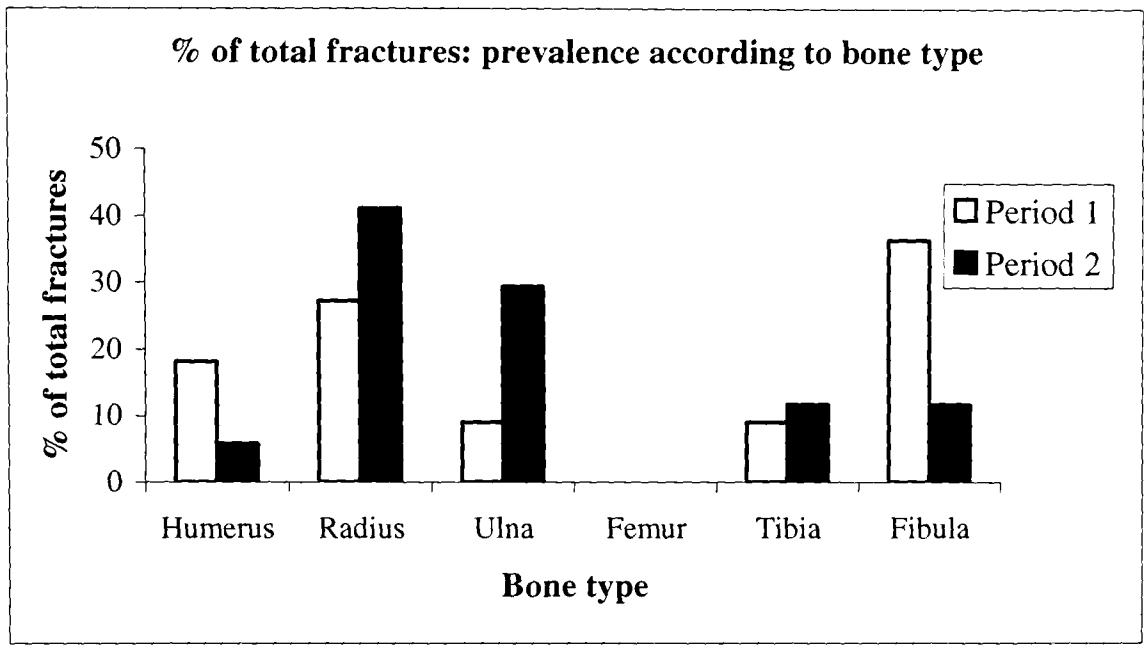
Observation	PERIOD 1		PERIOD 2		Statistical results	
	n/N	%	n/N	%	Chi-square	Significance
Proximal humerus	1/43	2.3	0/87	0	1.99	n.s.
Middle humerus	1/55	1.8	1/110	0.9	0.246	n.s.
Overall humerus	2/187	1.0	1/322	0.3	1.15	n.s.
Middle radius	0/63	0	1/81	1.2	0.774	n.s.
Overall radius	3/160	1.8	7/234	2.9	0.456	n.s.
Distal ulna	1/38	2.6	5/63	7.9	1.07	n.s.
Overall ulna	1/201	0.4	5/217	2.3	2.34	n.s.
Proximal tibia	0/22	0	1/91	1.0	0.241	n.s.
Proximal fibula	0/19	0	1/55	1.8	0.344	n.s.
Middle fibula	0/35	0	1/89	1.1	0.392	n.s.
Distal fibula	4/33	12.1	0/65	0	7.31	$p<0.05$
Overall fibula	4/87	4.5	2/209	0.9	3.82	n.s.

*Codes: n = number of segments with trauma; N = number of segments observed; % = percentage of segments affected (n/N x 100); n.s. = not statistically significant.

Comparisons between distal fibulae were significant ($p = 0.007$). Indeed, apart from the fibula, there appears to be homogeneity in fracture rates between Period 1 and Period 2.

Amongst the 11 and the 17 fractures observed in the Period 1 and Period 2 samples respectively, the distribution according to bone type was calculated (Figure 5.1.1). Thus in the first period, four (36.3%) occurred in fibulae, three (27.2%) in radii, two (18.1%) in humerii and only one (9.0%) among ulnae and among tibiae. In Period 2, trauma to radii predominated with a prevalence of 41.1% (7/17), followed by five (29.4%) cases in ulnae, two (11.7%) in tibiae as well as fibulae, and only one (5.8%) among humerii.

Figure 5.1.1. Percentages of bones with trauma according to bone type.



From Figure 5.1.1, it can be observed that the bone that was mostly fractured in Period 1 was the fibula. In Period 2, trauma to the forearms predominated. After performing statistical analyses, these differences however were not statistically significant, presumably in part due to the small sample size. This accounted for comparisons between Period 1 and Period 2 humerii ($x^2 = 0.834$; $p = 0.361$), radii ($x^2 = 0.273$; $p = 0.601$), ulnae ($x^2 = 1.11$; $p = 0.293$), tibiae ($x^2 = 0.040$; $p = 0.841$) and fibulae ($x^2 = 1.50$; $p = 0.220$).

Other skeletal elements were also compared. Low trauma rates were found in the shafts of adult clavicles, metacarpals, metatarsals and phalanges (Table 5.1.10). Left and right sides were pooled. Feet and hand phalanges were grouped together.

Table 5.1.9.Trauma frequencies in other skeletal elements.

PERIOD	CLAVICLES	METACARPALS	METATARSALS	PHALANGES
PERIOD 1	0% (0/30)	0% (0/307)	0.2% (1/393)	0% (0/313)
PERIOD 2	1.8% (1/53)	0% (0/206)	0% (0/314)	0.2% (1/356)

In the sample from Period 1, only a possible healed fracture in the fifth metatarsal (PCHN-H10) was present. Some periostitis was observed in the shaft of this bone. No epiphyses were present for the observation of any osteoarthritis resulting from fracture complications.

The samples from Period 2 showed that one clavicle (AR33-N-F) and one phalanx (HLL405.3) suffered fractures. The healed fracture from the adult left clavicle was located in the shaft, near the acromial (lateral) end. The phalanx had a healed fracture in the middle of the shaft. Overlapping and shortening were observed. The implications of these lower frequencies of trauma are discussed later.

Differences according to sex were also examined. Males in Period 1 clearly had more trauma than females, despite a large sample of bones not sexed. Frequencies between the sexes were more similar in Period 2, although with regard to radii, females had more injuries than males. When both periods were compared, females had similar frequencies except for the radius, which was more affected in Period 2 although caution is given because the analysed sample was larger in this period. In fact, the difference in trauma prevalence in the distal radius between these two periods was not statistically significant ($x^2 = 0.476$; $p = 0.490$). In Period 1 males had higher frequencies than their

Period 2 male counterparts in the overall rates for the humerus, radius, tibia and fibula. In Period 2 only the ulna showed higher rates. These differences in the male sample were examined further by performing statistical tests (Table 5.1.9).

Table 5.1.9. Differences in trauma between Punic and Late Antiquity-Early Byzantine males*.

MALE SAMPLE	PERIOD 1		PERIOD 2		Statistical results	
	N/N	%	n/N	%	Chi-square	Significance
HUMERUS	1/65	1.5	1/111	0.9	0.145	n.s.
RADIUS	2/28	7.1	0/83	0	5.63	$p<0.05$
ULNA	0/9	0	2/35	5.7	0.509	n.s.
TIBIA	1/30	3.3	1/127	0.7	1.20	n.s.
FIBULA	3/27	11.1	0/51	0	5.30	$p<0.05$

*Codes: n = number of segments with trauma; N = number of segments observed; % = percentage of segments affected (n/N x 100); n.s. = not statistically significant.

From the above data, Punic males appear to have had significantly higher fracture rates only when comparing radii ($p = 0.018$) and fibulae ($p = 0.021$).

5.1.5.7 Additional observations regarding trauma

Prevalence of cranio-facial trauma was difficult to assess due to the fragmentary, incomplete and fragile nature of the bones. Many bones were also missing *post-mortem.* Nasal bones, for instance, are commonly a location of traumatic injuries but most were lost *post-mortem.* Thus, only anecdotal cases were reported here and these may contribute to the reconstruction of past lifestyles in Ibiza.

The sample from Period 1 did not reveal any evident signs of interpersonal violence: no *peri-mortem* fractures in the skeleton, and no healed cranial fractures that may have been caused by weapons (e.g. sword or a sling).

In the Period 2 sample, at least three skulls displayed some type of trauma. These cases were healed. One corresponded to a slight depression in a left parietal of a young adult male (HLL203.1). The other case corresponded to a depressed fracture (Ill. 5.4), 17.4 mm wide and 22.5 mm long, located in the midline of the frontal bone near bregma of an adult male (AR33-M). Only part of the frontal and the right parietal bones were present from this skull. A possible slight depressed fracture (10.24 mm diameter, 0.70 mm deep) was also observed in the left frontal of male AR33-N-F. A healed fracture on the left body of a mandible (AR330L-J) was observed. This case belonged to an elderly person (>50 years).

No clear evidence was found for *peri-mortem* trauma. One left ulna (AR33-N-C) exhibited a clean cut in the distal shaft. This was the only possible case related to *peri-mortem* trauma. This bone belonged to a 10-15 year old individual and the right ulna was also identified (ARR33-F). Both ulnae displayed severe active periostitis. Whether the lesion was *peri-mortem* cannot be guaranteed, but it certainly differed from the other *post-mortem* fractures observed in the Ibizan samples. The violent or accidental nature cannot be confirmed either and, when periostitis is taken into account, other contributing factors such as surgical intervention cannot be ignored.

In general though, *peri-mortem* injuries were not obvious especially when compared to the many expected in warfare contexts (e.g. Fiorato *et al.*, 2000).

Evidence for violence may also be inferred by examining trauma in children. From the 1090 subadult long bone segments observed, only two showed signs of possible trauma[84]. These affected cases belonged to a 10-15 year old and corresponded to the left (AR33-M) and right (AR33-I) tibiae. The middle shafts revealed a localised 'bulge' possibly related to trauma and were accompanied by severe active periostitis.

Trauma in ribs was also evidenced. Two ribs (PCHN-H7) from the Punic rural site had fractures near the angle area of the shaft. These examples were not completely healed and had considerable callus formation (Ill. 5.5), a surprising amount in comparison to any other rib fractures from Ibiza. In the urban context, at least one right upper rib (PM01/UE62) displayed a healed fracture.

Eleven cases of adult healed rib fractures were found in the Period 2 samples: three labelled AR33-G-D, four labelled AR33-L-E, one labelled AR33-M; another (HLL4040.1) from a male individual, one (HLL803.1) from a 15-20 year old male, and a right rib from skeleton HLL809.2. All of these ribs account for a minimum number of four individuals. All these fractures occurred in the middle shaft. Most of these ribs

[84] Complete subadult bone shafts could be observed in each site and these were: 1 from PCHN, 29 from Punic urban sites, 86 from HLL and 138 from AR33. The percentage of affected subadult long bones in the Punic period was 0% (0/115). A low rate (2/177, 1.1%) was also found in Period 2. When segments were counted, incomplete bones were included, thus increasing the representativity of the sample. The total number of segments observed were 39 in the Punic rural and 119 in the Punic urban sites. In the Period 2 sample, 2449 segments from HLL and 493 from AR33 were observed.

belonged within the group from the third to the tenth ribs, but one could be precisely identified as a second right rib (HLL803.1).

Other lesions of traumatic injury were apparent. A right adult male femur (HLL404.1) provided evidence of soft tissue trauma (*myositis ossificans*) from a 15 mm (minimum) lesion at the bone's *linea aspera*. In the site AR33, one distal humerus (AR33-B) and ulna with massive osteophytes may be indicative of a traumatic episode in the elbow, while other lesions in femora (AR33-H) and pelvis (AR33-H) from the same individual may relate to *myositis ossificans traumatica*[85]. However, all these lesions could not contribute towards any further insights into violence or lifestyles. No trauma was observed in the bone of the pelvic girdle and shoulder girdle. Apart from Schmorl's nodes (see Section 5.2), vertebrae did not reveal any evidence for trauma (e.g. compression fractures).

5.1.5.8 Summary of key findings

Overall, morbidity in relation to trauma was low in the Punic period. This conclusion applied to both rural and urban contexts. When the Punic data were compared to the Late Antiquity-Early Byzantine results, there were no differences in trauma prevalence. All long bone types, with the exception of the femur and the metacarpals, suffered from trauma.

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[85] I thank Dr. Conrado Rodríguez-Martín from the 'Instituto Canario de Bioantropología', Tenerife, Spain, for kindly examining photographs of these pathological specimens.

During closer examination of individual bones and segments, certain trends were apparent. In the Punic rural context, fibulae were more affected, although when compared to the radii and ulnae, the differences were not statistically significant. In the Punic urban context, radii and tibiae displayed the highest frequencies. No significant differences in fracture rates were found between the rural and the urban contexts. In the Punic period overall, fibulae and radii were the most affected bones. Although males tended to show a higher prevalence of trauma, no statistically significant differences were found between the sexes.

In Period 2, there was a clear predominance of fractures in the forearm bones (radii, ulnae). Moreover, trauma rates in upper limb bones were significantly higher than rates in lower limb bones. With regards to sexual dimorphism, rates between females and males were similar, except for the radius, which was significantly more affected in females.

When data from both periods were compared, no significant differences were found except for fibulae, which were more affected in Period 1. Differences between females from Period 1 compared to females from Period 2 were not significant. However, when the male groups were compared, Punic males had significantly higher frequencies of trauma among radii and among fibulae.

Finally, cranial trauma was identified only in the Period 2 samples, while fractured ribs were present in both periods. Apart from two ribs in the Punic context, all fractures observed were well healed.

5.1.6 Discussion

From the above findings, several issues are discussed: a) interpretation of trauma rates in view of the hypothesis; b) possible factors contributing to fractures; c) sexual dimorphism in trauma rates; d) further inferences on the lifestyle of the Ibizan populations, particularly in relation to care and treatment, warfare and violence.

5.1.6.1 Discussion: interpretation in view of the hypothesis

If lower morbidity is associated with well-being, in view of the hypothesis, low morbidity in Period 1 was expected. Low trauma rates in the Punic sample support this statement. If trauma rates had been high, however, this would not have been surprising either. Longer life expectancy and economic productivity could have resulted in increase of exposure to factors (e.g. accidents) contributing to trauma.

What had been expected was a difference in trauma rates between Period 1 and Period 2, due to hypothesized different cultural, social, economic and environmental circumstances. Overall rates were surprisingly identical. The only differences appeared

in relation to patterns of trauma. In Period 1, higher prevalence was found in fibulae and ulnae and to a lesser extent in radii. In Period 2 forearm prevalence rates predominated. The different trends might be a reflection of different causative agents.

The pattern in Ibiza revealing predominance of fractures in the forearm and the fibula appears to be within the norm when compared to other populations. Forearm fractures are common in archaeological populations (e.g. Neves *et al.*, 1999; Jurmain, 2001; Judd, 2004) and also in clinical studies (Grauer and Roberts, 1996: 540-541). Although methodologies differ depending on the researcher, the overall frequencies of trauma (c.1%) in the Ibiza samples was slightly lower (<2%) than archaeological populations from prehistoric California (Jurmain, 2001), Egypt (Judd, 2004) and Medieval Britain (Judd and Roberts, 1999). By contrast, the Ibizan fractures are higher (>1%) than the 0.8% prevalence in urban York (Grauer and Roberts, 1996) as well as the lower rates in one Siberian sample (see Murphy, 2003). Overall, with caution when comparing crude prevalence rates from different studies, the frequencies in Ibiza seem to correspond within the normal range.

There were no statistically significant differences between the rural and the urban contexts, even though the trauma rate in fibulae was higher in the rural context and that for the radii was higher in the urban. This similarity contrasts with other studies where urban rates are higher than rural (e.g. Mafart, 1987) or, generally speaking, where the rural frequencies are higher than those from the urban environment where life seemed to be less hazardous (Grauer and Roberts; 1996; Judd and Roberts,

1999). Clinical studies have shown that trauma associated with agriculture can be frequent and diverse (Cogbill and Busch, 1985; Cogbill *et al.*, 1991; Walker-Bone and Palmer, 2002). For example that resulting from non-mechanised factors such as working alongside farm animals and/or milking them (Björnstig *et al.*, 1991; Cogbill, 1991; Boyle *et al.*, 1997; Norwood *et al.*, 2000; Criddle, 2001; Hendricks and Adekoya, 2001). Bovines, horses and asses were present since Phoenician times in the Iberian Peninsula (Riquelme, 2001).

The urban environment was more protected from military incursions. The terrain would have been less hazardous than the rural surroundings and perhaps urban occupations predisposed individuals to lower levels of occupational-related trauma. Nevertheless, Ibizan merchants, sailors and fishermen played a considerable part in the Ibizan economy, and some associated injuries may have been expected. Fishing, for instance, has also been regarded as one of the most dangerous occupations today; where fishermen suffer from back problems, lacerations, as well as head, leg and arm injuries (Thomas *et al.*, 2001; Lawrie *et al.*, 2003).

Considering these low morbidity levels and the risks of farming and sailing, the Ibizan Punic populations were well adapted to their environment. The same would apply to the Late Antiquity-Early Byzantine population although it is uncertain in how much economic productivity the inhabitants would have been engaged in, taking into account that several agricultural settlements were abandoned and trade was not as active.

5.1.6.2 Discussion: factors contributing to trauma

Factors that would have contributed to trauma would have been predominantly accident related. Most of the fractures in Ibiza were located in distal fibulae, ulnae and radii. Fractures were less frequent in humerii and tibiae. Trauma rates for clavicles, metatarsals and phalanges were very low. No fractures were present in femora and metacarpals.

Fractures in the distal third of the fibula (e.g. Pott's fracture) are common and can be a result of an awkward fall and/or twisting the ankle (Galloway, 1999c: 203-206). In modern farm settings, falls from haylofts, wagons or from ladders are common (Jones, 1990; Cogbill *et al.*, 1991). In past populations, trauma in fibulae may have been caused by accidents during horse-riding, construction work or during ploughing (Farwell and Molleson, 1993: 199). Fractures in the distal radius are a result of falling, especially in elderly females with osteoporosis, and in general due to low energy forces causing the trauma (Galloway, 1999b: 138-139). Many of the fractured radii in the Period 2 sample belonged to elderly individuals over the age of 50 years. In young individuals, fractures in this region of the radius are a consequence of a direct blow or indirectly from falling on an outstretched hand while undertaking occupational or recreational activities (Galloway, 1999b). These mechanisms also apply to fracture in clavicles (Galloway, 199b).

Fractures in the humeral shaft are usually the result of an accident (e.g. falls) or a violent act (Galloway, 1999b: 125). Trauma in the tibial shaft is a result of direct blows, common today in traffic accidents or sport injuries (Galloway, 1999c: 193). One case of a fractured fifth metatarsal was present in the Punic rural site. Trauma in this bone is common in active individuals today that practice sports, or from 'marching' or falling from a height (Yu and Shapiro, 1998; Galloway, 1999c: 220-222). Fractures in ribs would have been caused by falling, coughing or from a direct blow (Judd, 2002a: 101).

The absence of fractures in some bones is also informative. No trauma was present in femora. Today they are rare too but can be present in elderly women with fragile bones or in young individuals participating in situations involving considerable force such as in car accidents (Galloway, 1999c: 180). Hand bones are vulnerable to trauma particularly as they are at increased risk when they are used to manipulate tools (Galloway, 1999b: 152), but no trauma was present in these Ibizan bones.

5.1.6.3 Discussion: sexual dimorphism in trauma rates

When sex differences are compared, it must be remembered that the sex refers only to the skeleton, not to the social perception (gender) of a particular individual. Gender rather than biological sex may have affected choice of professions.

Overall, the impression given is that there were no differences in trauma frequencies between females and males. The only exceptions were fibulae, which were more affected in males than females from Period 1; and radii, more fractured in females than in males from Period 2. Fractures in fibulae may have been associated with increased mobility (not sedentary activities) of men in the rural areas and/or ploughing. In modern agricultural communities males have more injuries than females, although women are more commonly injured by animals (Dimich-Ward *et al.*, 2004). In the recent past, rural women in Ibiza worked mainly in the house and on minor agricultural activities, while men would do the harder labour such as ploughing the fields (Miguélez, 1985). Farm tools from pre-Roman and Roman times have been found in Spain and these included ploughs (see Miguélez, 1985). Fractures in the female radii may have been influenced by age, where old females with osteoporosis would have been more prone to fracture at this site during a fall.

The overall similarities between males and females indicate that they might have practiced similar activities. Alternatively, they practiced different activities but these had similar levels of risk.

Finally, males in Period 1 tended to have higher trauma rates than males from Period 2. Statistically significant differences were only found between male radii and fibulae. This would suggest that Period 1 men were more involved in activities related

to economic production, although this statement must remain inconclusive until further evidence is obtained in the future.

5.1.6.4 Discussion: further inferences about the lifestyles of the Ibizan populations

Apart from two partially healed ribs, all the cases in Ibiza were well healed. Angulation was slight and marked shortening was only present in an ulna and a phalanx. The analysis of complications resulting from trauma, such as periostitis and osteoarthritis, might provide some information on the availability of medical treatment and/or its effectiveness (Grauer and Roberts, 1996: 541). Periostitis was present in five long bones with trauma, including the fifth metatarsal, although the direct relationship with the fracture was not always evident. Osteoarthritis was present in some bones that displayed fractures. Although most epiphyses had been lost *post-mortem*, in some cases observations could be made. Marginal osteophytes were present in the Punic rural radius that displayed a Colles' fracture. More marked osteophytes and contour deformation were present in the distal epiphyses of two Punic rural fibulae out of three observed. In Period 2, a fibula with trauma did not have osteoarthritis in the joint surface and neither did the epiphyses of four distal radii. Only one fractured ulna from this period had marginal osteophytes in both epiphyses. Only the osteoarthritic changes in the two fibulae from the Punic rural sample provided some certainty that they had been secondary to trauma.

Despite these minor complications, which would have not affected mobility considerably and that would have not caused much major soft tissue trauma once healed, healing was successful. No major angulation or shortening was found except for one ulna (HLL202) and one phalanx (HLL405.3). Only the ribs in the rural site had a massive callus formation and were only partially healed. It might have been possible that in these cases the individual had no choice (forced?) but to work rather than to rest (Márquez-Grant, 1999a: 46).

Apart from the cases cited above with some complications during healing, the people that suffered from trauma seem to have been able to (could spare the time, were not forced to work) immobilise the limb and were cared for. For instance, only slight angulation was present in the fractured fibulae. Usually, a fracture in the ankle requires rest for several months if possible without placing weight on the joint. The alignment of the fractured parts with the rest of the long bone diaphyses was also good in general, with only slight angular deviation and very little shortening of the bone in most cases. With this in mind, it is possible to think that splints would have existed as well as medical or personal care. For instance, those with a fractured tibia would not have been able to walk using the leg for weeks (Murphy, 2003: 44). The individual with the fractured mandible would have also required a person to help and care for him or her. Already in Antiquity, Celsius (*De Medicina*, Book VIII.7. 5-8) indicated how a fractured mandible could be treated and the type of food that the patient should eat. Medical knowledge and bone-setters have existed since at least the second millennium, at least in Egypt, China and India (see Chapter 1, Section 1.9.4.). The ancient writer

Pliny (Book XXVIII.LXV.65) wrote that *'For broken bones (...) boiled bacon-fat, tied around the fracture, heals with marvellous rapidity'*. In Ibiza there is epigraphic evidence confirming the presence of at least one doctor in the second century AD (Juan, 1988: 51).

With regard to violence in the Punic period, evidence for violence in a scale such as war is lacking for Ibiza where people did not seem to indulge in warfare (see also Chapter 1, Section 1.9.6.). In general for Punic times, a pacific lifestyle has been backed up by other physical anthropologists (Gómez, 1989: 322). Only one fracture in a Punic humerus from *Can Marines* may be interpreted as being caused by a piercing object during an act of violence (Gómez, 1989: 306).

Low trauma rates in this study do suggest a low level of conflict in Ibiza, although the extent of soft tissue trauma is unknown. If the hand bones are considered, there were no fractures apart from one phalanx from Period 2. The commonest causes of fractures in the hand bones are falls or crushing injuries but, particularly, a blow to the knuckles, for instance whilst fighting/punching (Galloway, 1999b). A review of the clinical literature has seen that the hands are the preferred method of assault in violence today (Judd, 2004: 36). The absence of trauma in these bones would support the idea of a 'pacific' lifestyle.

Fractures in ulnae have typically been regarded as resulting from parrying or buffering a blow to the head during an act of violence. However, recent studies have

show that these lesions can only be partially informative about violence and that statements made on the ulna alone are unreliable (Alvrus, 1999; Jurmain, 2001; Judd, 2004; Lessa and Mendonça de Souza, 2004). Moreover, most of the ulnae fractures in the Ibizan samples are oblique fractures, and would rather be interpreted as caused by an uneven bending force such as a fall rather than by a direct blow (Grauer and Roberts, 1996: 539). Indeed, evidence for lack of violence is also supported by no significant sexual differences overall and by an absence of high rates of trauma in children (after Neves *et al.*, 1999).

The only direct evidence that seems to be related to acts of violence, come from the Period 2 sample where depressed cranial fractures have been recorded. These depressed fractures were probably caused by blunt weapons. Ramon (1985, 1995b) on a preliminary note indicated that Byzantine skulls from Ibiza, at the site of *C/Aragó, 33* revealed possible signs of violence. This could only be confirmed through healed cranial depressed fractures rather than by *peri-mortem* trauma. Without an anthropologist examining the skeletons *in situ* it is rather difficult to obtain more precise information (Etxeberria and Carnicero, 1998: 38). However, the number of fractures discovered must have related to only a small amount of violence if any. Similar types of fracture have been associated in areas of military activity (e.g. see Šlaus *et al.*, 2004; Kjellström, 2005) although not always (e.g. see Papathanasiou, 2005) and did not cause enough damage to cause death. Trauma in the lower jaw can also be attributed to a violent act such as fistfights although accidental reasons such as a fall cannot be excluded (Murphy, 2003: 45; Galloway, 1999a: 77).

A reliable interpretation of violence, apart from *peri-mortem* fractures, requires combination of evidence for trauma in metacarpals, phalanges, ulnae and depressed skull fractures, as well as an examination of mortality rates and artefactual evidence such as arrowheads embedded in the bones (Jurmain, 2001; Lessa and Mendonça de Souza, 2004: 377-378). The burial context also provides important clues. Although these fractures were present in the Period 2 samples, these were only very few cases. They are not convincing enough but to suggest a potential presence of violence in this period that can only be confirmed by future investigations on other sites.

Low frequencies of trauma have been suggestive of times of social balance and political agreement (Lessa and Mendonça de Souza, 2004: 385). These conclusions can probably be applied to the Ibizan periods.

The results from this analysis on violence suggest that several military incursions did not have an impact on trauma rates in Ibiza. During the Punic wars, Livy (Book XXVIII. 37) informs that a Carthaginian fleet harboured in Ibiza in the third century BC where it was supplied with young men and arms. Except those soldiers that would have died and were buried abroad, those warriors (e.g. slingers) that survived would have returned home with their healed injuries. In addition, there was a failed Roman siege on *Eivissa* in 217 BC that resulted in plundering the more vulnerable rural areas instead (Costa, 2000a). Livy stated (Book XII. 20) that the Romans '(...) crossed over to the island of Ebusus. There they endeavoured strenuously for two days, but

without success, to capture the chief city of the island. And when they saw that their hopes were vain and their time was being wasted, they betook themselves to pillaging the country-side, and after sacking and burning several villages, returned to their ships with more booty than they had collected from the mainland'.

Although the texts by Livy may be somewhat inaccurate (see Costa, 2000a for a critique), the relevant issue here is that Ibiza appears to have been involved to some extent in military actions. The fracture rates in the limited Punic sample have so far yielded little evidence of such incursions increasing the incidence of fractures.

In Period 2, some violence might have been expected in view of the hypothesized unfavourable living conditions and therefore possible social unrest, as well as Vandal and later Islamic incursions. Certainly in Late Antiquity some Vandal and Byzantine frontier areas have seen conflicts as evidenced by battle wounds in skeletons (Martí, 2001: 19). This might be reflected in cranial and forearm fractures but their prevalence rates were too low to be convincing at present.

In summary, different trauma frequencies would have been expected between periods. In the Punic period, intensive agricultural exploitation, maritime navigation for commercial or fishing purposes, would have seen a number of traumatic incidences. Although this may be true with regard soft tissue, it was not the case in relation to skeletal lesions. Although larger samples would be required, the trend observed here is of successful adaptation to the cultural (e.g. tools, transport) and physical environment

(e.g. terrain), especially if work would have been more physically demanding in the Punic period. In the few cases with trauma, adequate adaptation was also observed from the successful treatment and healing of injuries. This adaptation accounted for both care for people, opportunities to rest and adequate medical action.

The general impression is that these injuries were not attributable predominantly to violent events, but to accidental injuries, especially when oblique types of fractures are considered. Overall, there was no clear discrimination between the sexes, reflecting some homogeneity in the level of risk in acquiring fractures. Apart from the differences in fibulae as well as radii rates, overall similarities in trauma prevalence between the sexes show similar levels of risk in their lifestyles and/or professional activities.

5.2 Osteoarthritis

Amongst the degenerative lesions, osteoarthritis (OA) is one of the most abundant skeletal pathology and is relatively easy to diagnose. Archaeological studies in relation to OA have primarily followed two avenues (Roberts and Manchester, 1995: 110): studies that examine the pattern or distribution of OA in a population; and studies that examine the prevalence of OA through time and its association with changing economies. OA prevalence, for example, has been employed in archaeology to investigate differences between hunter-gatherers and agriculturalists (Bridges, 1991).

The variation in patterns and prevalence of OA throughout the world may be a reflection of different lifestyles and occupations (Roberts and Manchester, 1995: 107). Rural populations in the U.S.A. today exhibit a higher prevalence of hip and knee joint OA than the general urban population (Jordan *et al.*, 1995). In China, chopstick use and habitual squatting may be influential factors resulting in hand and knee OA respectively (Hunter *et al.*, 2004; Zhang *et al.*, 2004). Data from a high class urban population from eighteenth and nineteenth century AD Netherlands, revealed that hip OA was more common in the past while knee OA is a more recent phenomenon (Baetsen *et al.*, 1997). In archaeological populations carrying heavy loads on the head might have resulted in an increased prevalence of OA in cervical vertebrae (Bridges, 1994; Lovell, 1994).

5.2.1 Definition

Osteoarthritis (OA), also known as arthrosis or degenerative joint disease (DJD), is the most common of all articular diseases (Ortner and Putschar, 1981: 419; Roberts and Manchester, 1995: 105). Although its definition is problematic[86], with regard to palaeopathology OA can be defined as a disorder of the synovial joints that consists of the deterioration of the articular cartilage and the formation of new bone in the articular surfaces (after Steinbock, 1976)[87]. More precisely, OA is a 'non-inflammatory, chronic, progressive pathological condition characterized by the loss of joint cartilage and subsequent lesions resulting from direct interosseous contact within diarthrodial joints. (...). The disease is the most common form of joint pathology and is usually detectable during the fourth decade of life.' (Aufderheide and Rodríguez-Martín, 1998: 93).

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[86] Concepts of OA can differ according to the clinical (symptoms) or pathological condition, this latter involving the observation of cartilage degeneration and/or bone changes (Debono *et al.*, 2004: 399). OA used to be considered a 'wear and tear' disease caused by age and trauma. More recently it has been defined not as a disease but as a process of 'repair' of a failed joint in response to an abnormal biomechanical environment (Doherty, 1994; Dieppe, 2000; Waldron, 2001; Lane and Nevitt, 2002: 2). In addition, some authors (e.g. Rothschild and Martin, 1993) agree that the term 'osteoarthritis' is incorrect as there is no inflammation or atrophy. It is even unclear whether OA is a single disease or rather a combination of many disorders (Felson *et al.*, 2000a: 636). Vertebral osteophytosis is a more accurate term for the degeneration that occurs in the articular surfaces of the vertebrae.

[87] There are different types of joints. Joints can be classified depending on the mobility of the bones that form that articulation. Skull sutures are classified as fixed or rigid (synarthrosis); others such as the pubic symphysis are more moveable (amphiarthrosis) whilst the most freely moveable joints such as the typical ball-and-socket joints (e.g. hip) are termed as diarthrodial (Roberts and Manchester, 1995: 100). In the hip, knee and elbow joints there are a synovial fluid contained within the synovial membrane. This fluid is what characterises these articulations as synovial joints (Roberts and Manchester, 1995: 101).

5.2.2 Aetiology

The aetiology of OA is multifactorial, including a combination of biochemical and biomechanical factors (Felson, 2000; Jordan *et al.*, 2000; Vitanzo and McShane, 2000). The 'health and fitness' of the whole joint is important and this includes the surrounding muscles, tendons, ligaments and the articular cartilage (Roberts and Manchester, 1995: 101; Arokoski et al., 2000).

Age, 'wear and tear'; obesity and/or high body mass index (Shiozaki *et al.*, 1999a, 1999b; Brismar *et al.*, 2003); heredity (Jimenez *et al.*, 1998); trauma (Jurmain, 1977); smoking and diabetes mellitus (Cooper and Dieppe, 1994); *genus varus* deformity (Veerapen *et al.*, 2004); selenium deficiency and/or consuming cereals with fungal growths[88] are some contributing factors. Other associated factors include climate, hormonal influences, metabolism, impaired nutrition, bone density, vascular deficiencies, infection, bone geometry, weakness of the quadriceps muscle as well as the constructive characteristics of the joint (Rothschild and Martin, 1993; Larsen, 1997a; Aufderheide and Rodríguez-Martín, 1998; Dieppe, 2000). The pathogenesis of the disorder can be found detailed elsewhere (Arokoski *et al.*, 2000; Felson and Neogi, 2004; Ubelaker, 1999: 108), but the first change of deterioration of the joint involves the articular cartilage, which has a number of functions including transmission and distribution of loads, and the absorption of shock (Roberts and Manchester, 1995: 101; Ghosh, 2003: 84).

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[88] This is known as Kashin-Beck's disease (e.g. see Haubruge *et al.*, 2000).

5.2.3 Methodological advantages and limitations

Although all joints were observed for pathology, only OA was analysed in detail in order to test the hypothesis. It is the joint disease most frequently encountered in skeletal remains and in addition, amongst all the joint diseases, it is the most correlated with neuromechanics (Roberts and Manchester, 1995: 101). It can be primary (with increasing age), or it can be secondary (at any age) as a consequence of previous trauma to the joint (Roberts and Manchester, 1995: 101).

In this chapter, OA was employed to investigate different morbidity rates between populations as well as the distribution patterns of OA in the skeleton. Potentially, different distribution patterns between populations might be a result of different activity patterns. Despite the multifactorial aetiology, this assumes that mechanical or physical work acting on the joints results in OA in most cases. Brismar and colleagues (2003) experimenting on guinea pigs found that although physical activity may be chondroprotective at an earlier stage, it is no longer the case when frequent joint loads during physical activity and large body mass started to affect the cartilage (Brismar *et al.*, 2003: 446). Some occupational related OA is found in farmers who have a high prevalence of hip and knee OA than the more sedentary urban populations (Jordan *et al.*, 1995). Lovell's (1994) study on a Bronze Age site in Pakistan concluded that the aetiology of OA in the cervical spine was occupational-related.

However, although this assumption of mechanical stress seems reasonable, there is no clear relationship between occupation and incidence of OA (Waldron and Cox, 1989; Waldron, 1994, 2001; Jurmain, 1991; see also Debono *et al.*, 2004). Individuals undertaking heavy manual work may not get OA, while others with a more sedentary life do (Knüsel, 1993; Waldron, 2001). Exercise helps prevent osteoarthritis (Lane, 1996; Manninen *et al.*, 2001; Conaghan, 2002; Jones *et al.*, 2003), unless intensive high levels of impact and torsional loading are present such as in occupations involving recurrent jumping, heavy lifting, kneeling or squatting (Vitanzo and McShane, 2000; Felson *et al.*, 2000b: 641; Zhang *et al.*, 2004: 1191). People who started hard labour during the growth period may have built up bone accordingly in preparation for higher strains. This would make them less predisposed to OA in later years compared to those that had a sedentary lifestyle and later in adulthood started strenuous activities (Knüsel, 1993).

Ortner and Putschar (1985: 422) formulated the following question: 'What is the effect of relatively continuous but moderate stress on a joint, as contrasted with intermittent but high stress?'. It is possible that one of the reasons for the presence of OA is not necessarily the continued repetition of routine activities, but the undertaking of infrequent activities that are highly intense and for which people have not yet adapted to (Bridges, 1991).

Finally, determining the pattern of involvement requires ascertaining the age of onset of the OA lesions, the frequency and severity of involvement of different joints,

sexual differences and its OA in relation to age (Jurmain, 1990a: 88). An important problem that may arise, however, is that in isolated remains from disarticulated contexts, the specific age of the bone (age-at-death of the individual) cannot be determined.

5.2.4 Materials and methods

This study examined joint changes in the skull (temporo-mandibular joint), axial (vertebra and ribs) and appendicular skeleton (major long bones, hand and foot bones). Within the skull, the mandibular condyles and the temporo-mandibular fossa of the temporal bone were considered. Vertebrae and ribs were treated separately and for now are for later discussion below. The other bones analysed were: clavicles, humerii, radii, ulnae, femora, patellae, tibiae and fibulae. Both epiphyses were observed in each long bone. In addition, carpals, metacarpals, tarsals, metatarsals and phalanges were observed.

All of these bones were later pooled to allow observation of OA in the following joints: temporo-mandibular joint (TMJ), sterno-clavicular joint (SCJ), shoulder, elbow, wrist, first metacarpophalangeal joint (MCP), hip, knee, and ankle joint.

Every joint surface was scored for presence or absence of OA. In palaeopathology, presence of OA is characterised by *ante-mortem* or sub-chondral

pitting in the articular surfaces (Ill. 5.6, Ill. 5.7), bone growth (osteophytes) in the margins or on the joint surface (Ill. 5.8), joint contour deformation and eburnation (Ortner and Putschar, 1981; Rogers and Dieppe, 1993; Rothschild and Martin, 1993; Rogers and Waldron, 1995; Rogers, 2000; Waldron, 1992, 2001). Eburnation, a polished or ivory-like surface, is the clearest sign of OA (Ill. 5.9). In some instances, eburnated surfaces may exhibit grooving (Rogers and Dieppe, 1993). When eburnation is absent other criteria must be considered, otherwise there might be an under representation of OA prevalence. In addition, some joints are more likely to exhibit eburnation than others (Ortner and Putschar, 1981: 420). Thus, when eburnation is absent, the cited literature recommends that a positive diagnosis of OA requires the presence of at least two of the remaining criteria (e.g. osteophytes and sub-chondral pitting). Even though these criteria have been used to standardise the methodology, inter-observer variation is present both in terms of scoring and positive identification of OA (Waldron and Rogers, 1991). In this study, only the present author examined the material, which reduced any inter-observer error and increased the reliability of the comparisons.

Due to of problems with the disarticulated remains, it was unknown what bones belonged to which individual. The prevalence rates were thus not given per joint (composed by many bones), but rather per number of joint surfaces observed. This approach to look only at joint surfaces has been undertaken in past studies (e.g. Jurmain, 1980, 1991; Bridges, 1991; Lovell, 1994). Moreover, when there is

incomplete preservation with many joint compartments missing, prevalence according to the number of surfaces observed is more reliable.

Many studies incorporate degrees of severity in their recording scheme, such as mild, moderate or severe (e.g. Jurmain, 1980; Bridges, 1991; Cope *et al.*, 2005). This was also undertaking and can be found recorded in the original archives. With regards to the grade of severity, only the number of cases with eburnation was highlighted in the results below, since eburnation is the most severe manifestation of OA (Ortner and Putschar 1981: 420).

Analysis of degenerative changes in vertebrae differed slightly. Degenerative joint disease (DJD)[89] in vertebral bodies was scored according to the stages defined by T.D. Stewart (1958) (in Ubelaker, 1999: 85) and P. Sager (1969) (in Brothwell, 1987: 214). Prevalence rates were obtained per vertebral body count, as well as per vertebral facet count. Severe cases, including those with eburnation, were also highlighted separately. These severe cases corresponded with 'stage 4' and 'grade III' in the schemes of Stewart and of Sager respectively.

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[89] In vertebrae there are characteristically several types of joint disease commonly studied (e.g. see Maat *et al.*, 1995; see recording schemes in Campo, 1997). One is *spondylosis deformans*, which accounts for marginal lipping of the vertebral bodies (vertebral osteophytosis or VO), sometimes associated with Schmorl's nodes. This lipping is horizontal as opposed to vertical, which is characteristic of syndemophytes and enthesophytes. OA is commonly referred to as 'degenerative joint disease' or DJD. OA or DJD is a term especially employed for synovial joints. The articulation between the atlas and the axis, as well as between vertebral facts, is a synovial joint, but the remaining joints between vertebral bodies are composed of fibrocartilaginous tissue (Jurmain, 1990a: 84; Maat *et al.*, 1995: 289). DJD in the vertebrae is aetiologically and pathogenetically different from that degeneration occurring at the synovial joints (Jurmain, 1980: 143). For instance, while VO is primarily a result of weight bearing functions, DJD or OA in the facets is a result of body movements (Maat *et al.*, 1995: 289).

Schmorl's nodes (SN) were also recorded in each vertebral body surface. Although SN may be traumatic in origin, they are often considered within degenerative joint disease. SN reflect a herniated or extruded intervertebral disc cartilage (Schwartz, 1995: 240). The recording classified these lesions as slight or barely discernable, moderate or marked expression (Buikstra and Ubelaker, 1994: 115). Medium lesions usually extended between 10% and 30% of the surface, and marked lesions were larger and deeper.

Since degenerative changes are not common in immature skeletons, all specimens observed were based on adult skeletons (>15 years). With regard to the TMJ, adult age was basically confirmed with the eruption of the third molar and/or dental wear. For vertebrae and ribs, all epiphysis and secondary ossification centres were fused. When the sternal epiphysis was observable, only clavicles with completely fused sternal epiphysis were employed. With regard to the major long bones only fused epiphysis were considered. The ossification of the patella is usually complete by puberty or shortly thereafter (Bass, 1995: 237), but texture (appearance) and size were also considered with reference to known adult patellae from Ibizan sites.

Every surface that was scored had to be at least 75% preserved including both the joint surface and the joint margins. Some epiphyses and vertebral bodies were fragmented and often damaged. Unobservable joint surfaces were noted but not included in the calculation of prevalence rates.

Waldron (1991) has pointed out that it is necessary to calculate age-specific rates. Primary OA as opposed to secondary (e.g. related to previous injury to the joint), is strongly correlated with age. Thus, OA is a normal process unless it occurs at a young age or prematurely (Ubelaker, 1999: 108). Unfortunately due to the commingled remains at the Punic rural site, at the Punic urban site (PM01), in the Period 2 site AR33 and some disarticulated tomb assemblages in HLL, a specific age for each bone could not be obtained. This is a limitation of this study and warrants caution when interpreting the results.

A sample with older individuals will probably reveal higher frequencies than a sample predominantly composed of young adults. Nevertheless, older age individuals do not comprise a large proportion in each of the Ibizan samples, thus minimising the error when comparing the skeletal assemblages. In addition, age profiles are roughly similar between contexts and periods, although many individuals could not be aged. Amongst the aged, the highest mortality rates appear in the 30-50 year age group both in the rural sample (47% of aged adults) and the urban sample (31.5% of aged adults). The percentage of people over the age of 50 years was 14.7% in the rural sample and 21.0% in the urban.

The frequency of 30-50 year old individuals is higher in the Punic period (41.5%) compared to the Late Antiquity-Early Byzantine period (24.6%), but this is

compensated by higher percentage of old individuals (>50 years) in the latter period (23.0%) as opposed to Period 1 (16.9%).

Moreover, individuals can develop OA at a relatively young adult age, especially those involved in more physically intense and active lifestyles (Roberts and Manchester, 1995: 107). Nathan (1962) has reviewed the literature and found that already a large proportion of individuals in the third decade of life had vertebral osteophytosis (Roberts and Manchester, 1995: 107).

Added to this problem is that the anthropologist estimates age for most of the adult skeletons based on degenerative changes. It is plausible that demanding physical activities at a young adult age may accelerate the process of degeneration in the skeleton. Therefore, although it may appear that older individuals may have more OA, the old age of these individuals could be based on skeletal age, which may be far from the true chronological age of the individual. Furthermore, lesions in old individuals in archaeological populations, does not provide an indication of age of onset, which might have started many years before death. Roberts and Manchester (1995: 109) make a good point in indicating that to counteract the effect of ageing it would be useful to study young adults to examine whether there is a high prevalence of OA in their skeletons. If the prevalence is moderate or high it may be possible to view the appearance of OA in associations with occupation. This will be discussed elsewhere below, alongside possible alternative contributing factors. In brief, the disarticulated

nature of most of the bones, did not allow always for specific inferences about age or sex, or with regards to primary (and systemic) and secondary (and local) osteoarthritis.

Sexual dimorphism was also examined when possible. Apart from several articulated skeletons in VR28 and HLL, most sex diagnoses were limited to discriminant functions applied to long bone measurements. Sex was not assigned to vertebrae, ribs, patella and bones of the hands and feet.

5.2.5 Results

Raw data are first presented per bone element (joint/epiphyseal surface) observed, separated according to left and right sides. When samples were compared with each other, such as rural-urban or Period 1-Period 2, only joint groups were employed, pooling both left and right sides.

5.2.5.1 The Punic sample

Summary frequencies are first given for rural and urban contexts according to three different groups: a) temporo-mandibular joint (skull); b) vertebrae and ribs; c) all long bones as well as scapulae, *os coxa*, patella, hand and foot bones. After the summary raw data are presented, the surfaces are later grouped according to joint and also to facilitate comparisons between rural and urban contexts.

Preservation bias was significant. For instance, only three epiphyses were preserved at the Punic urban site VR47.

5.2.5.1.1 The Punic sample: the temporo-mandibular joint

Only a reduced sample represented the temporo-mandibular joint (TMJ). Observations were made on the temporo-mandibular fossa in the temporal bone and mandibular condyles. The data are presented in Table 5.2.1 separated by rural and urban context, left and right sides. None of these bones had eburnation.

In addition, prevalence rates for the number of affected individuals in the population could be determined, based on either repeated bone elements or clearly distinguished according to tomb boundaries.

Table 5.2.1. OA prevalence in the temporo-mandibular joint*.

Element	Context	Left n/N	Right n/N	Total	Individuals
Temporal bone	Punic rural	0/0	0/1	0/1 (0)	0/1 (0)
	Punic urban	0/1	0/1	0/2 (0)	0/1 (0)
	Punic total	0/1	0/2	0/3 (0)	0/2 (0)
Mandible	Punic rural	2/3	0/2	2/5 (40.0)	2/4 (50.0)
	Punic urban	2/4	2/2	4/6 (66.6)	3/5 (60.0)
	Punic total	3/4	2/4	5/8 (62.5)	4/6 (66.6)
Overall TMJ with OA	Punic rural	2/3	0/3	2/6 (33.3)	2/4 (50.0)
	Punic urban	2/5	2/3	4/8 (50.0)	3/6 (50.0)
	Punic total	4/8	2/6	6/14 (42.8)	4/8 (50.0)

*n = number of cases with OA; N = number of cases observed; number in brackets denotes percentages and is the result of n/N x 100.

With regard to the mandibular condyles alone, 62.5% of the surfaces had degenerative changes characteristic of OA. The percentage of individuals affected was also high (66.6%). The total sum from the temporal bones and the mandibles, resulted in 42.8% OA prevalence for all the Punic surfaces, and 50% for all the individuals examined.

5.2.5.1.2 The Punic sample: vertebrae and ribs

Frequencies obtained for the remaining bones of the axial skeleton are found in Table 5.2.2[90]. A total of 188 vertebral bodies from the Punic rural context and 72 from

[90] Occipital articular condyles were observed, but comparisons were not made here. Only one skull from the Punic assemblage had sufficient preservation to count as a reliable observation. No degenerative changes were observed in its two occipital condyles. With regard to Period 2, only five condyles from

the urban context provided information on presence or absence of degenerative changes. A total of 17.0% and 34.7% respectively had DJD. The overall for Period 1 was estimated in 21.9% (57/260). No individual frequencies per vertebral column were obtained, except for the dens of the axis, which is a unique unilateral landmark in the skeleton. Only the rural period provided data for this location, with 22.2% (4/18) dens, and therefore individuals, affected with DJD.

Vertebral facets, Schmorl's nodes (SN) and OA in ribs were also examined (Table 5.2.2). Most vertebral elements, apart from the atlas and the axis, could not be specifically identified to a particular vertebra, so most were grouped into cervical (C3-C7), thoracic or lumbar vertebrae.

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three different individuals (HLL202, HLL213, HLL609.2) could be examined and none presented arthritic changes.

Table 5.2.2. Degenerative joint disease in vertebrae and ribs*.

Element	Punic rural[91]	Punic urban	Period 1
Atlas (facet for dens of axis)[1]	0/8	1/4	1/12
Axis (dens)[1]	4/18 [E]	-	4/18
CV bodies (C2-C7)	7/40 [3,3,3,3,3]	12/25 [3,3,3,3]	22/65 [3,3,3,3,3,3,3,3,3,3]
TV bodies (T1-T12)	5/101	20/59 [3]	25/160 [3]
LV bodies (body)	17/43 [3,3,3]	13/25	30/68 [3,3,3]
Vertebral bodies unidentified	3/4 [3,3,3]	-	3/4 [3,3,3]
CV facets (C1-C7)	10/224	6/101	16/325
TV facets (T1-T12)	0/40	1/160	0/200
LV facets (L1-L5)	0/26	3/20	3/46
Facets of unidentified vertebrae	2/14	34/82	36/96
SN (C3-C7)	0/52	0/48	0/100
SN (TV)	5/205	29/111	34/316
SN (LV)	0/86	5/47	5/133
SN (unidentified vertebrae)	1/1	-	1/1
Sacrum (1st sacral vertebra)[1]	2/5	1/3	3/8
Rib facets (TV)	0/26	0/90	0/102
Rib facets (ribs: head and neck)	12/50	59/101	71/151

*Codes: [1] = these anatomical landmarks are specific, the prevalence of these also provides a prevalence of individuals affected; CV = cervical vertebrae; TV = thoracic vertebrae; LV = lumbar vertebrae; SN = Schmorl's nodes; [E] = facet with eburnation (the number of repeated letters denotes the number of cases); [3] = body with severe (grade 3, stage 4) DJD. Repeated numbers refer to the number of cases.

This data are later pooled according to joint or vertebral group and compared performing statistical analysis (Section 5.2.5.1.4).

5.2.5.1.3 The Punic sample: remaining skeletal elements

The raw data for each Punic context are presented in Table 5.2.3. Left and right sides are also given, which also provides an individual prevalence. Percentages are included in brackets. Further comparisons are later made according to joint and both

[91] There were more vertebrae in the rural sample. However these were very fragmented and although only 15% or 20% could be enough to see presence of DJD, it was not sufficient to make this sample quantifiable for the prevalence of OA. Amongst 900 grams of vertebral body fragments from the rural site (PCHN), the following fragments had severe osteophyte and subchondral macropitting: four CV, seven TV and twelve LV fragments.

series are observed for any significant differences. Few acetabula were observed due to their fragmentary state. Due to fragmentation, the prevalence for the proximal epiphysis of the tibia is given according to the number of articular surfaces observed (i.e. two compartments per each proximal epiphysis).

Table 5.2.3. OA frequency in the appendicular skeleton and the pelvis*.

Element	PUNIC RURAL			PUNIC URBAN		
	Total[4]	L	R	Total	L	R
Clavicle (sternal end)	12/21 (57.1)	4/6	7/11	5/7 (71.4)	3/5	2/2
Clavicle (acromial end)	5/25 (20.0)	0/8	4/14	0/4 (0)	0/3	0/1
Scapula (glenoid cavity)	8/20 (40.0)	3/7	5/13	1/4 (25.0)	0/2	1/2
Humerus (PE)	3/34 (8.8)	1/4	1/8	2/10 (20.0)	1/2	1/8
Humerus (DE)	10/51 (19.6) [E,E]	6/22 [E,E]	4/26	2/15 (13.3) [E,E]	1/7 [E]	1/8 [E]
Radius (PE)	7/24 (29.1) [E,E]	1/8 [E]	6/14 [E]	1/13 (7.6)	0/6	1/5
Radius (DE)	5/17 (29.4)	4/10	1/7	2/9 (22.2)	1/4	1/5
Ulna (PE)	19/92 (20.6) [E]	0/49	19/43 [E]	1/11 (9.0)	1/4	0/6
Ulna (DE)	4/21 (19.0)	1/3	0/0	1/8 (12.5)	0/1	1/6
Carpals	0/3 (0)	0/1	0/2	2/67 (2.9)	0/32	0/35
Metacarpals (B)	1/137 (0.7)	0/56	0/77	4/83 (4.8)	1/36	3/47
Metacarpals (H)	9/92 (9.7) [E]	6/39	2/47 [E]	8/76 (10.5) [E]	2/37	6/39 [E]
Hand phalanges (B)[1]	3/103 (2.9) [E]	-	-	4/134 (2.9)	-	-
Hand phalanges (H)[2]	2/93 (2.1)	-	-	11/117 (9.4)	-	-
Os coxa (acetabulum)	0/0	-	-	0/3 (0)	0/2	0/1
Femur (PE)	8/78 (10.2) [E]	5/11 [E]	2/17	2/11 (18.1)	1/3	1/5
Femur (DE)	4/26 (15.3) [E,E,E]	3/15 [E,E]	1/11 [E]	1/10 (10.0)	1/4	0/3
Patella	10/40 (25.0) [E]	5/20	4/19	14/20 (70.0) [E]	9/11 [E]	5/9
Tibia (PE)[3]	2/16 (12.5) [E]	1/7 [E]	0/1	2/18 (11.1)	2/7	0/8
Tibia (DE)	2/18 (11.1)	2/10	0/8	0/9 (0)	0/5	0/4
Fibula (PE)	1/10 (10.0)	0/3	1/5	0/6 (0)	0/1	0/5
Fibula (DE)	5/16 (31.2)	1/8	3/7	0/16 (0)	0/7	0/9
Tarsals	7/107 (6.5)	4/57	3/50	12/105 (11.4)	8/58	4/57
Metatarsals (B)	1/131 (0.7) [E]	0/63	1/67 [E]	1/119 (0.8)	1/63	0/56
Metatarsals (H)	4/71 (5.6) [E]	0/26	3/ 39 [E]	2/86 (2.3)	2/50	0/36
Foot phalanges (B)[1]	0/10 (0)	-	-	5/72 (6.9)	-	-
Foot phalanges (H)[2]	0/10 (0)	-	-	2/63 (3.1)	-	-

*Codes: PE = proximal epiphysis; DE = distal epiphysis; B = base; H = head; [1] = phalanges were not sided; [2] = the prevalence of OA in the head of phalanges excludes the distal phalanges as these are not articulated with any other bone; [3] = proximal tibia prevalence rates are given by counting the number of articular condyles observed; [4] = the total number includes those added from the left and right side, but also from those bones that could not be sided. Therefore, if the total from left and right sides are not equal to the overall count, it is because of additional bones that could not be sided; [E] facet with eburnation (the number of repeated letters denotes the number of cases). Numbers in brackets denote percentages.

Most of these surfaces were pooled according to joint, which provided a better picture of the pattern of OA throughout the skeleton (Section 5.2.5.1.4).

Meanwhile, differences according to sex could be examined (Table 5.2.4) when sexed long bones were taken into account. Most of the Punic material, especially in the rural context, was solely sexed on long bone measurements. Although the long bone sex discrimination functions (see Chapter 2) provide reliable results (>85%), caution must be borne in mind since the sexual dimorphism in the Ibizan skeletons has not yet been understood.

Table 5.2.4. Sexual dimorphism in OA in the Punic period*.

BONE	PUNIC RURAL		PUNIC URBAN		TOTAL PUNIC PERIOD	
	Females	Males	Females	Males	Females	Males
Humerus (PE)	1/4	0/5	0/3	1/6	1/7	1/11
Humerus (DE)	4/16	5/29 ^{E,E}	0/3	1/11 ^{E}	4/19	6/40 ^{E,E,E}
Radius (PE)	2/7 ^{E}	4/12 ^{E}	0/1	0/6	2/8 ^{E}	4/18 ^{E}
Radius (DE)	0/2	2/8	0/2	2/5	0/4	4/13
Ulna (PE)	-	1/1	0/0	0/1	-	1/2
Ulna (DE)	0/1	-	0/0	0/0	0/1	-
Femur (PE)	1/9	6/17	2/6	0/4	3/15	6/21
Femur (DE)	0/7	3/13 ^{E}	0/2	1/5	0/9	4/18 ^{E}
Tibia (PE)	0/2	0/8	0/4	2/9	0/6	2/17
Tibia (DE)	0/3	1/4	0/1	0/2	0/4	1/6
Fibula (PE)	-	-	0/2	0/2	0/2	0/2
Fibula (DE)	0/6	1/6	0/7	0/8	0/13	1/14
TOTAL	14% (8/57)	22% (23/103)	6% (2/31)	12% (7/59)	11.3% (10/88)	18.5% (30/162)

* Rates given as: n (number of surfaces with OA)/N (number of surfaces observed). Codes: PE = proximal epiphysis; DE = distal epiphysis; ^{E} = surface with eburnation (repeated letters indicate the number of surfaces affected).

Females were less affected by OA than males. These differences however were not statistically significant among the rural (x^2 = 1.12; p = 0.291), the urban (x^2 = 0.550; p = 0.458) and the overall Punic samples (x^2 = 1.60; p = 0.205). Among the cases with OA, males had more eburnated surfaces (5/30, 16.6%) than females (1/10, 10%), but this difference was not significant (x^2 = 0.199; p = 0.665). The elbow, comprising the distal humerus and the proximal radius and ulna, displayed more cases of eburnation in males than in females. Overall rates for eburnated surfaces in the elbow were 36.3% (4/11) amongst the cases with OA in males, compared to 16.6% (1/6) in females. However, the difference was not significant (x^2 = 0.417; p = 0.519).

5.2.5.1.4 The pattern of OA in the Punic period

The pattern between rural and urban has to be interpreted with much caution due to possible age bias in the incidence of OA. This section reviews the prevalence of OA according to joint (e.g. elbow) or anatomical region (e.g. hand). The results are presented in Table 5.2.5 and are compared by employing chi-square tests.

In addition to the overall hand and foot bones, a separate analysis was also made according to wrist and ankle, which include some hand and foot bones respectively. An independent analysis was also taken with regard to the base of the first metacarpal (Ill. 5.10). The first metacarpal (part of the trapezio-metacarpal joint) may be more affected than other fingers due to pinching and gripping mechanisms (Cope *et al.*, 2005: 392).

Table 5.2.5 indicates the bones that comprise each joint. The different types of vertebral groups relate to different actions. For instance, degeneration in the vertebral body may be a result of repetitive rotation movements, DJD in the cervical area due to carrying loads and SN from weight bearing stresses. Later, all vertebral types were pooled according to number of bodies and facets observed. SN were only counted in thoracic and lumbar vertebrae since these are the most susceptible to these lesions. Data on rib DJD were pooled from facets on the vertebrae and the ribs themselves.

Table 5.2.5. DJD according to joint or anatomical region in both rural and urban samples*.

Anatomical region	Bones considered	Punic rural	Punic urban	Chi-square	Significance
Temporo-mandibular joint	Temporal, mandible	33.3% (2/6)	50% (4/8)	0.159	n.s.
Atlanto-axis articulation	Atlas, axis[0]	15.3% (4/26) [E]	25% (1/4)	0.156	n.s.
Cervical region of vertebral column	Bodies of C2-C7	17.5% (7/40) [3,3,3,3,3]	48.0% (12/25) [3,3,3,3]	3.64	n.s.
Thoracic region of vertebral column	Bodies of T1-T12	4.9% (5/101)	33.8% (20/59) [3]	16.4	P<0.001
Lumbar region of vertebral column	Bodies of L1-L5	39.5% (17/43) [3,3,3]	52.0% (13/25)	0.378	n.s.
Vertebral column	Bodies of all vertebrae and first sacral segment	17.6% (34/193) [3,3,3,3,3,3,3,3,3,3,3]	41.0% (46/112) [3,3,3,3,3]	11.3	p<0.005
Vertebrae facets	All vertebrae	3.9% (12/304)	12.1% (44/363)	12.2	p<0.001
SN in vertebral column	Thoracic and lumbar vertebrae	1.7% (5/291)	21.5% (34/158)	40.6	p<0.001
Ribs	Ribs and thoracic vertebrae	15.7% (12/76)	30.8% (59/191)	3.89	p<0.05
Sternoclavicular joint	Clavicle[1]	57.1% (12/21)	71.4% (5/7)	0.105	n.s.
Shoulder	Humerus (PE), clavicle, scapula	20.2% (16/79)	16.6% (3/18)	0.082	n.s.
Elbow	Humerus (DE), radius (PE), ulna (PE)	21.5% (36/167) [E,E,E,E,E]	10.2% (4/39) [E,E]	1.85	n.s.
Wrist (radiocarpal joint)[2]	Radius (DE), ulna (DE), scaphoid, lunate and triquetral	22.5% (9/40)	6.5% (3/46)	3.42	n.s.
Hand	All joint surfaces of carpals, metacarpals and phalanges	3.5% (15/428) [E,E]	6.0% (29/477) [E]	2.94	n.s.
Trapeziometacarpal joint[3]	Trapezium, base of first metatarsal	6.6% (1/15)	9.0% (2/22)	0.060	n.s.
Hip	*Os coxa* (acetabulum), femur (PE)	10.2% (8/78) [E]	14.2% (2/14)	0.156	n.s.
Knee[2]	Femur (DE), patella, Tibia (PE)	19.5% (16/82) [E,E,E,E,E]	35.4% (17/48) [E]	2.34	n.s.
Ankle[2]	Tibia (DE), fibula (DE), talus	10.5% (8/76)	2.0% (1/49)	2.83	n.s.
Foot	All joint surfaces of tarsals, metatarsals and phalanges.	3.6% (12/329) [E,E]	4.9% (22/445)	0.695	n.s.

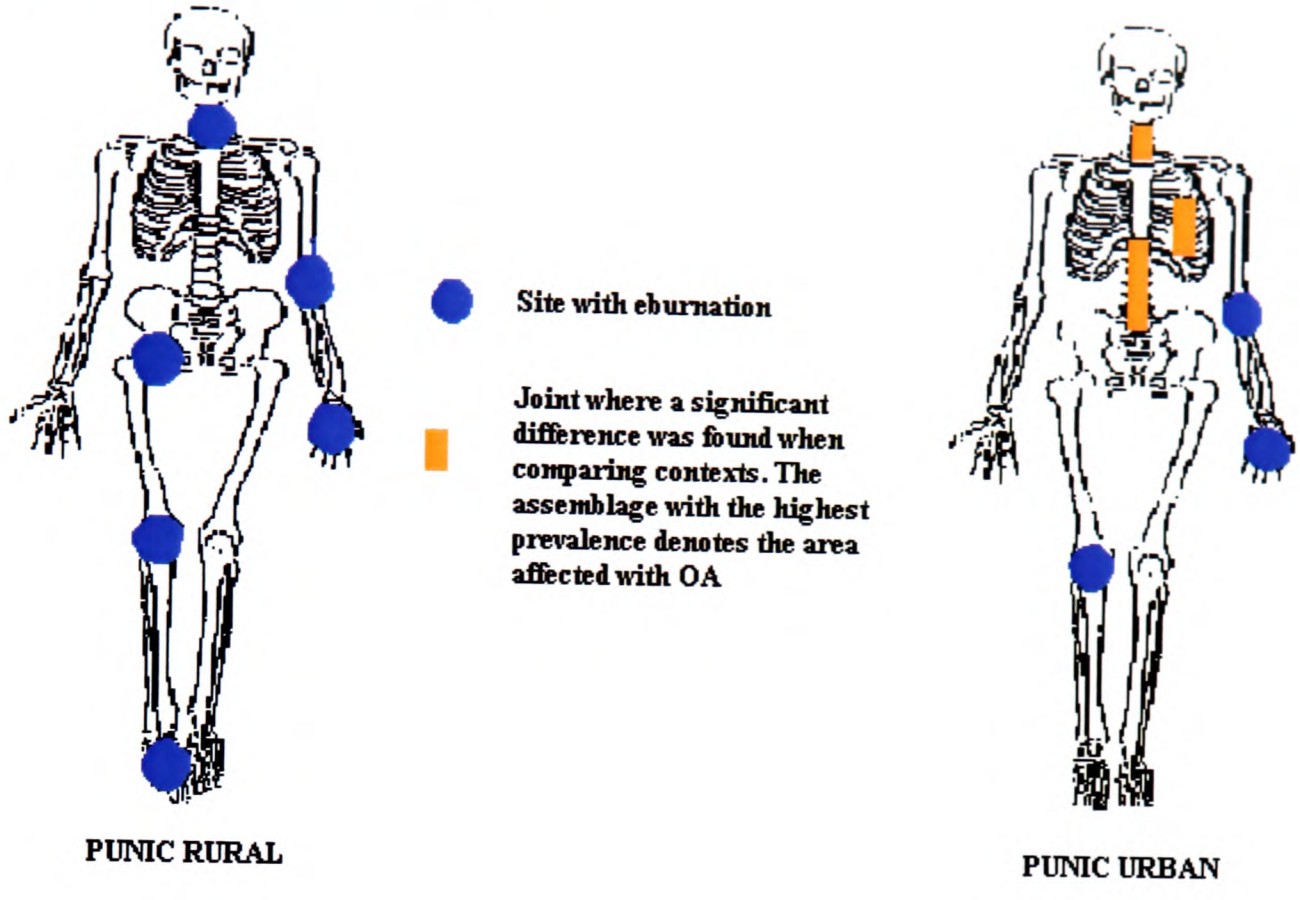
* Codes: SN = Schmorl's Nodes; [0] = the atlanto-axial articulation comprises the facet for dens articulation in the axis as well as the dens of axis; [1] = No sterna were available for observation; [2] = these are the bones that compose the joint, as indicated in anatomical textbooks (e.g. Gray, 1858; McMinn *et al.*, 1993); [3] = one trapezium came from the Punic urban individual VR28/311 and five from PM01/UE62; PE = proximal epiphysis; DE= distal epiphysis; [E] = surface with eburnation; [3] = body with grade three severity; n.s. = not statistically significant.

Unexpectedly, except for the shoulder, elbow, wrist and ankle, the urban population had predominantly more OA than the rural population. However, significant differences were only found in some cases resulting in higher frequencies in the urban context: DJD in the thoracic vertebrae ($p = 0.000$), in the overall vertebral bodies ($p = 0.001$), in the vertebral facets ($p = 0.000$) and with regard to SN ($p = 0.000$). Higher rates were also evident in rib facets from the urban sample ($p = 0.048$).

A relatively high number of cases with eburnation appeared in the rural area. However, when the total counts of affected OA surfaces with eburnation were considered, the proportions were similar between the rural (9/93, 9.6%) and urban (3/30, 10%) contexts. The proportion of severely affected vertebrae amongst those with osteophytosis was higher in the rural area (11/34, 32.2%) compared to the urban (5/46, 10.8%), although this difference was just off the significant level ($x^2 = 3.69$; $p = 0.055$).

Locations with eburnation are illustrated in blue in Figure 5.2.1. In addition, regions where prevalence was significantly higher in one context are also highlighted (orange rectangle).

Figure 5.2.1. OA patterns in Punic contexts.



Most major joints and anatomical regions in the rural skeleton had at least one surface with eburnation, except for the sterno-clavicular joint, the shoulder, the ankle and the wrist. In the smaller urban sample, the available joint surfaces only displayed eburnation in the elbow, the hand and the knee. DJD in the vertebral column, ribs and hands, as well as Schmorl's nodes were more prevalent in the urban areas.

Differences in patterning between samples could also be observed through ranking the most severely affected down to the least affected (Table 5.2.6). The joints that are highlighted in Table 5.2.6 are the anatomical regions where significant differences were found between contexts. Since sample sizes vary according to joint,

and considering possible age biases, caution must be taken when interpreting these results.

Table 5.2.6. Rank order in DJD prevalence in each Punic group*.

% affected	Punic rural	Punic urban
>50%	Sterno-clavicular joint	Sterno-clavicular joint LV TMJ
30-50%	LV TMJ	CV **V. Bodies** Knee **TV** **Ribs**
10-30%	Wrist Elbow Shoulder Knee CV **V. Bodies** **Ribs** Atlanto-axial articulation Hip Ankle	**SN** Atlanto-axial articulation Shoulder Hip **V. Facets** Elbow
5-10%	TMC	TMC Wrist Hand Foot
<5%	**TV** **V. Facets** Hand Foot **SN**	Ankle

* Codes: CV = cervical vertebrae; LV = lumbar vertebrae; SN = Schmorl's nodes; TMC = trapeziometacarpal joint; TMJ = temporo-mandibular joint; TV = thoracic vertebrae; V. Bodies = vertebral bodies; V. Facets = vertebral facets.

From the above average prevalence rates, there were a number of joints highly affected such as the sterno-clavicular joint, the temporo-mandibular joint, the vertebrae and, in the urban case, also the knee. The rural population displayed OA in the major

joints (shoulder, elbow, wrist, hip, knee, ankle) clustered into a similar prevalence group, while in the urban sample these joints were more sparsely distributed. The implications of these findings are discussed later. The lower back (LV) is the most highly affected vertebral group in both series. Interestingly, there is also a high proportion of affected CV in the urban area.

The Punic rural population revealed only a slightly higher number of OA in the joint surfaces of the upper limbs (humerus, radius, ulna) with a prevalence of 9.58% (63/657) compared to the 8.25% (44/533) in the lower limbs (femur, tibia, fibula), although these differences were not significant ($x^2 = 0.535$; $p = 0.465$). In the urban context, the proportion of affected upper limbs was similar to the proportion in the lower limbs, with a prevalence of 7.63% (32/419) and 7.83% (30/383) respectively.

5.2.5.2 The Late Antiquity-Early Byzantine sample

A summary of the raw data is presented first for the temporo-mandibular joint, followed by the vertebrae and ribs, and later by the remaining bones.

5.2.5.2.1 The Late Antiquity-Early Byzantine sample: the temporo-mandibular joint

The data for TMJ are presented in Table 5.2.7. None of these bones had eburnation. The minimum number of individuals represented was calculated by

identifying different individuals according to tomb boundaries or by counting the repeated number of elements in the disarticulated contexts.

Table 5.2.7. OA prevalence in the temporo-mandibular joint*.

Element	Left n/N	Right n/N	Total	Individuals
Temporal bone	7/20	7/17	14/37 (37.8)	9/23 (39.1)
Mandible	2/17	2/15	4/32 (12.5)	4/23 (17.3)
Overall TMJ with OA	9/37	9/32	18/69 (26.0)	9/24 (37.5)

*n = number of cases with OA; N = number of cases observed; number in brackets denotes percentages and is the result of n/N x 100.

The lowest rates were found in the mandibular condyles, while the temporal were being more affected. The overall prevalence of OA was 26% according to the number of surfaces observed, and 37.5% according to the number of individuals.

5.2.5.2.2 The Late Antiquity-Early Byzantine sample: vertebrae and ribs

Frequencies obtained for the remaining bones of the axial skeleton are found in Table 5.2.8. The overall frequency of affected vertebral bodies was 27.0% (92/340).

Table 5.2.8. Degenerative joint disease in vertebrae and ribs*.

Element	Period 2
Atlas (facet for dens of axis)[1]	9/21 [E]
Axis (dens)[1]	10/26 [E]
CV bodies (C2-C7)	17/61 [3,3,3,3,3,3,3]
TV bodies (T1-T12)	36/165 [3,3,3,3]
LV bodies (body)	31/84 [3,3,3,3,3,3,3]
Vertebral bodies unidentified	5/21 [3,E,E]
CV facets (C1-C7)	28/319
TV facets (T1-T12)	35/254
LV facets (L1-L5)	57/201
Facets of unidentified vertebrae	26/239
SN (C3-C7)	0/86
SN (TV)	41/263
SN (LV)	24/146
SN (unidentified vertebrae)	1/33
Sacrum (1st segment)[1]	3/9
Rib facets (TV)	44/160
Rib facets (ribs: head and neck)	95/237 [E]

*Codes: [1] = these anatomical landmarks also provides a prevalence of individuals affected. CV = cervical vertebrae; TV = thoracic vertebrae; LV = lumbar vertebrae; SN = Schmorl's nodes; [E] facet with eburnation; [3] = body with severe (grade 3, stage 4) DJD. Repeated numbers or letters refer to the number of cases affected.

The data are later grouped into larger categories in Section 5.2.5.3 and compared to the data from the Punic period.

5.2.5.2.3 The Late Antiquity-Early Byzantine sample: remaining skeletal elements

The data for this period are presented in Table 5.2.9. The total number of affected surfaces includes left, right and those unsided elements. Percentages are provided in brackets.

Table 5.2.9. OA frequency in the appendicular skeleton and pelvis*.

Element	PERIOD 2		
	Total	**L**	**R**
Clavicle (sternal end)	3/15 (20.0)	2/7	1/8
Clavicle (acromial end)	7/16 (43.7)	5/8	2/8
Scapula (glenoid cavity)	10/23 (43.4)	4/10	6/13
Humerus (PE)	2/19 (10.5)	1/14	1/5
Humerus (DE)	2/33 (6.0)	1/12	1/21
Radius (PE)	1/20 (5.0)	1/6	0/14
Radius (DE)	6/29 (20.6)	3/13	3/16
Ulna (PE)	9/27 (33.3)	4/14	5/13
Ulna (DE)	6/19 (31.5)	3/13	3/6
Carpals	2/36 (5.5)	2/18	0/18
Metacarpals (B)	2/64 (3.1)	0/26	2/38
Metacarpals (H)	2/55 (3.6)	1/23	1/28
Hand phalanges (B)	5/209 (2.3)	-	-
Hand phalanges (H)	6/190 (3.1)	-	-
Os coxa (acetabulum)	5/17 (29.4)	2/5	3/11
Femur (PE)	0/56 (0)	0/26	0/23
Femur (DE)	6/43 (13.9) [E]	3/17 [E]	3/16
Patella	2/15 (13.3)	1/7	1/8
Tibia (PE)	7/45 (15.5)	2/22	4/15
Tibia (DE)	3/30 (10.0)	2/15	1/14
Fibula (PE)	0/5 (0)	0/3	0/2
Fibula (DE)	0/19 (0)	0/9	0/10
Tarsals	24/89 (26.9) [E]	2/28	3/36 [E]
Metatarsals (B)	0/46 (0)	0/26	0/19
Metatarsals (H)	0/29 (0)	0/17	0/10
Foot phalanges (B)	0/63 (0)	-	-
Foot phalanges (H)	0/53 (0)	-	-

* Codes are provided in Table 5.2.3.

The surfaces were later pooled in Section 5.2.5.3 and then compared to the Punic sample. Meanwhile, differences according to sex were analysed considering the long bones (Table 5.2.10). The sex of some bones could be inferred, apart from long bone dimensions, by examining the pelvis and/or the skull in the articulated skeletons (site HLL).

Table 5.2.10. Sexual dimorphism in OA in the Late Antiquity-Early Byzantine period*.

BONE	TOTAL PERIOD 2	
	Females	Males
Humerus (PE)	0/2	2/14
Humerus (DE)	0/6	1/20
Radius (PE)	0/7	1/9
Radius (DE)	2/8	4/16
Ulna (PE)	0/2	1/9
Ulna (DE)	1/3	0/3
Femur (PE)	0/19	0/27
Femur (DE)	0/9	4/19
Tibia (PE)	0/8	6/30
Tibia (DE)	0/7	1/16
Fibula (PE)	0/0	0/3
Fibula (DE)	0/12	0/6
TOTAL	3.6% (3/83)	11.6% (20/172)

* Codes: PE = proximal epiphysis; DE = distal epiphysis.

None of the surfaces below revealed any signs of eburnation. Due to the small sample sizes, the prevalence rate is given as an overall figure of all the observed joint surfaces. Overall, males were more affected than females, although the difference was just outside the significant value ($x^2 = 3.76$; $p = 0.053$).

5.2.5.3 Comparisons between Period 1 and Period 2

Comparisons between Period 1 and Period 2 are given in Table 5.2.11, together with the statistical results. Some significant differences in OA were found between the periods.

Table 5.2.11. DJD prevalence in each anatomical region divided into Period 1 and Period 2*.

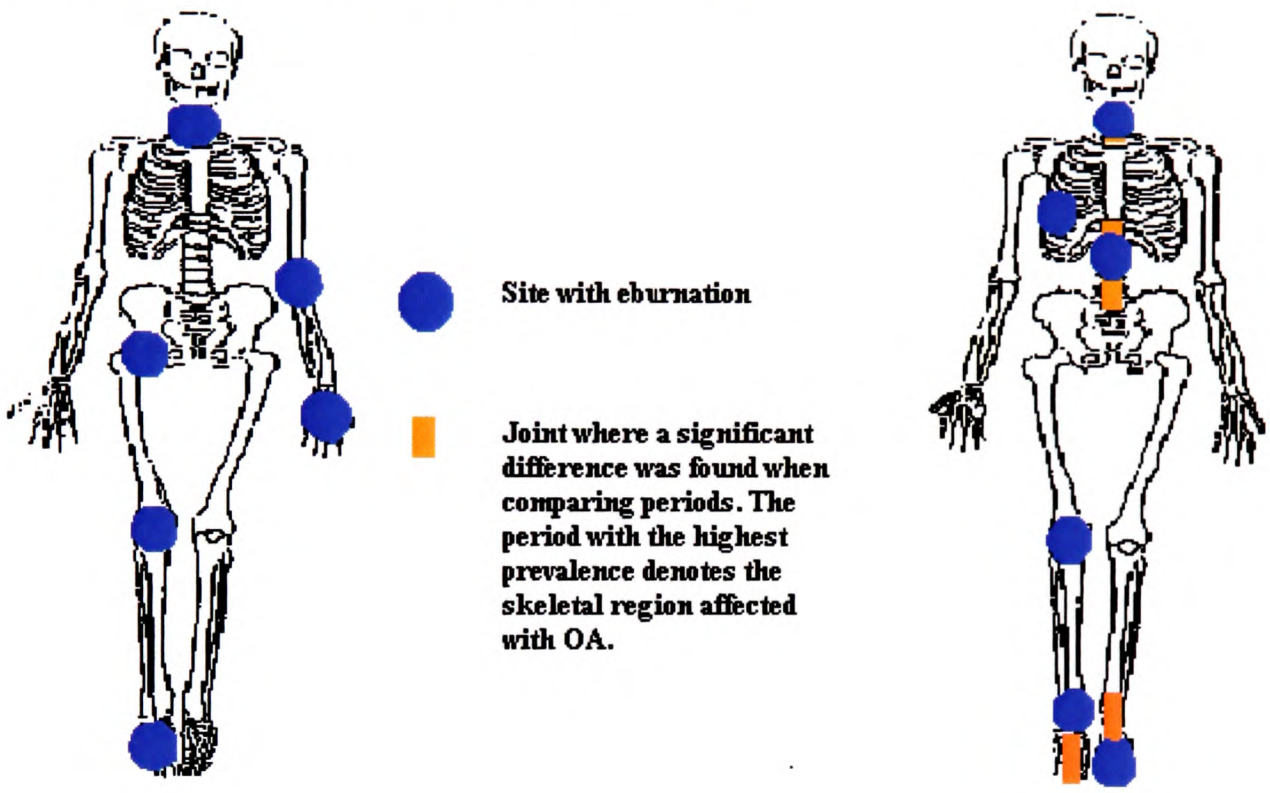
Anatomical region	PERIOD 1	PERIOD 2	Chi-square	Significance
Temporo-mandibular joint	42.8% (6/14)	26.0% (18/69)	0.810	n.s.
Atlanto-axis articulation	16.6% (5/30) [E]	66.0% (19/47) [E, E]	2.66	n.s.
Cervical region of vertebral column	29.2% (19/65)	27.8% (17/61)	0.015	n.s.
Thoracic region of vertebral column	15.6% (25/160)	21.8% (36/165)	1.40	n.s.
Lumbar region of vertebral column	44.1% (30/68)	36.9% (31/84)	0.346	n.s.
Vertebral column	26.2% (80/305)	27.0% (92/340) [E, E]	0.032	n.s.
Vertebrae facets	8.3% (56/667)	14.4% (146/1013)	10.9	p<0.005
SN in vertebral column	8.6% (39/449)	15.8% (65/409)	8.16	p<0.005
Ribs	26.5% (71/267)	35.0% (139/397) [E]	2.76	n.s
Sternoclavicular joint	60.7% (17/28)	20% (3/15)	2.64	n.s.
Shoulder	19.5% (19/97)	32.7% (19/58)	2.01	n.s.
Elbow	19.4% (40/206) [E, E, E, E, E, E, E]	15.0% (12/80)	0.532	n.s.
Wrist	13.9% (12/86)	20% (13/65)	0.697	n.s.
Hand	4.8% (44/905) [E, E, E]	3.0% (17/554)	2.55	n.s.
Trapeziometacarpal joint[1]	8.1% (3/37)	10.0% (2/20)	0.048	n.s.
Hip	10.8% (10/92) [E]	6.8% (5/73)	0.666	n.s.
Knee	25.3% (33/130) [E, E, E, E, E, E]	14.5% (15/103) [E]	2.74	n.s.
Ankle	7.2% (9/125)	17.6% (15/85) [E]	4.27	P<0.05
Foot	4.3% (34/774) [E, E]	8.5% (24/280) [E]	6.07	P<0.05

* Codes are provided in Table 5.2.5; [1] = only one trapezium was observed in the Punic period and five in the Late Antiquity-Early Byzantine period, none of which had any signs of OA.

Results varied depending on the joint. Similar results between periods were obtained for the cervical region of the vertebral column, as well as in the overall prevalence of DJD in the vertebral bodies. Period 1 had higher rates at the TMJ, the lumbar region of the vertebral column, the sternoclavicular joint, the elbow, the hand, the hip and the knee. The remaining joints displayed higher frequencies in Period 2. However, only the results obtained for the vertebral facets ($p = 0.001$), Schmorl's nodes ($p = 0.004$), the ankle ($p = 0.039$) and the foot ($p = 0.014$) bones provided significant results. In these cases, OA prevalence was significantly higher in Period 2. The pattern of eburnation differed slightly between the periods (Figure 5.2.2). The Period 1 sample displayed eburnation in the atlanto-axial articulation, elbow, hand, hip, knee and foot.

In the Period 2 sample, eburnation was observed also in the atlanto-axial articulation, the knee and the foot, but the vertebrae, ribs and ankle were also affected.

Figure 5.2.2. Pattern of DJD in Period 1 and Period 2



At first sight there was a higher number of cases with eburnation in Period 1, especially at the elbow and knee joints. However, on closer examination the number of observed surfaces at these locations was larger in the Period 1 sample. At the elbow, there were seven surfaces (7/40, 17.5%) with eburnation in Period 1 and none in Period 2 (0/12). However, the difference was not statistically significant ($x^2 = 2.03$; $p = 0.154$). At the knee, there was also a higher frequency of eburnated surfaces in Period 1 (6/33, 18.1%) compared to no surfaces with this trait in Period 2 (0/15), but the difference was

not significant either ($x^2 = 2.60$; $p = 0.107$). In the vertebrae, there were fewer severe cases in Period 1 (16/80, 20.0%) compared to Period 2 (21/92, 22.8%), but the difference was not significant ($x^2 = 0.131$; $p = 0.717$).

When all the affected surfaces from the major joints (shoulder, elbow, wrist, hip, knee, and ankle) were considered, 11.3% (14/123) from Period 1 had eburnation compared to 2.5% (2/79) in Period 2. This difference was significant ($x^2 = 4.50$; $p = 0.034$).

Females in Period 1 had more long bone surfaces affected with OA (10/88, 11.3% of surfaces) than females from Period 2 (3/83, 3.6%), but the difference was not significant ($x^2 = 3.15$; $p = 0.076$). Period 1 males also had a higher frequency (30/162, 18.5%) than Period 2 males (20/172, 11.6%), but this difference was not significant either ($x^2 = 2.30$; $p = 0.129$).

When rank order was investigated, the sternoclavicular joint (SCJ) was the bone most affected in Period 1. In Period 2, the highest frequencies derived from the atlanto-axial articulation (AAA). Hand bones revealed the lowest frequencies in both periods. Table 5.2.12 provides a rank taken from the information in Table 5.2.11. The elements that are highlighted include areas where significant differences were found between the periods.

Table 5.2.12. Rank order in DJD prevalence in each Period*.

% affected	PERIOD 1	PERIOD 2
>50%	Sterno-clavicular joint	Atlanto-axial articulation
30-50%	LV TMJ	LV Ribs Shoulder
10-30%	CV Ribs V. Bodies Knee Shoulder Elbow Atlanto-axial articulation TV Wrist Hip	CV V. Bodies TMJ TV Wrist Sterno-clavicular joint **Ankle** **SN** Elbow Knee **V. Facets** TMC
5-10%	**SN** **V. Facets** TMC **Ankle**	**Foot** Hip
<5%	Hand **Foot**	Hand

* Codes are provided in Table 5.2.6.

This ranking is also illustrated in figures 5.3.3 and 5.3.4, after which a more detailed examination follows.

Figure 5.3.3. Punic period: rank order in OA prevalence.

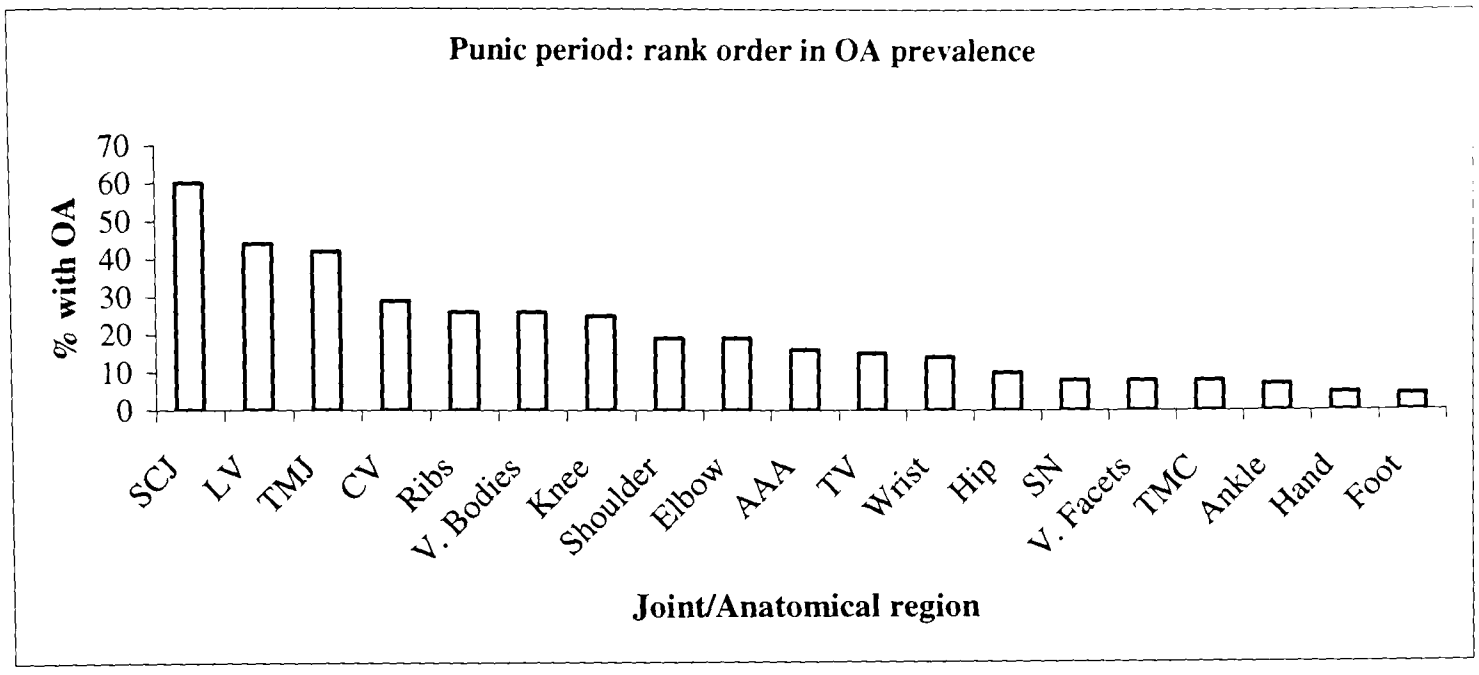
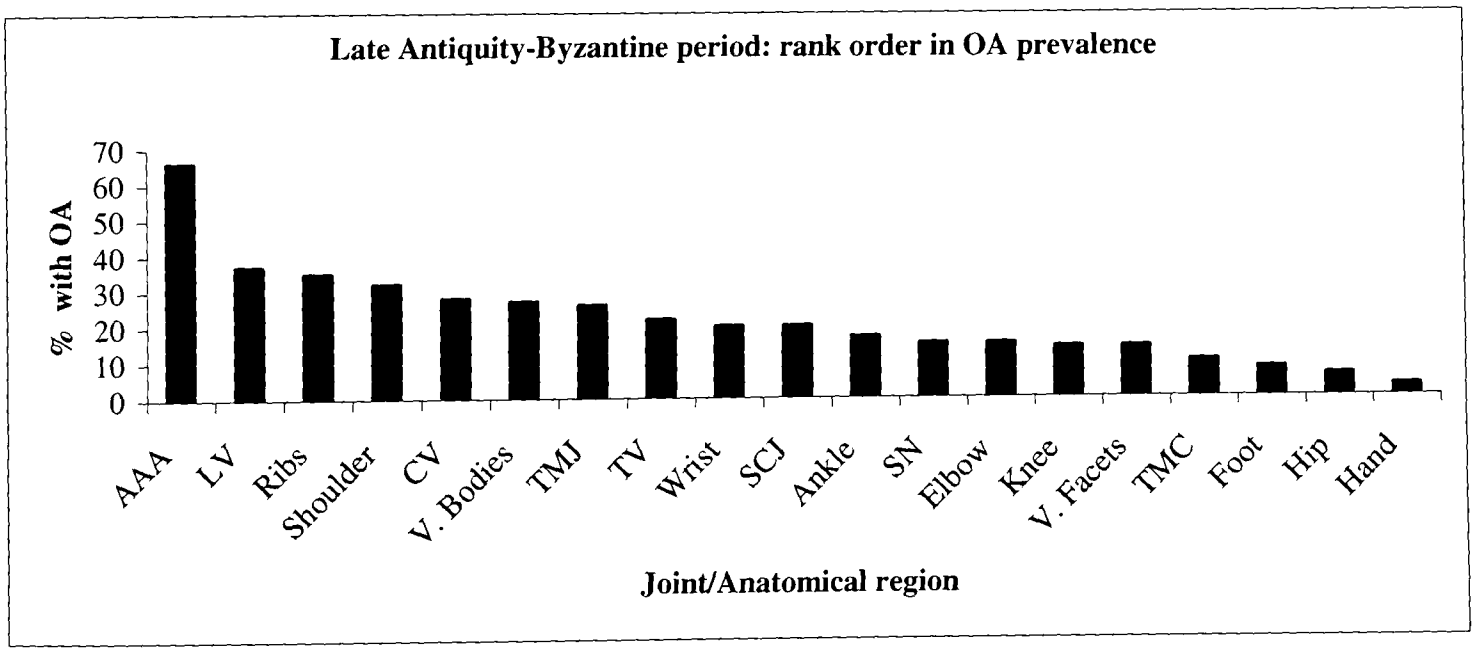


Figure 5.3.4. Late Antiquity-Early Byzantine period: rank order in OA prevalence.



The lower back (LV) was highly affected in both periods, although in general the vertebral column was slightly more affected in Period 2. There were differences in the major joints, for instance the ranking of the shoulder, the elbow and the knee. The least affected joints in both periods were those of the hands and feet. Among the major

joints, OA in the knee was more prevalent in Period 1, while the shoulder was ranked higher in Period 2. The elbow and the hip were modestly placed in the lower half of the rank, although frequencies were slightly higher in the Period 1 sample.

Prevalence rates for upper long bones were similar, although slightly lower in Period 2. Lower limb bones from both periods also had similar prevalence rates. Affected upper limbs joint surfaces in Period 1 accounted for 8.82% (95/1076) compared to the 6.35% (43/667) in the Period 2 sample. Lower limb bones accounted for 8.0% (74/916) and 8.6% (42/488) in the former and latter periods respectively.

With regard to laterality, no differences were observed between left and right sides. All long bones, including clavicles, metacarpals and metatarsals were calculated for each side. In the Punic period, 9.6% (68/702) of bone articular surfaces from the left side and 9.6% (74/764) from the right side were affected. Eight right surfaces and seven left surfaces had eburnation. In Period 2, results were also similar between left and right bones. The total joint surfaces affected were 8.4% (26/309) and 8.9% (28.312) for the left and right sides respectively. There was one surface with eburnation in each side.

5.2.5.4 Summary of key findings

OA or DJD rates in the Punic period did not tend to surpass over 20% of affected surfaces, except for the vertebrae (especially LV), the ribs, the sternoclavicular joint and the knee, which had much higher frequencies. The hip, the hand and foot

bones displayed lower rates of OA. Eburnation was predominant in the limbs, especially the elbow and the knee. Frequencies of upper limbs were similar to lower limbs, and likewise between left and right sides.

When the rural and urban samples were compared, significant differences were found only in the vertebrae and the ribs, which were more affected in the urban sample. The shoulder and the elbow were more affected in the rural area, while hip and knee OA was more prevalent in the urban sample. The rural sample, however, displayed the most severe cases.

In general, Punic males had more OA than females but the difference was not confirmed by statistical tests. The same trend was apparent in the Late Antiquity-Early Byzantine period, but the difference was not statistically significant either.

When OA prevalence in Period 1 was compared to that in Period 2, there were clearly more severe (eburnated) cases in the former period. No grooving (see Rogers and Dieppe, 1993) was found in any of the joint surfaces. This difference between periods was significant when the major appendicular joints were considered. The vertebral column was similarly affected, although the most severe cases were found in the Period 2 sample. Period 1 had higher frequencies than Period 2 with regard to the TMJ, SCJ, elbow, hand, hip and the knee. Period 2 showed higher rates for some vertebral groups, ribs, the shoulder, wrist, trapezio-metacarpal joint, ankle and the foot. The only significant differences, however, were found in the vertebral facets, SN in

vertebrae, the ankle and foot, all exhibiting a higher prevalence in Period 2. From the ranking order (ascending to descending), among the major appendicular joints, the knee was placed higher in Period 1, while the shoulder was higher in Period 2. The hands and feet displayed very low rates.

With regard to eburnation, the pattern also differed. The difference between the two periods was the presence of eburnation in the hip, elbow and hand in Period 1; and in vertebrae, ribs and ankle in Period 2.

5.2.6 Discussion

From the above findings, several issues need discussing. These issues correspond to obtaining a further understanding about the factors contributing to OA in the Ibizan samples and whether the observed rates support or reject the current hypothesis.

5.2.6.1 Discussion: factors contributing to the presence of OA in Ibiza

There were a number of possible factors influencing OA rates in the Ibizan samples. Although the aetiology of OA is multifactorial, some factors will have more weight than others. The data offer some possibility of exploring whether age, trauma, obesity, genetic or occupational circumstances played some role in the presence of OA.

An attempt to understand the relation of age (primary OA) in the Ibizan remains was possible through a limited number of articulated skeletons where age was known. Table 5.2.13 presents the available observed surfaces that belonged to individuals whose age was ascribed to one of the following categories: 20-30, 30-50 and >50 years. Bones from two Punic individuals came from the site VR28, while the remaining came from HLL (Period 2). Data are presented according to the number of surfaces (S) affected as well as the number of individuals (MNI) with the condition. Where a surface or an individual was affected, this was highlighted in the table.

Table 5.2.13. OA according to age.

Joint surface	20-30	30-50	50+
TMJ	S = 0/11 - MNI = 0/8	S = **5/10** - MNI = **4/5**	S = **1/5** - MNI = **1/5**
Atlas (any facet)	S / MNI = **1/5**	S / MNI = 0/1	S / MNI = **2/3**
Axis (dens only)	S / MNI = **1/4**	S / MNI = 0/1	S / MNI = 0/1
Scapula (glenoid cavity)	(No data)	S = **1/1** - MNI = **1/1**	S = **1/4** - MNI = **1/3**
Vertebral body	S = **4/47** – MNI = **2/8**	S = 0/3 - MNI = 0/1	S = **12/17** - MNI = **3/3**
SN (TV and LV only)	S = **13/35** - MNI = **2/5**	(No data)	S = **5/14** - MNI = **2/2**
Sacrum (1st segment)	S / MNI = **2/8**	S / MNI = **3/4**	S / MNI = 0/1
Rib	S = **12/26** - MNI = **2/4**	S =**1/6** - MNI = **1/2**	S = **10/19** - MNI = **2/4**
Long bone epiphyses	S = 0/37 – MNI = 0/9	S = 0/5 - MNI = 0/2	S = **2/22** - MNI = **2/4**
Patella	S = 0/2 - MNI = 0/2	(No data)	(No data)
TOTAL	S = 18.8% (33/175) MNI = 18.8% (10/53)	S = 32.2% (10/31) MNI = 52.9% (9/17)	S = 38.3% (33/86) MNI = 50% (13/26)

Despite the data being limited and most of the ageing based on degenerative changes in the pelvis and dental wear, some interesting trends were present. There was no OA at the temporo-mandibular joint in the young adult category. This is probably a result of its association with advanced dental wear in the older categories (Hodges, 1991). Vertebrae did seem to show that DJD and SN could occur at all ages. This also applied to ribs. A clear example of this conclusion was an articulated female skeleton aged 20-30 years (HLL819) buried separately from others. The young adult age was evident through observations from unfused sternal ends of clavicles, unfused segments (S1 and S2) of the sacrum, in addition to slight dental attrition. This female had SN and DJD in some vertebrae and ribs, although the rest of the joints in the skeleton were not affected.

OA in long bone epiphyses was only present in the older age category. When overall frequencies were considered taking into account all surfaces, the difference between the young age category and the old age category was significant ($x^2 = 6.62$; $p = 0.010$), and equally when the number of individuals affected was considered ($x^2 = 4.20$; $p = 0.040$). There was no significant difference when the young adult surfaces were compared to the joint surfaces from middle aged (30-50 years) individuals ($x^2 = 1.74$; $p = 0.187$), although there appears to be some significance regarding the number of individuals affected ($x^2 = 3.85$; $p = 0.050$).

Despite the small samples and although the age of onset of the lesions was unclear, apart from vertebrae, the trend seems to show that OA in long bones was correlated with age.

The high frequencies of OA at the sternoclavicular joint, mostly characterised by subchondral pitting, were also related to age since the specimens employed had fused epiphyses and were therefore likely to be from individuals over 30 years of age. Some observations during fieldwork saw deep costo-clavicular ligament impressions in the clavicles of adolescents and adults. Repetitive movements in this region, such as repeated raising and lowering of the arm (Stirland, 2000: 132), might reflect heavy physical work or repetitive physical stress in this area. Muscle insertions and bone geometry (e.g. platycnemia) may be an avenue to follow in the future to further understand the pattern of OA in past Ibizan populations.

Lacerations and dislocations can produce disruption to the joint, for instance by disrupting circulation or destroying the cartilage, which in turn may lead to bony changes around the joint (Ubelaker, 1999: 108). Trauma to the joint may have been a contributing factor for the presence of OA. One humerus (AR33-B) provides an example of massive osteophyte formation in its distal epiphysis, likely a result of trauma (Ill. 5.11). Laterality in joints might indicate local trauma, but although some cases (e.g. PM01/UE66) are clearly bilateral, other cases in the disarticulated assemblages provide difficulties establishing whether the degenerative changes were unilateral or bilateral. DJD in vertebrae may have been related at a young age to weight

bearing stresses (e.g. carrying heavy loads on the head) or repetitive rotation movements.

With regard to the knee, body mass index and obesity may have influenced the occurrence of OA. A general pattern of obesity in the population was unlikely particularly in the Punic period where most of the population were the main bulk of the labour force. However, estimating weight could be attempted by applying the formulae devised by Ruff and colleagues (1991) applicable to the dimensions of the femoral head. The equations devised by Ruff and his co-workers were developed against body weight in certain reference samples. The formulae were created for both males and females. It is recommended that the result is reduced by 10% to account for potentially poorer nutrition, more exercise and perhaps poorer living conditions in the past. Unfortunately, the data for this was very limited because it was only restricted to individuals sexed from skull and pelvis rather than solely on long bones. It was also limited to those bones where information on presence or absence of OA was available for the distal femur, the patella or the proximal tibia.

Only eight individuals from Period 2 met these criteria (Table 5.2.14). Unfortunately those individuals that could be measured did not have any OA in the knee (or hip) so that no comparisons in body weight could be made with those that had OA.

Table 5.2.14. Data on body weight obtained from adult femoral head breadths (FHB).

Skeleton	**Sex**	**Side**	**FHB (mm)**	**Body weight (kg)**	**Body weight - 10% (kg)**	**Joints observed**
HLL405.3	F	L	42.3	67.5	60.7	Femur DE, Tibia PE
HLL405.5	F	L	42.4	67.7	60.9	Femur DE, Tibia PE
HLL203.1	M	R	46.8	73.3	66	Femur DE, Tibia PE
HLL203.2	M	L	46.7	73.1	65.8	Femur DE
HLL801.1	M	L	48.8	79	71.1	Femur DE, Tibia PE
HLL809.5	M	L	46.4	72.5	65.2	Patella, Tibia PE
HLL818.2	M	L	48.3	77.6	69.8	Femur DE
HLL820	M	L	47.2	74.6	67.1	Femur DE, Tibia PE

Further data in the future can be added onto this in order to further understand some of the pre-eminent aetiological factors.

Finally, genetic predisposition (e.g. affecting the articular cartilage) may be a factor influencing presence or absence of OA. This may be explored through genetic traits, documentary evidence and material culture. It has been mentioned before that there were a variety of peoples in Ibiza in the past, with immigrants originating from various geographical regions. In this sense, genetic factors may have only contributed a little to the prevalence of OA in each period. However, obviously there were families and genetically related individuals. Some heritability might be evidenced in the prevalence of non-metric traits (NMTs). Although data have been recorded for the Ibizan material, a detailed study is required before any conclusions can be made. A

high frequency of certain NMTs that are dominant heritable traits, such as parietal foramina (see Hauser and De Stefano, 1989: 81), were present in Ibizan skulls. In addition, the site AR33 from Period 2 also shows a clear familial relationship between two individuals[92].

The problems with the material are not insignificant. The limitations imposed by the nature of the assemblages and post-excavation handling, have reduced the potential for such inferences. Not knowing the precise age of the bone can be problematic. In addition, because individuals have not been separately identified, results might be duplicated. It is also worth considering that the prevalence may be affected depending on laterality, sex due to division of labour and differences according to socio-economic status (see Bridges, 1992). Other Punic studies from Ibiza (Gómez, 1989; González-Martín and Lalueza, 2001) have only reported isolated cases or made short comments on osteoarthritis. Protocols for recording need to be established.

In both archaeological and modern populations the knees and the hips are the most affected joints, with those in the clavicle affected in many elderly today (Roberts and Manchester, 1995: 113-114). The Ibizan samples showed a higher percentage in the knee compared to other joints, and eburnation is present in both periods. Hip OA was

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[92] These two individual skulls were labelled AR33-I-B and AR33-I-J. They belonged to young individuals in the 15-20 year age group. At this age, the sex was rather ambiguous in both. They had both male and female traits and both had an occipital bun. Both skulls had a metopic suture, two apical bones and at least two ossicles at either side of the lambdoid suture. These traits are likely to be genetically related since they have a genetic expression and are dominant traits (see Hauser and De Stefano, 1989). Absence of parietal foramina is also a dominant genetic expression (Hauser and De Stefano, 1989: 89) but while one has absent parietal foramina the other has absence in only one of the parietal bones. Nevertheless, some congenital anomalies in atlas vertebrae from the same site also deserve further study in the future.

particularly low although preservation of acetabula was poor. However, if the pattern of more knee than hip surfaces affected with OA is real, this is in contrast to other studies where the knee has only become more prevalent in modern times (Rogers and Dieppe, 1994; Baetsen *et al.*, 1997; Waldron, 1995; 1997). OA prevalence in the knee was significantly higher than the hip in Period 1 ($x^2 = 5.03$; $p = 0.025$), but knee and hip rates were not significant in Period 2 ($x^2 = 2.09$; $p = 0.154$). Knee OA, however, may also be influenced by spending long hours squatting (Aliabadi and Felson, 2004; Zhang *et al.*, 2004).

Changes at the elbows and shoulder are usually rare except in histories of trauma or in jobs with repetitive involvement of those joints (Roberts and Manchester, 1995: 114). OA in the elbow, with severe cases in the rural Ibizan sample, would suggest mechanical stress at that particular joint (Jurmain, 1980; Bridges, 1991). Knee OA in the urban population may have been present according to occupations relating to the sea, amongst many other industrial occupations. Knee injuries are common today in seafarers due to working in the vertical and moving environment of a ship (Pearce *et al.*, 1996).

Lovell (1994) has suggested that lesions in the cervical vertebrae may be a result of carrying loads on the head. Prevalence of DJD in this spinal region reaches a figure closer to 30% of affected vertebral bodies. From the bibliography consulted, the only activity that is reminiscent with regard to carrying loads on the head, is that of farmers working in the Ibizan salt mines during the winter and who would be carrying

loads of salt in their heads as illustrated in some early twentieth century photographs (see Vilá, 1953).

Low frequencies were also informative. The bones in the hand displayed low frequencies of OA. The OA rate at the TMC was much lower than other populations where over 50% of the TMC joint surfaces have been affected (e.g. Cope *et al.*, 2005).

There was no attempt here, though, to associate an occupation with a pattern. This is almost impossible. In the urban environment, a variety of physical demanding professions were likely present. P.G. Mosca has studied epigraphic evidence from Carthage and some of the more physically demanding occupations were identified as goldsmiths, iron casters, craftsmen, salt workers and sailors (Stager and Wolff, 1984: 47).

The different examples employed, have been simply stated to support that the main aetiological factors in Ibiza, especially when the elbow and knee are considered, include physical stress, particularly when the cases with eburnation are taken into account. Obviously age does play a factor with regard to the length of exposure to a particular physical activity. Finally, at least one case of OA (AR33-B) appears to have been a result from direct trauma to the joint.

5.2.6.2 Discussion: relevance to the current hypothesis

In view of the hypothesis, low morbidity in Period 1 was predicted as a sign of the population's well being. OA causes pain, disability (walking, climbing, squatting) and affects the quality of life and the ability to work (Ghosh, 2003: 83; Veerapen *et al.*, 2004).

There were high rates of OA at the TMJ, vertebrae, sternoclavicular and the major appendicular joints such as the elbow and the knee. Especially in the rural context, there were a number of severe cases. These cases, especially at the elbow and at the knee, are a reflection of heavy physical demands on the rural inhabitants. Although longevity may see an increase in the number of joints affected with OA, the presence of this condition at the abovementioned locations rejects the hypothesis of well-being in the Punic populations. Moreover, these rates are probably a true reflection of the intensive economic productivity at the time. Many occupations would have lead to repetitive stain injury (RSI) especially when they involved heavy or manual labour (Roberts and Cox, 2003: 236-237). In the Punic period there was increasing intensification of production (Costa, 2000a: 65, 101) and exportation of Ibizan products elsewhere (e.g. see López and Fierro, 1994; Ramon, 1995c; González, 2004). Even coin production during the Punic Wars would have required a tremendous productive effort, with higher demands on different units of exploitation and more pressure applied to the farmers with perhaps more taxes to pay (Costa, 2000a: 105-106). Pottery manufacture would have caused a number of cases with osteoarthritis (Laraqui *et al.*, 2000; Cope *et*

al., 2005: 397). Potters in present day Sardinia can manufacture about 60 water jars of 15 litres each in a 10-hour working day (Annis, 1985: 247). In Egypt today, potters tend to dislike their job because it is physically demanding and up to 12 hours are invested working every day (Nicholson and Patterson, 1985: 236).

No differences were found between the rural and the urban contexts, except for vertebrae rates that were higher in the latter sample. This similarity probably represents the main bulk of labour in the urban environment and a similar level of physical demand, although probably from different activities to those present in the rural areas.

If intensive economic production and longevity were main factors contributing to the presence of OA in the Punic period, then in view of the hypothesis the similar and at times higher amounts of OA in the Late Antiquity-Early Byzantine sample are puzzling. If it is assumed that OA at a population level is particularly affected by occupations involving intensive production of agricultural products in the rural areas and industrial production in the urban areas, Does this mean similar levels of productivity and similar lifestyles in both periods? Similar lifestyles may then be suggested despite the apparent economic differences. The only clue as to higher intensity of production in the Punic period would be the significantly higher number of cases with eburnation.

The Period 2 sample had significantly higher frequencies of DJD in the vertebrae (also higher SN rates), ankle and the foot. The significantly higher

frequencies in this Period 2 urban sample, also coincides with the Punic urban sample, where DJD in vertebrae was more prevalent than in the rural population.

Similarities between contexts and periods were also found in trauma frequencies. The implications of the results on OA prevalence are difficult to establish, but they would seem to suggest that physical demands, and thus economic activity, were equally present in both periods. When the most severe cases were considered, then Period 1 revealed yet more intensity than Period 2. Thus, there is a possibility that similar environmental or cultural (occupations) circumstances might have been present in Period 2 although at a slightly lower scale than Period 1. The urban contexts, both from Period 1 and Period 2, would see more osteoarthritis in the thorax region from lifting heavy objects, weight bearing stresses and possibly repeated rotational movements due to a number of occupations. In the rural areas, however, severe cases of the elbow and knee must have been associated with repeated movements at these locations due to a number of rural occupations involving the use of tools such as picks, axes, ploughs and sickles as evidenced by archaeological and ethnographic evidence from the Iberian Peninsula and Ibiza (Miguélez, 1985).

5.3 Activity related skeletal modifications: non-metric traits

Non-metric traits (NMTs) are modifications in the skeleton and the teeth that vary between people and/or populations[93]. While some have a strong genetic component (see Hauser and De Stefano, 1989), others are environmentally induced. With an archaeological interest, genetically determined NMTs may be used, for instance, to understand any potential genetic relationships between individuals within the same tomb. Environmentally induced NMTs offer further insights into the lifestyles of past populations. Two most commonly used traits were employed here: *torus auditivus* and squatting facets.

5.3.1 *Torus auditivus*

The presence of these bony growths has been related to subsistence economy, particularly the exploitation of marine resources (Standen *et al.*, 1997; Velasco *et al.*, 2001). Differences between populations may relate to different subsistence economies and also to behavioural factors associated with gender and socio-economic status (see Manzi *et al.*, 1991).

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[93] To understand the concept of non-metric traits in bones, an analogy can be made with pottery. Pottery artefacts can be of various shapes (e.g. plates, drinking vessels). Skulls can also be classified into shapes (e.g. dolicocephalic, brachycephalic). Within the same shape (e.g. pot) NMTs are to the skull what decorative impressions are to the pot. In a range of pots with similar size and shape, many different decorations can be applied to the surface, such as floral and geometrical motifs. This will not affect the shape (the measurements, the metric data) of the pots. In a number of similar pots, variations in floral motif reveal differences according to design or decoration but not according to shape. Likewise, the additional sutures (e.g. metopic suture) or additional bones (e.g. Inca bone) that may show variation in skulls in the same population, do not necessarily affect the shape of the skull, but just its 'design'.

5.3.1.1 Definition

Torus auditivus is a bone growth in the ear, located in the auditory meatus of the temporal bone (Ill. 5.12). These benign bony growths can be classified into two different types (see review in Hutchinson *et al.*, 1997): osteoma (e.g. see Capasso, 1997, 2004) and exostosis (e.g. see Kennedy, 1986: 402).

5.3.1.2 Aetiology

Recently, most authors agree that the appearance of these bony growths, particularly exostosis, is the result of environmental factors such as prolonged irritation (Hauser and De Stefano, 1989: 187). Irritation to the ear may be caused by many factors. They are common in swimmers today and one of such factors contributing to their presence are changes in the pH, which influence the appearance of otitis externa (see Hutchinson *et al.*, 1997). These lesions are also common today in surfers and lifeguards (Chaplin and Stewart, 1998; Wong *et al.*, 1999), especially when active in cold waters (Kennedy, 1986). However, cold water is not the only explanation for these exostoses (Hutchinson *et al.*, 1997; Dr. Conill, pers. comm.).

In past populations they seem to have been associated with subsistence economies. A higher prevalence of *torus auditivus* has been found in populations that exploited marine resources (Kennedy 1986; Velasco *et al.*, 2001; Standen *et al.*, 1997).

5.3.1.3 Methodological advantages and limitations

These bony lesions are relatively easy to identify. Differences between populations might reflect different subsistence economies or different cultural behaviours. It can, thus, provide a further insight into the lifestyles of the ancient inhabitants of Ibiza.

One limitation discussed later below, is that other sources of information are needed in order to interpret the prevalence of these bony lesions in a population.

5.3.1.4 Materials and methods

Observation was based on presence or absence of exostosis or osteoma in the acoustic meatus. Only temporal bones were examined from individuals older than 15 years of age-at-death. When present, drawings and photographs were undertaken that illustrated the morphology, severity and position of the *torus*. Severity was recorded as weak, strong or excessive as indicated by Hauser and De Stefano (1989: 187), weak merely being a small nodule or ridge, and excessive when the bone growth almost or completely occludes the meatus. More recently, similar stages have been recommended elsewhere (Brothwell and Zakrzewski, 2004: 33, fig. 11). Care was taken to classify the lesion into exostosis or osteoma (see Hutchinson *et al.*, 1997: 418). Both lesions are not

easily distinguished (Hauser and De Stefano, 1989: 187), but all those identified in the Ibizan examples appeared to be exostoses located on the external acoustic meatus.

5.3.1.5 Results

Results were given according to number of temporal bones affected. An additional count was made to establish the number of individuals in the sample with the lesions. This latter count was calculated from repeated bone elements, as well as considering differences according to sex, age and tomb boundaries.

5.3.1.5.1 The Punic sample

Table 5.3.1 presents the summarised data subdivided into rural and urban, left and right sides, males and females. The overall rate is also given. The rates include the number of bones with *torus auditivus* (n) and the number of auditory meatuses that were observed (N).

Table 5.3.1. Prevalence rates for *torus auditivus* in the Punic period*.

PERIOD 1	Left temporal bones			Right temporal bones			All[1]	Individuals affected		
	TOTAL	F	M	TOTAL	F	M	TOTAL	TOTAL	F	M
RURAL	2/9	0/4	0/3	3/15	0/1	1/7	5/24	3/15	0/4	1/7
URBAN	0/2	0/2	0/0	0/2	0/1	0/1	0/4	0/3	0/2	0/1
TOTAL	2/11	0/6	0/3	3/17	0/2	1/8	5/28	3/18	0/6	1/8
%	18.1	0	0	17.6	0	12.5	17.8	16.6	0	12.5

* Codes: F = female; M = male; [1] = sum of left and right sides.

The sample was too reduced to make any reliable comparisons between rural and urban settings. The samples were much underrepresented taking into account that thousands of inhabitants lived in *Eivissa* and were buried there in Punic times. The overall frequency of temporal bones with exostosis was 17.8%, while the proportion of individuals affected was estimated as 16.6%. Differences between female and male temporal bones ($x^2 = 0.702$; $p = 0.402$) and between female and male individuals with *torus auditivus* ($x^2 = 0.714$; $p = 0.398$) were not statistically significant.

5.3.1.5.2 The Late Antiquity-Early Byzantine sample

The data for this period are summarised in Table 5.3.2. Overall rates were slightly lower compared to the previous period. The bony lesions were present in male individuals. No female bones displayed the lesions.

Table 5.3.2. Prevalence rates for *torus auditivus* in the Late Antiquity-Early Byzantine period*.

PERIOD 2	**Left temporal bones**			**Right temporal bones**			**All[1]**	**Individuals affected**		
	TOTAL	**M**	**F**	**TOTAL**	**M**	**F**	**TOTAL**	**TOTAL**	**M**	**F**
TOTAL	4/31	4/22	0/6	2/30	2/15	0/7	6/61	4/40	4/25	0/10
%	12.9	18.1	0	6.6	13.3	0	9.8	10.0	16.0	0

* Codes: F = female; M = male; [1] = sum of left and right sides.

Overall prevalence for bones and individuals was similar (c.10%). Although there was a higher number of male temporal bones affected compared to female bones, this differences was not significant (x^2 = 2.03; p = 0.154). When male and female individuals were compared, although the trend suggested that males had more lesions, the difference was not significant either (x^2 = 1.54; p = 0.215).

5.3.1.5.3 Comparisons between Period 1 and Period 2

Prevalence of temporal bones with auditory exostosis was only slightly higher in Period 1 (17.8%) compared to Period 2 (9.8%). The difference was not significant when the number of bones (x^2 = 0.867; p = 0.352) or when the number of individuals (x^2 = 0.399; p = 0.527) were compared.

There was a trend in both periods that males were more affected than females. This difference was not statistically significant, even when all female individuals from both periods (0/16, 0%) were compared to the total number of males (5/33, 15.1%) from the two periods (x^2 = 2.32; p = 0.128).

The clearest cases were found in material from Period 2. All bony growths were weakly expressed, except in two individuals from Period 2 (HLL811.1, 30-50 year old male; HLL203.1, 20-30 year old male) who displayed medium expression. The case that showed more occlusion and involved all the walls of the tympanic part surrounding the external acoustic meatus was AR33-E-C1 (Ill. 5.13), which belonged to an old (>50

years) male[94]. Both temporal bones were present in two of the skulls (HLL203.1, AR33-E-C1) that had bilateral exostoses. This bilateralism also confirmed their diagnosis as exostoses as opposed to osteomata.

5.3.1.6 Discussion

Compared to larger studies reporting on exostoses, the prevalence in Ibiza was lower. A male sample near Rome and dated to the first and third centuries AD had an occurrence of over 30% of individuals (Manzi *et al.*, 1991). Standen and co-workers (1997) reported differences in Chilean populations according to location and subsistence economy. Coastal people were more affected (30.7%) than valley people (2.3%) and highlanders (0%). The conclusions they reached supported a relation between external auditory exostoses and food procurement, in their case probably related to maritime activities involving diving or shell fishing. In a study of 358 adult prehistoric skulls from the island of Gran Canaria (Spain), 13.4% (48/358) of skulls had auditory exostosis (Velasco *et al.*, 2001). The sites that were closes to the coast had a prevalence of 34.3% skulls with exostosis. Those located most inland only had a prevalence of 1.3%. The results have suggested some reliance and exploitation of the neighbouring water resources in the coastal groups, which has also been corroborated with palaeodietary analysis (Velasco et al., 1997).

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[94] I thank Dr. L. Conill, otolaryngologist in Ibiza, for his time, comments and confirmation of the exostosis in this individual.

Information on subsistence economy (see Chapter 6) has indicated that the inhabitants of Ibiza predominantly relied on the land. Marine protein was not a basic foodstuff, although some activities related to the sea would have been present. One such activity might have been diving to provide shellfish (e.g. *Murex trunculus*) for the purple dying industry. The extent of bathing or swimming is unknown as well as its influence on the appearance of these bony lesions. However, it would be prolonged and repetitive irritation that would have caused the appearance of these lesions.

The differences between males and females suggest a clear trend, despite the results not being statistically significant. Similar trends are found in other studies (Manzi *et al.*, 1991; Standen *et al.*, 1997) where females have low or no exostoses compared to males. If division of labour is not one possible explanation, Manzi and colleagues (1991) provide an alternative with regard to the Roman period, and which could be equally applicable to Late Antiquity. The authors propose that certain rituals in the thermal baths with both cold and hot water resulted in a 'thermal shock' and irritation in the ear canals. Regarding the difference between males and females they proposed that males during bathing went through the *frigidarium*, a cold swimming pool (Manzi *et al.*, 1991). This would have caused a 'hyperaemia' and irritation in the auditivus meatus (Prada *et al.*, 2004). This would also be related to the hypothesis that an irritating factor is cold water (Kennedy, 1986). By contrast, females may not have gone through this bathing ritual as attested by the absence of a *frigidarium* in the female sector in Pompeii (Manzi *et al.*, 1991: 259). The thermal bath theory is also one

possible interpretation given to a Spanish sample where males were more affected than females who did not reveal any exostoses (see Prada *et al.*, 2004).

Towns in Late Antiquity and Byzantine times had baths (Mango, 1980: 61, 63; Foss, 2002: 76). Whether baths were present in Ibiza or whether they were different for men and women, rich and poor, is unknown. It is in these situations, that other sources of information (the 'biocultural approach') will be essential in the future.

Other Punic sites have not reported any exostoses. The only case that was found for Spain came from a skull from Cadiz dated to the second century BC (Macías *et al.*, 1999). From the report it is difficult to calculate the prevalence, the adult male affected was the only one affected from a sample of at least 31 individuals as inferred from the report, which would result in a frequency of 3.2%. Submersion in cold water may have been a possible contributing factor in this individual (Macías *et al.*, 1999: 104).

Certainly those individuals in Ibiza and elsewhere must have been undertaken some activity related to marine life for some time. A study of surfers and life savers (n = 92) from New Zealand indicated that 73% of the subjects had exostoses and that 40% had their auditory canals narrowed by over 50% (Chaplin and Stewart, 1998). The number of years was highly significant, with obstruction appearing after around 7 years. Over 90% of subjects that had been surfing or life saving for over 10 years had exostoses, and those with more practice years had the most severe cases (Chaplin and Stewart, 1998: 327). In their study of 307 surfers, Wong and colleagues (1997) also

found a high prevalence of exostosis and a positive correlation between time spent surfing, and presence and severity of these pathological conditions. From the sample, 30% with exostoses had surfed more than 300 days a year and those surfing in cold water had a higher prevalence than those surfing in warmer waters or only in the warmer months (Chaplin and Stewart, 1998: 328-329).

In order to interpret accurately the frequencies of *torus auditivus*, future sources of information will be needed. This information could derive from documentary sources, structural remains (e.g. baths) and artefacts that might provide information about how the marine ecosystem was exploited if that was the case. This additional information could basically indicate whether the bony lesions were a result of subsistence (e.g. diving) or personal leisure activities (e.g. bathing).

They key finding from the analysis of *torus auditivus* is that the population in general was not regularly involved in exploiting the marine resources, a conclusion confirmed from the dietary evidence (Chapter 6).

5.3.2 Squatting facets

Variation in squatting facets between populations has been noted since at least the end of the nineteenth century (e.g. Thomson, 1889). The prevalence of squatting facets as observed in the tibiae may reveal something about habitual posture in relation

to occupation or domestic living. In addition, regular squatting may influence the prevalence of knee OA (Aliabadi and Felson, 2004; Zhang *et al.*, 2004).

5.3.2.1 Definition

Squatting facets are smooth areas of articulation that can be found as extensions of the distal epiphysis in the tibia (Ill. 5.14) and in the trochlear surface of the talus (e.g. see Thomson, 1889; Barnett, 1954; Boulle, 2001a).

5.3.2.2 Aetiology

These facets are present in adult individuals that have spent a lot of time squatting, and thus with their legs hyperdorsiflexed (Ubelaker, 1999: 102). Kneeling may also cause alterations in bone, both pathological and non-pathological, due to a hyperdorsiflexion position (Ubelaker, 1979, 1999: 103; Molleson, 1994; Prada and Stepstone, 1999).

In archaeological populations, squatting facets are usually present in skeletons of individuals who usually did not have furniture or worked on low ground (Mays, 1998). In medieval Europe, the frequency of squatting declined due to the wide use of furniture in dwellings (Wells, 1964: 132; Boulle, 2001b). High frequencies have also been found in rural populations that practised farming (e.g. Ari *et al.*, 2003). Squatting facets are also likely to occur frequently in skeletal samples from monastic contexts,

whose people had spent much time kneeling or with the lower limbs dorsiflexed during prayer (Ullinger *et al.*, 2004). Arguably, these facets may also appear in horse riders (Molleson and Hodgson, 1993: 96).

5.3.2.3 Materials and methods

A total of 45 tibiae from the Punic period and 20 from the Late Antiquity-Early Byzantine period were employed. Only adult tibiae were considered where the distal epiphysis was fused to the diaphysis. Both left and right tibiae were observed.

None of the analysed bones had any apparent severe pathological condition. Apart from prevalence rates according to tibiae observed, data analysis also investigated frequencies of individuals with squatting facets. The individual prevalence ensured a more reliable count with regard to number of individuals affected and reduced the error of including duplicates. This was undertaken considering repeated elements, differences according to sex and different tomb boundaries.

The anterior margin of each distal tibia was observed for presence or absence of a squatting facet on the lateral aspect. The inferior articular surface of the distal epiphysis continues anteriorly when squatting is present and on the lateral border (Ari *et al.*, 2003: 144). Medial facets were also recorded but appear less frequently in the literature cited above, and hence only the lateral facet was selected since it would be more representative of the population.

5.3.2.4 Results

A summary of the data is provided. No inferences could be made about sexual dimorphism due to the small sample of sexed tibiae in the commingled assemblages.

5.3.2.4.1 The Punic sample

Table 5.3.3 provides a summary of the data according to number of cases with lateral squatting facets and the number of distal tibiae observed (n/N). Male and female tibiae counts are also given.

Table 5.3.3. Lateral tibial squatting in the Punic sample.

Context	Tibiae	Individuals	Males	Females
Rural	37/38	19/19	1/1	1/1
Urban	7/7	4/4	2/2	1/1
Total Period 1	44/45	23/23	3/3	2/2
%	97.7	100	100	100

From the information above 100% (23/23) of individuals observed had lateral squatting facets. The prevalence was equal in the rural and urban contexts although the latter was very poorly represented.

5.3.2.4.2 The Late Antiquity-Early Byzantine sample

Table 5.3.4 summarises the data for this period. A total of 66.6% (10/15) individuals had lateral squatting facets in their distal tibiae.

Table 5.3.4. Lateral tibial squatting in the Late Antiquity-Early Byzantine.

Context	Tibiae	Individuals	Males	Females
Total Period 2	12/20	10/15	5/7	2/2
%	60.0	66.6	71.4	100

5.3.2.4.3 Comparisons between Period 1 and Period 2

There were more individuals and tibiae affected in Period 1 compared to Period 2. In the former, 100% of individuals had squatting facets, while in the latter 66.6% had the traits. Despite this apparent difference, the results were not statistically significant ($x^2 = 0.651$; $p = 0.420$). Even when tibiae affected were compared, 97.7% (44/45) in Period 1 and 60% (12/20) in Period 2, the difference was not significant ($x^2 = 1.35$; $p = 0.245$).

5.3.2.5 Discussion

From the above data it would appear that individuals in the Punic period were more involved in habitual squatting than those in the later period. The small samples cannot be representative of each period however and this was a severe limitation.

Statistical tests revealed the results were not significantly different between Period 1 and Period 2.

Perhaps, from this perspective, future examination of material culture such as terracotta figurines (Aubet, 1957; García, 1990; San Nicolás, 1983, 1984a, 1987) may reveal some habitual postures, although these representations are mainly religious and funerary in character.

At the Romano-British site at Poundbury 32% of female tibia had squatting facets compared to only 12% of male tibiae (Farwell and Molleson, 1993: 200). The authors pointed out that these differences could relate to women spending much time kneeling in activities such as grinding corn (also see Molleson, 1994). Brown (1987: 277) writes that in towns in Late Antiquity there were 'crippled and indigent, vagrants and immigrants' who squatted at the entrance of the basilica. Squatting facets may have also been present in monks (Ari *et al.*, 2003; Ullinger *et al.*, 2004). In late medieval or post-medieval European contexts presence of squatting facets in an individual might indicate a person of low socio-economic status (Wells, 1964: 132). Today squatting facets are frequent in countries where there is poverty (see bibliography in Kennedy, 1989).

What can be gathered from this data is that at least a large number of individuals were involved in activities that required hyperdorsiflexion. The prevalence in each period was high. No differences between sexes could be explored due to the small

sample size. The results suggest no differences between periods. Whether these similarities are a reflection of similar life conditions (e.g. similar dwellings, similar amount of furniture) or whether they relate to occupations requiring similar postures, awaits clarification.

6 CHAPTER SIX - DIET, NUTRITION AND SUBSISTENCE ECONOMY

Diet can be defined essentially as the kinds of foods that are eaten (e.g. beef, bread) and the pattern of consumption. Nutrition is the nutritional value (nourishment) of that food (e.g. protein, carbohydrate). Subsistence in relation to diet can be defined as the way in which people managed to acquire foodstuffs (e.g. hunting, farming).

An understanding of the diet, nutrition and subsistence economy of past people, especially with regard to the present hypothesis on morbidity, should inform about the well-being of the population. The assessment of the health status of the population should also consider oral pathology. In addition, the type of diet and nutrition might provide some clues as to possible contributing factors for the presence of pathological conditions such as *cribra orbitalia*. Information about subsistence economy might provide some insights into activities (e.g. farming) that might increase the risk of suffering from trauma or OA. Knowledge of subsistence may also provide further interpretations as to the prevalence of *torus auditivus*. These issues are only but a few addressed within the broader context of nutritional anthropology (see Harrison, 1985), although in the present research this information was restricted to the skeletal remains.

Nutrition, diet and subsistence can be associated with mortality and fertility (Harrison, 1985: 338). Malnutrition is the most important associated factor leading to high mortality rates in developing countries (Gabr, 1987: 5). Moreover, severe

malnutrition in females can affect the age of menarche and increase the risk of miscarriage and stillbirth (Santley and Rose, 1979; Gabr, 1987).

Stature and morbidity will also be affected. Good nutritional availability might lead to increased stature and provide better adaptation to infections. Diet may be seen as a possible aetiological factor of iron-deficiency anaemia. For instance, reliance on marine resources in Chinchorro people from Chile may have exposed them to helminth parasites if eaten raw or poorly cooked (Arriaza, 1995). This might have resulted in an increase in anaemia and thus *cribra orbitalia.* Pathological conditions may show a different trend between meat-eaters and vegetarians (Robinson, 2001). Socio-economic status in relation to diet may also result in different disease conditions. In a mediaeval monastic community in England, high prevalence of diffuse idiopathic skeletal hyperostosis (DISH) may have been related to a 'rich' diet (Rogers and Waldron, 2001).

Such dietary influences act upon disease response, reproductive competence, cognitive functions, intellectual development, work output, productivity, social and behaviour functions, socio-economic consequences, individual behaviour, morbidity and mortality, amongst others (Gabr, 1987). Productivity can be affected by nutrition (Gilbert, 1985: 342; Gabr, 1987: 10) that will, in turn, worsen the quality of life. Such influence acts upon finger dexterity, limb coordination, physical performance and muscle strength (Gabr, 1987; Henneberg *et al.*, 2001).

There is a synergistic effect between nutrition and disease. Those undernourished are more prone to infections; but also those with infections tend to worsen their nutritional state (Gracey, 1987: 201; Gabr, 1987: 4-5). In addition, poor dental health (e.g. gingivitis, abscess, tooth loss) associated with diet can promote poor nutrition if the oral pathological conditions are painful (Powell, 1985: 307). This would lead to a loss of appetite, less resistance to infection and thus might influence mortality levels (Powell, 1985: 308).

Diet may be inferred from various sources (see Brothwell and Brothwell, 1998). These include animal and plant remains (Alonso, 2000; Canal, 2000), stomach contents in mummies (Brothwell, 1986), settlement sites, coprolites, artefacts, epigraphy and documentary sources. Some inferences can also be made from observations on the present landscape (e.g. Rivera and Obon, 1989). If there is a lack of faunal remains, their presence may be inferred through their 'secondary products' (see Sherratt, 1981), such as bone implements, leather or egg shells.

More directly by examining human skeletal remains data on diet can be gathered from a number of dental and skeletal indicators (see Polet and Orban, 2001). These are dental attrition (Smith, 1984) and dental microwear (Pérez-Pérez *et al.*, 1991a; Lalueza, 1992), oral pathology including caries and dental calculus (e.g. Turner, 1979; Littleton and Frohlich, 1993; Lieverse, 1999), trace element analysis (see Spanish studies by Pérez-Pérez *et al.*, 1991b; Subirà and Malgosa, 1992; Malgosa, 1997) and stable isotope analysis (e.g. Schwarcz and Schoeninger, 1991; Tieszen *et al.*, 1992; Richards *et al.*,

1998; Katzenberg, 2000; Lillie and Richards, 2000). Some information may also be gathered from pathological conditions such as those affected by vitamin deficiencies (see Stuart-Macadam, 1989b; Roberts and Manchester, 1995). Some human bones may also provide evidence for cannibalism (White, 2001). Advantages and disadvantages in using these sources, particularly with regard to Ibiza, have been reviewed elsewhere (Márquez, 2003), some of which are discussed below.

With regard to diet, cultural factors must be taken into account when attempting to reconstruct the lifestyle of past peoples. Food selection may be associated with political, moral, religious and spiritual issues (Parker, 2003; also see Grimm, 1995). For instance, in the light of some evidence, fish consumption might have been a taboo in prehistoric Britain (Parker, 2003: 15-16) and even in Roman times (see Purcell, 1995).

In summary, as many parameters as possible should be employed in order to obtain a more complete picture of a population's diet. All methods complement each other. Faunal remains provide clues as to the animals that may have been consumed. They do not provide, however, direct evidence for the amount of consumption or its pattern with regard to age and sex, but stable isotope analysis does. This chemical analysis obtains a direct measure of an individual's dietary protein consumed over several years during his or her life. This method, however, requires some destruction of bone, appropriate equipment and financial resources. Documentary evidence may only mention diet in the higher social classes, while oral pathology may provide clues as to the general diet in all social and economic classes of society. By contrast, oral pathology

will generally reveal general patterns of consumption (e.g. high carbohydrate intake) but will not provide evidence of particular foodstuffs that were consumed (olives, fish sauce, honey, figs) which may be found through documentary evidence and/or bioarchaeological analysis.

The methods employed in this thesis to investigate the diet, nutrition and subsistence economies of the Ibizan populations relied on oral pathology and stable isotope analysis. It also considered other sources of information such as artefactual and documentary evidence.

6.1 Oral pathology

Oral pathology was employed here primarily to investigate the diet of past populations from Ibiza. Dental pathology can also serve as a possible means of inferring cultural change (Emery, 1963). In addition, low levels of oral hygiene (e.g. abscesses, gingival inflammation) might promote poor nutrition through loss of appetite due to pain and also due to a reduced efficiency in mastication (Powell, 1985: 307-308). Thus, 'population morbidity and mortality levels are directly affected to some degree by the prevalence quality of dental health, which in turn is influenced by directly and indirectly dietary factors' (Powell, 1985: 308).

In this chapter, the examination of oral pathology was divided into: a) a detailed study of dental caries and *ante-mortem* tooth loss; b) a brief examination of other conditions including dental attrition, dental calculus, periodontitis and periapical cavities.

6.1.1 Dental caries and *ante-mortem* tooth loss

Prevalence of dental caries (DC) is strongly influenced by diet and subsistence technology (Larsen, 1997a). *Ante-mortem* tooth loss (AMTL) may be a result of DC (Larsen, 1997a). AMTL in combination with DC can serve as a general indicator of diet (Kelley *et al.*, 1991). For instance, advanced attrition (see below), low caries rates and

no *ante-mortem* tooth loss may be characteristic of a diet relying predominantly on marine resources (Littleton and Frohlich, 1993).

6.1.1.1 Definitions

DC consists of an infection that destroys tooth enamel and in occasions also the dentine and the cementum, as a consequence of the acid produced by bacteria and dental plaque (Hillson, 1996; Langsjoen, 1998). This destruction results in a cavity (Ill. 6.1, Ill. 6.2).

AMTL refers to those teeth lost (e.g. by extraction) during an individual's life (see Ill. 2.28). Thus, AMTL is different to *post-mortem* tooth loss (PMTL). PMTL refers to any teeth lost after death, for instance, due to taphonomic factors.

In clinical dentistry, most AMTL are a result of extraction of a tooth with advanced DC (Kelley *et al.*, 1991: 205). For this reason, the prevalence rates for AMTL and DC must be investigated together in order to obtain a more reliable estimate of the real DC frequency in a population (Kelley *et al.*, 1991; Lukacs, 1995; Erdal and Duyar, 1999; Duyar and Erdal, 2003).

6.1.1.2 Aetiology of dental caries

According to Palmer (1989: 134), the presence of DC depends on three interacting factors: a susceptible host, a sufficiently virulent agent and a caries-promoting environment.

The main factor associated with the presence of DC is the consumption of carbohydrates, in particular sugar (Hillson, 1996; Moyniham, 1998), although other factors must also be considered (Woodward and Walker, 1994). High frequencies of DC are usually present in populations that base their diet mainly on vegetables (Hillson, 1979).

A diet mainly relying primarily on the consumption of marine resources and meat will result in a lower frequency of caries compared to a diet including vegetables and more refined products such as sugar (Polet and Orban, 2001). Milk, cheese and some plant foods stimulating salivary production are anticariogenic (Moyniham, 2000; Grenby *et al.*, 2001). Proteins and fat and some nuts may also have a protective effect (Palmer, 1989: 139, 146). Eskimo groups that consumed seals and other fats, rather than refined sugar products, had a low prevalence of DC (Costa, 1980a, 1980b; Price, 1945: 68). Dried fruits such as figs also have high sugar concentrations and are very cariogenic. They are sticky and retentive in nature and if held in the mouth for a relatively long time, provide a favourable environment for bacteria (Palmer, 1989: 141-142).

Tooth crown shape and size, attrition, food texture, frequency of consumption, chemical composition of food, age and heredity also influence caries prevalence (Powell, 1985; Larsen *et al.*, 1991). Fluorine also has a protective effect and water fluoridation will reduce dental decay (see Jones and Worthington, 2000), but detecting levels of environmental fluorine in the context of past populations is difficult (Hillson, 1996). Finally, oral hygiene is important in preventing DC.

6.1.1.3 Methodological advantages and limitations

DC is possibly the most commonly reported of the dental diseases (Roberts and Manchester, 1995: 45). Alongside other indicators such as dental attrition and stable isotopes, dental caries is regarded as 'one of the most important ways in which the diet of past populations can be reconstructed' (Hillson, 2001: 249). An additional advantage is that teeth are usually well preserved in skeletal assemblages.

Some potential problems to consider when employing DC are diagnostic in nature. Diagnosis of fissure caries may be difficult (Hillson, 1996). Moreover, radiographs have proved to be an essential diagnostic tool for discovering some cavities (Lingström and Borrman, 1999), but access to radiographic facilities may not always be possible. There is also a need for standardisation and to consider important factors such as dental wear, tooth type, age, and type of carious lesion (Hillson, 2001).

In addition, when comparing populations, there is a need to distinguish rates according to age and sex groups, as well as upper and lower dentition but not essentially according to left and right sides (Hillson, 2001). Costa (1980a: 504) states that 'Epidemiological trends can only be established if age and sex are known for a sufficient number of individuals to ensure statistical reliability'.

DC is correlated with increasing age (Costa, 1980a: 505; Hillson, 2001: 253), unless a sudden cultural or dietary change is involved (Costa, 1980a: 512). Populations with a higher number of older individual may have a higher incidence of DC than a sample comprised mainly of younger adults (Larsen *et al.*, 1991: 182). This also applies to deciduous teeth (e.g. see Watt *et al.*, 1997). Although upper and lower teeth can be easily differentiated, attempts to classify teeth into age and sex categories are more difficult since it depends on the skeletal preservation and archaeological context (e.g. articulated, disarticulated). Even when teeth are aged according to dental attrition, dental caries is still not specifically related to trends in age, but rather in dental wear (Hillson, 2001: 272).

Sex is also an important consideration. Higher frequencies of caries in females tend to be common in many archaeological populations and the reasons for this may be earlier dental eruption in girls, easier access to food during food preparation and the effects of hormonal fluctuations (Šlaus *et al.*, 2004: 258). The physiological changes during pregnancy may predispose women to dental caries (Laine, 2002).

With regard to interpreting the results, in general low socio-economic status is associated with an increase in caries. This association is partly a result of poor people having to rely on cheaper foodstuffs such as carbohydrates foods (e.g. bread) other than meat or fish (Larsen, 1997a; see Salvadei *et al.*, 2001). Contrastingly, however, high status individuals can also exhibit higher frequencies of dental caries if they consumed certain high status or exotic products, for example sticky fruits such as figs and dates, which may not have been readily available to poor individuals (Roberts and Manchester, 1995: 48). The Roman diet for the rich included many foodstuffs, which along with the amount taken and the frequency of consumption fulfilled all the requirements of a cariogenic diet (Emery, 1963: 280). In general, however, the Ibizan cemetery populations will primarily represent the average population in terms of socio-economic status.

In general, a higher incidence of DC in past populations appears to be closely related to deteriorating living conditions (e.g. Manzi *et al.*, 1999; Bonfiglioli *et al.*, 2003). In the Roman world cereal, particularly in the form of bread, was the staple food of the poorer rural classes, while meat would only be eaten sporadically such as on festive occasions (Bonfiglioli *et al.*, 2003: 53). Pork and meat consumption was mainly restricted to high status and some military individuals (King, 2001; see also Frayn, 1995). By contrast, 'improvement' in the living standards has also seen an increase of degeneration in oral health (Price, 1945; Bennike, 1985). Periods of technological innovation, increased trade relations, increased products with refined sugars, and increased longevity may be factors influencing this trend. These factors may be partly

true for the higher prevalence rates of dental disease in the Roman Period in Britain compared to prehistoric and the early medieval periods (Emery, 1963; Roberts and Cox, 2003).

6.1.1.3.1 Remarks on *ante-mortem* tooth loss

As stated previously, AMTL is associated with DC. The aetiological factors of DC have been listed above. Kelley *et al.* (1991) in a study of five Chilean populations representing a variety of subsistence patterns indicate how the combination of dental caries and AMTL is a sensitive indicator of the diet in general. Foragers predominantly eating animal protein have low prevalence of DC and AMTL (Larsen, 1997a).

One limitation in using AMTL to obtain reliable DC rates is that it is difficult to determine the cause of tooth loss (Hillson, 2001: 255-256). As Hillson (2001: 268) indicates, 'Once erupted, permanent teeth are lost only when they are removed mechanically through injury or surgery, or when so much supporting bone is lost through remodelling of the alveolar process that they can no longer be sustained in position. This remodelling takes place in relation to continuous eruption, the changing occlusal relationships between teeth resulting from attrition, periodontal disease, and periapical bone loss relating to exposure of the pulp to infection' (Hillson, 2001: 268). Most AMTL however will result from advanced attrition resulting in continuous eruption and subsequent tooth loss, or will be caused by DC. Lukacs (1995) has designed a formula to determine what proportion of teeth lost *ante-mortem* is due to

dental wear rather than dental caries. His formula is explained below and later applied to the Ibizan dental sample.

A further contributing factor in AMTL, however, might have been cultural practices involving the removal of teeth (Townsend *et al.*, 1994). Tooth ablation for aesthetic and other purposes would affect anterior teeth and has been carried out since prehistoric times (see Fitton, 1993). A sample where many anterior teeth have been lost *ante-mortem*, especially when young adults are considered, some cultural (e.g. ritual) factors might explain this loss (Costa, 1980b: 583). Loss of posterior teeth would tend to be rather a result of extraction (e.g. due to pain) through medical intervention. Examples of true dental prosthesis have been found dated to the seventh and fifth centuries BC from Etruscan and Phoenician contexts (Clawson, 1934; Emptoz, 1987). One of the Phoenician examples from the Eastern Mediterranean displays a lower jaw where six teeth are held in place with a golden appliance in order to bridge them together (Clawson, 1934). On occasions, the decayed teeth are replaced by other human or animal teeth. In Carthage, there is evidence of prosthetic replacement of human teeth with animal teeth since Phoenician times (Brisko and Dozier, 1986). One later example, dated to the sixth century AD (Early Byzantine period) reveals an implanted goat premolar in a human maxilla (Brisko and Dozier, 1986).

Finally, another potential problem is that the alveoli of teeth lost just before death will not show recognizable signs of remodelling and may be confused with *post-mortem* tooth loss (Lukacs, 1995: 151-152). However, 'The effects of this type of error

in counting antemortem versus post-mortem tooth loss is small and has a negligible effect on subsequent calculations of dental lesion frequency' (Lukacs. 1995: 152).

6.1.1.4 Materials and methods

The materials and methods are reviewed separately for DC and AMTL.

6.1.1.4.1 Dental caries

Erupted deciduous and permanent teeth were examined for DC. A total of 69 deciduous teeth in Period 1 and 182 deciduous in Period 2 were examined. Permanent teeth accounted for a total of 519 in Period 1, divided into 217 from the rural sample and 302 from the urban. The Period 2 sample consisted of 1214 permanent teeth.

If dental eruption was not confirmed in isolated deciduous and permanent teeth, they were only counted if their roots had completely formed. In the case of deciduous teeth with resorption (occurring after completion), these were also taken into account.

All teeth were examined for general dental pathology apart from caries. Teeth were observed macroscopically. On some occasions a dental probe was employed in order to verify possible carious lesions in occlusal surfaces (Chimenos *et al.*, 2001: 540). These probes were run along the fissure or groove and DC was suspected when they catched or sticked (Hillson, 2001: 261). A diagnosis of caries was made in all

surfaces when there was clear evidence of loss of tooth substance. The DC rates reflect cavities and not any possible presence of pre-cavitated lesions (see Hillson, 2001), which are more complex to diagnose.

For the identification and recording of dental caries the recommendations by Hillson (2001) were followed. Hillson (1996: 291, 2001) has based his recommendations primarily on studies by Moore and Corbett (1971, 1973). Each tooth was examined visually for evidence of a black or necrotic site. Recording the area of the initiation of caries is important as the different types of location are related to different types of aetiology and cariogenic potentials (Ortner and Putschar, 1981: 438; Hillson, 2001).

The number of teeth affected was counted instead of the number of mandibles/individuals affected. Many teeth were found loose and many mandibles fragmented. Presenting caries as a percentage of teeth affected was advantageous because it included isolated teeth and increased the sample size (Hillson, 2001: 256). It also allowed obtaining frequencies according to tooth type. In addition, most mandibles or maxillae did not preserve all the teeth, and making inferences about prevalence of DC in an individual when teeth were missing would have been unreliable.

Scoring accounted for the overall tooth and also for its surfaces (e.g. see Whittaker *et al.*, 1981). When a lesion was present in a tooth, the type of tooth was indicated, together with the location in the tooth where the infection originated:

occlusal caries (pit and fissure), coronal caries (mesial, distal, buccal, lingual surfaces), cemento-enamel junction (CEJ) or cervical caries (mesial, distal, buccal, lingual sides), and finally those classified as root caries and as gross lesions. Gross lesions referred to large cavities in the crown or, when the crown had been destroyed completely, lesions that had left the pulp exposed[95]. Thus, the term 'gross' referred to lesions where the site of caries initiation was unclear.

The severity of the lesion was classified according to the categories drawn by Brothwell (1981) and Kelley *et al.* (1991). Photographs, drawings and measurements were taken for each lesion.

Although information was obtained from each surface and tooth, when comparing sites analysed in this thesis, DC frequencies were pooled to overall rates according to tooth class (anterior, posterior). Anterior teeth included incisors and canines, while posterior teeth included premolars and molars. Despite these recommendations by Hillson (2001) and earlier authors (e.g. Moore and Corbett, 1971, 1973), overall caries rates for all teeth are still published today and used in order to make inferences about populations. According to Hillson (1996: 280), 'most archaeological studies still express the count of caries teeth only as a percentage of teeth present. This is unsatisfactory because if tooth classes are not separated, the overall percentage is influenced by the pattern of postmortem tooth loss. Dental caries is more common in molars than anterior teeth and molars are less likely to be lost

[95] Sometimes only roots (without crowns) are preserved. These can be a result of attrition or caries, apart from *post-mortem* damage. Differences distinguishing pulp exposure due to caries or due to attrition is provided by Lukacs (1995) and Hillson (2001: 264).

postmortem so that archaeological collections with poor anterior tooth preservation will have artificially inflated caries rates'.

Even when dental types are provided, certain authors still do not distinguish between surfaces observed (e.g. occlusal *versus* coronal). At the time of Hillson's (2001) publication, the author indicated that the recording methods he proposed were being tested (Hillson, 2001: 274). The proposed methods provide reliable estimates of DC, although unfortunately it did not allow comparisons with other sites from Ibiza that have employed different methods or have only provided overall rates. These recommendations have highlighted that the percentage of caries should be obtained from the number of *surfaces* observed rather than the number of teeth observed. Surface count was useful since not all the tooth might have been available for observation. Wear, soil, preservation and dental calculus may have impeded observation (scored as 'unobservable) in one surface but not in the other. With regard to calculus, for instance, Hillson (2001: 265) recommends that because there is no guarantee whether a surface underneath calculus is caries-free, then it should be scored as unobservable.

Initially, pit and fissure caries was scored on occlusal surfaces of premolars and molars if the enamel had not been worn away. Examination of coronal caries, such as approximal contact caries was scored per two surfaces observed (mesial and distal). Only one contact surface was scored for the last tooth (e.g. the third molar) of the dental quadrant. When third molar agenesis was present, the last tooth in the quadrant

was the second molar. However, in isolated second molars and in fragmented mandibles, third molar agenesis was unknown. In these cases, the second molar was still scored on its two surfaces (mesial and distal).

Presence or absence of coronal caries was also scored on the buccal/labial and lingual surfaces of the tooth. In cases where attrition had worn over one third of the crown, it was thought appropriate not to count the observations of coronal surfaces in the DC prevalence rates for those surfaces. Recording also considered lesions at the cemento-enamel junction (CEJ), also known as 'root surface lesions' (Hillson, 2001). These were also scored according to the number of surfaces observed (mesial, distal, buccal and lingual). Observations were also made in the lower root of isolated teeth only, scoring present or absence of DC although prevalence rates were not given for this area since it is strongly associated with periodontal disease in advanced age[96]. If only the root was present as a result of advanced caries, then the lesion was classified as a gross lesion. Gross lesions were classified as gross coronal, gross cervical or simply as gross when all or most of the crown was absent. In summary, apart from gross lesions, following recommendations in the literature (Hillson, 1996: 291), fissure and pit caries was scored according to one observed surface, approximal as two observed surfaces, bucco-lingual also as two and CEJ as one overall surface[97].

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[96] The number of cases of root lesions located well below the CEJ was seven, excluding those with gross lesions and that were counted. A more detailed breakdown of all DC lesions is included in the original archives and in a 'Microsoft Excel' database, which are available for consultation if required.

[97] Coronal caries in deciduous teeth was only scored as one count (one for the whole of all four coronal surfaces) because crowns were small and most were found isolated so it was practical to observe the whole crown especially when the DC rates were low.

Once these frequencies were obtained for upper and lower, left and right tooth surfaces, when comparisons were made between samples overall DC assessment per tooth as a *whole* (instead of its six scored surfaces) was necessary if the different caries correction factors were to be applied (Lukacs, 1995; Erdal and Duyar, 1999; Duyar and Erdal, 2003). These correction factors provided a more 'real' and reliable estimate of the true caries rate by considering the number of teeth with caries and the effects of AMTL and PMTL. In order to achieve reliability, separate tooth classes were necessary rather than overall tooth rates. Separation according to tooth class was important since posterior teeth (especially molars) are more susceptible to DC than anterior teeth (Hillson, 2001: 252). Hence, the dental samples were grouped into the following tooth classes: anterior (incisors and canines) and posterior (premolars –only in permanent dentitions- and molars).

6.1.1.4.2 *Ante-mortem* tooth loss

AMTL was distinguished from PMTL by observing at least some remodelling of the alveolar bone and tooth socket, which occurs after a tooth is lost (Costa, 1980b: 580).

The loss of teeth during life or a*nte-mortem* was identified through the observation of degree of alveolar bone resorption. All the alveoli that could be observed were counted and a note was made of those sockets that had started to regenerate or that were completely regenerated before death. In a few clear cases of individual tombs

where all the teeth were present (n = 32), but were isolated due to jaw fragmentation, tooth loss was also counted in view of the available teeth (e.g. 0/32, 0%).

When patterns were established according to age, caution was given to dentitions classified in the old age category (>50 years) since most of these dentitions were aged in such a category according to the amount of AMTL when other indicators were not available (see Chapter 2).

6.1.1.4.3 Caries correction factors

The conventional caries rate, calculated as the number of teeth with DC/number of teeth observed does not reflect a real prevalence of DC and is a fallacy in skeletal studies because AMTL and PMTL are not accounted for (Erdal and Duyar, 1999; Duyar and Erdal, 2003: 58).

In modern living populations, caries rates are calculated counting the number of decayed, missing and filled teeth (DMF index). These scores are not appropriate in archaeological situations for a number of reasons including assumptions on missing teeth due to DC and not differentiating between tooth types (Hillson, 2001). A modified version of the DMF Index, only considering decayed and missing teeth *ante-mortem* (DM Index), has been used in archaeological studies (Kelley *et al.*, 1991). The DM Index is useful if comparisons are to be made with living populations (e.g. see Costa, 1980a). This assumes that all AMTL is due to dental caries. In clinical dentistry, most

AMTL is due to the extraction of teeth due to advanced DC (Kelley *et al.*, 1991: 205). However, while caries rate estimated from carious teeth alone underestimates the real caries rate for the population (Saunders *et al.*, 1997: 77), the DM index overestimates the true prevalence rate (Lukacs, 1995). In archaeological populations, this assumption is probably inappropriate in populations experiencing heavy wear, severe periodontal disease or severe dental trauma (Saunders *et al.*, 1997: 77).

Lukacs (1995) devised a 'caries correction factor' (CCF) where the proportion of AMTL due to caries is estimated by considering the proportion of teeth whose roots are exposed due to caries and due to attrition. The number of teeth lost *ante-mortem* is here multiplied by the ratio of teeth with exposed pulp chambers due to caries. The difference between exposed pulp chamber caused by DC and that caused by attrition is explained elsewhere (Hillson, 2001: 264). Differential factors include the stage of attrition, the exposure of an open pulp chamber and the presence of secondary dentine.

Duyar and Erdal (2003) are of the opinion that Lukacs' (1995) CCF achieves reasonable results but that there is a need to distinguish between anterior and posterior teeth due to different resistance to cariogenic factors. Otherwise, if these categories are pooled together, the rate in anterior teeth might increase while the rate in posterior teeth, will likely decrease (Duyar and Erdal, 2003: 66). Furthermore, there is also a need to consider *post-mortem* tooth loss since anterior and posterior teeth are lost in different proportions and thus distort results (Saunders *et al.*, 1997). To account for AMTL and PMTL in both anterior and posterior teeth separately, the 'proportional

correction factor' or PCF (Erdal and Duyar, 1999) was employed. After estimating the rates employing the CCF, the proportional correction factor (PCF) was applied.

The PCF corrected for the disproportion caused by *post-mortem* tooth loss. After applying the CCF, the results obtained for anterior and posterior teeth were multiplied by 0.375 and 0.625 respectively (see Table 6.1.1). In a complete permanent dentition these rates 0.375 and 0.625 refer to the proportion of anterior teeth to overall teeth (12/32; or per quadrant 3/8), and to the proportion of posterior teeth to overall teeth (20/32; or per quadrant 5/8) respectively[98]. Table 6.1.1 indicates the steps to follow and provides instructions in accordance with the cited authors. An example is provided and refers to the Punic rural sample.

[98] For deciduous teeth the ratio for anterior teeth would be three-fifths (0.6) of teeth in one quadrant and, for posterior teeth, two-fifths (0.4).

Table 6.1.1. Steps followed in calculating CCF and PCF.

Step	Instructions	EXAMPLE (Punic rural site)	
		ANTERIOR	POSTERIOR
A	Number of teeth lost *ante-mortem* (A)	**15**	**33**
B	Ratio of teeth with pulp exposed due to caries (B)[1]	**0.50** (1/2)	**0.20** (6/30)
C	Estimated number of teeth lost due to DC (C) = (A) x (B)	**7.5** (15 x 0.50)	**6.6** (33 x 0.20)
D	Number of carious teeth present (D)	**1**	**17**
E	Total estimated number of teeth with DC (E) = (C) + (D)	**8.5** (7.5 + 1)	**23.6** (6.6 + 17)
F	Total number of teeth observed (F)	**42**	**167**
G	Total number of original teeth (G) = (A) + (F)	**57** (15 + 42)	**200** (33 + 167)
H	Caries correction factor or CCF (Lukacs, 1995) (H) = (E)/(G)	**14.9%** (8.5/57)	**11.8%** (23.6/200)
I	Proportional correction factor or PCF (Erdal and Duyar, 1999, 2003)[2]	**5.5%** (14.9 x 0.375)	**7.3%** (11.8 x 0.625)
J	Sum of corrected rates for anterior and posterior teeth	**Total = 12.8%** (5.5 + 7.3)	

[1]Ratio calculated from all teeth with exposed pulps, the percentage was calculated by dividing those with DC (and not attrition) by those teeth observed with pulp exposure; [2] = the PCF is calculated by taking the CCF result for anterior teeth and multiplying by 0.375 and also the CCF for posterior teeth and multiplying by 0.625.

6.1.1.5 Results

Results were presented separately for deciduous and permanent teeth. These results only present summaries. All samples contained a cross-representation of adult ages and sexes.

6.1.1.5.1 The deciduous dentition

Since no deciduous teeth were present in the Punic rural sample, comparisons could be made directly between Period 1 (urban context) and Period 2. Table 6.1.2 provides frequencies of teeth affected according to occlusal, coronal and cervical (CEJ) locations. Occlusal caries only referred to fissure and pit caries, and therefore only

unworn molars were considered. All subadult age groups have been pooled together due to the small sample size. The range of erupted deciduous teeth covered an age between about 1.5 to about 12 years.

Table 6.1.2. Percentage of deciduous teeth with dental caries*.

DECIDUOUS DENTITION								
Teeth	**PERIOD 1**				**PERIOD 2**			
Upper	**Occlusal**	**Coronal**	**CEJ**	**Gross**	**Occlusal**	**Coronal**	**CEJ**	**Gross**
Is & Cs	N/A	0/21 (0)	0/21 (0)	0/21 (0)	N/A	0/23 (0)	1/23 (4.3)	0/23 (0)
Ms	0/10 (0)	1/10 (10)	0/11 (0)	2/12 (16.6)	0/35 (0)	0/38 (0)	2/36 (5.5)	7/46 (15.2)
Lower	**Occlusal**	**Coronal**	**CEJ**	**Gross**	**Occlusal**	**Coronal**	**CEJ**	**Gross**
Is & Cs	N/A	0/16 (0)	0/16 (0)	0/16 (0)	N/A	0/36 (0)	0/36 (0)	0/37 (0)
Ms	0/18 (0)	0/19 (0)	0/19 (0)	1/20 (5)	1/67 (1.4)	3/70 (4.2)	1/69 (1.4)	3/76 (3.9)

* Codes: Is & Cs = incisors and canines; Ms = molars; N/A = not applicable. Number in brackets denotes percentages of affected teeth.

No anterior teeth in Period 1 were affected but a total of four molars were. In Period 2, one anterior tooth and 17 posterior teeth were affected. The most affected teeth were deciduous molars and the most popular location for DC was the crown of molars, but also the CEJ in anterior teeth from Period 2. The youngest occurrence for a carious lesion was 3-4 years, one from Period 1 and two from Period 2. No DC was present in erupted teeth (n = 38) from individuals under three years of age.

Gross lesions accounted for most of the DC prevalence. In both periods, it was the gross caries that was more represented. Gross lesions only appeared in molars. From the molars observed, 9.3% (3/32) had gross cavities in Period 1 and 8.1%

(10/122) had cavities in Period 2. Most of the teeth (n = 10) with gross lesions came from individuals aged between 5 and 10 years. Two came from two 1-5 year old individuals and one from a 10-15 year-old.

The overall rate of affected teeth in Period 1 was 0% (0/37) in the anterior teeth and 12.5% (4/32) in the posterior. In Period 2, 1.6% (1/60) anterior teeth and 13.9% (17/122) posterior teeth were affected. These were similar to those in the Punic period, especially when taken into account that the sample sizes for Period 2 were larger and that age might have contributed to bias. When the PCF was applied, the result for Period 1 anterior teeth still remained at 0% but that for posterior teeth resulted in 5%, which was the overall rate for Period 1. When the correction formulae were applied to Period 2, DC in anterior teeth accounted for 0.9% and 5.5% for posterior, totalling a corrected caries rate of 6.4%. Thus, total DC rate between periods was similar even though a slightly lower rate could be detected in Period 1.

6.1.1.5.2 The permanent dentition

Since DC was employed mainly to infer about diet, the overall result was of interest here. Data are only summarised according to prevalence of DC per tooth count, rather than surfaces. Firstly, uncorrected rates are given for each context and each period. Later, all contexts and periods are compared with the calibrated frequencies.

6.1.1.5.2.1 The Punic sample

Summary data are provided separately for the Punic rural and the Punic urban samples.

6.1.1.5.2.1.1 The Punic rural sample

No permanent teeth were identified as belonging to subadult individuals. Eight cases could not be assigned to an age grouped and were therefore classified as unaged[99]. These cases did not have DC. Only the adult sample was considered when comparing contexts and periods.

A table was devised to understand the proportion of teeth missing *post-mortem.* Table 6.1.3 examines the number of permanent teeth in adults obtained for the Punic rural sample, as well as those missing *post-mortem.* Upper and lower, left and right permanent teeth are considered together.

[99] In all samples these teeth were fully formed. The teeth tended to belong to the anterior dentition and had little or no wear, making it difficult to ascribe them to an older subadult or a young adult age category.

Table 6.1.3. Number of teeth present, lost *ante-mortem*, lost *post-mortem* and generally missing.

Permanent dentitions	**PUNIC RURAL (MNI = 66 adults)**		
	Anterior teeth	**Posterior teeth**	**Total**
Total teeth expected for 66 complete adult dentitions[1] (a)	792 (66 x 12)	1320 (66 x 20)	2112 (66 x 32)
Teeth preserved *in situ* (in sockets) (b)	46	153	199
Teeth found loose/isolated (adults) (c)	6	11	17
Teeth found loose/isolated (unaged) (d)	3	3	6
Teeth lost *ante-mortem* (e)	15	33	48
Total teeth present and lost *ante-mortem* (f) = (b) + (c) + (d) + (e)	**70**	**200**	**270**
Total Sockets present (g)	252	360	612
Teeth missing *post-mortem* (h) = (g) – (f)	182	160	342
Number of teeth not present (i) = (a) – (f)	**722**	**1120**	**1842**
Percentage of teeth missing (j) = (i)/(a)	91.3%	84.8%	87.2%
Number of teeth for which status (AMTL, PMTL) is unknown (no sockets preserved)[2] (k) = (i) – (h)	540	960	1500

[1] = There was a minimum of 66 adult individuals at this site. The expected number of anterior and posterior teeth results from multiplying this number (66) by the number of anterior teeth (12) and posterior teeth (20) that would be present in each individual if preservation was complete and assuming there was no *ante-mortem* tooth loss; [2] = The difference between this count compared to the number of teeth not present (i), is that from those teeth not present, some were known to have been lost *post-mortem* (h) since the jaw was preserved and available for examination. The count in (j) includes the number of sockets not present at all in the assemblage and therefore there was no knowledge whether the teeth were lost *post-mortem* or *ante-mortem*.

The proportion of missing teeth is considerably high in this assemblage. This bias in preservation and recovery is probably due to a number of *post-mortem* disturbances explained earlier in Chapter 2.

The percentage of teeth present and with dental caries has been broken down in Table 6.1.4 according to tooth type and upper and lower dentition. Adult teeth represent all of those teeth belonging to individuals older than 15 years of age-at-death.

Table 6.1.4. Number of permanent teeth present in the Punic rural sample and affected with DC*.

PUNIC RURAL PERMANENT DENTITION					
Maxilla	**Unaged**	**Subadult**	**Female**	**Male**	**Total Adults[2]**
I1	-	-	-	-	-
I2	-	-	-	-	-
C	-	-	-	0/2	0/5
P1	0/1	-	-	0/1	0/5
P2	-	-	-	0/1	0/5
M1	-	-	-	0/2	0/8
M2	-	-	-	0/2	1/7 (14.2%)
M3	-	-	-	-	0/2
Mandible	**Unaged**	**Subadult**	**Female**	**Male**	**Total Adults[2]**
I1	-	-	-	0/4	0/7
I2	0/2	-	-	0/5	1/12 (8.3)
C	0/2	-	0/1	0/6	0/17
P1	0/1	-	0/1	0/7	0/23
P2	-	-	0/2	0/8	1/21 (4.7)
M1	0/1	-	0/4	0/11	5/45 (11.1)
M2	0/1	-	0/1	1/7 (14.2)	5/33 (15.1)
M3	-	-	-	1/5 (20.0)	5/19 (26.3)
TOTAL[1]	**0/8 (0)**	**-**	**0/9 (0)**	**2/61 (3.2)**	**18/209 (8.6)**

* The numerical figures (n/N) represent the number of teeth with DC/number of teeth observed. Percentages are indicated in brackets in cases where DC was present. [1] = crude (uncorrected) DC prevalence rates; [2] = these rates include teeth from the female and male samples, as well as those from unsexed adult individuals.

From this data, the most affected tooth was the lower third molar, with a DC rate of 26.3%. This was followed by the lower second molar (15.1%) and the upper second molar (14.2%). Differences according to sexes are not taken into account due to the small sample size of female teeth. From all the carious teeth observed (n = 18), the highest proportion (87.5%) was found in molars.

Although sample sizes varied, posterior teeth were more affected than anterior, and overall the posterior mandible exhibited higher DC frequencies. However, these differences were not statistically significant (Table 6.1.5).

Table 6.1.5. Dental caries crude prevalence rates according to anterior and posterior teeth in maxillae and mandibles*.

Teeth (location)	PUNIC RURAL ADULT SAMPLE				Statistical results	
	Females	Males	Total[1] (n/N)	Total (%)	Chi-square	Significance
Anterior maxilla	-	0/2	0/5	0	0.184	n.s.
Posterior maxilla	-	0/6	1/27	3.7		
Anterior mandible	0/1	0/15	1/37	2.7	2.22	n.s.
Posterior mandible	0/8	2/38	16/140	11.4		
All maxilla	-	0/8	1/32	3.1	1.27	n.s.
All mandible	0/9	2/53	17/177	9.6		
All anterior	0/1	0/17	1/42	2.3	2.28	n.s.
All posterior	0/8	2/44	17/167	10.1		

* Codes: anterior teeth = incisors and canines; posterior teeth = premolars and molars; n.s. = not statistically significant; [1] = the total prevalence also includes those adult dentitions that could not be sexed.

The ratio of anterior to posterior preserved teeth in a normal dentition is 0.60. In archaeological populations deviation from this ratio is normal (e.g. see Erdal and Duyar, 1999: 238) and indicates the differences between one tooth class and another. The preservation ratio between anterior and posterior teeth in the Punic rural sample was 0.25 (42/167)[100].

The lesion in the anterior tooth (I2) was classified as a gross lesion. In posterior teeth, the occlusal surface was the most affected (7/103 teeth, 6.7%), followed by lesions in the crown (2/124, 1.6%) and at the CEJ (1/150, 0.6%). Gross lesions were present in 4.7% teeth (8/167). Table 6.1.6 provides a breakdown of these locations. Upper and lower teeth have been pooled. Prevalence (n/N) is given according to number of teeth observed with regard to a particular part of the teeth (occlusal, coronal, cervical or CEJ). The number of teeth observed according to occlusal, coronal or the

[100] The normal ratio for a complete preserved dentition is 0.6 (12 anterior teeth : 20 posterior teeth).

CEJ surfaces varied depending on heavy wear or calculus deposits that may have not allowed observation.

Table 6.1.6. Location of cavities in the adult dentition*.

Adult	PUNIC RURAL ADULT SAMPLE						
	Anterior teeth			Posterior teeth			
	Gross	Coronal	CEJ	Gross	Pit/fissure	Coronal	CEJ
Female	0/1	0/1	0/1	0/8	0/7	0/7	0/8
Male	0/17	0/11	0/17	1/44	0/27	1/35	0/37
Total[1]	1/42	0/32	0/41	8/167	7/103	2/124	1/150
%	2.3	0	0	4.7	6.7	1.6	0.6

*Codes: CEJ = cemento-enamel junction; [1] = the total is the sum of the female sample, the male sample and those unsexed specimens.

The age factor in caries prevalence could also be investigated. Table 6.1.7 includes both DC and AMTL prevalence in anterior and posterior dentition, broken down into age and sex groups. The categories 15-20 and 20-30 years have been pooled into one young adult age category (15-30 years). Only teeth from adults identified to a specific age category were included.

Table 6.1.7. Distribution of DC and AMTL in adults according to age and sex*.

PUNIC RURAL ADULT SAMPLE												
	FEMALE TEETH				MALE TEETH				TOTAL ADULT TEETH[1]			
AGE	Anterior		Posterior		Anterior		Posterior		Anterior		Posterior	
	DC	AM	DC	AM	DC	AM	DC	AM	DC	AM	DC	AM
15-30	-	0/12	0/5	1/13	0/8	0/22	1/23	0/26	0/15 (0)	0/34 (0)	9/72 (12.5)	1/39 (2.5)
30-50	-	-	-	-	0/9	0/21	1/20	0/40	1/14 (7.1)	0/21 (0)	5/65 (7.6)	0/40 (0)
50+	-	0/5	0/1	0/5	-	0/3	0/1	0/4	0/3 (0)	0/8 (0)	1/18 (5.5)	0/9 (0)

*Codes: DC = dental caries (figures given as the number of cases with DC/number of teeth observed); AM = tooth lost *ante-mortem* (figures given as the number of cases with AMTL/number of sockets observed); [1] = these rates include teeth from the female and male samples, as well as those from unsexed adult individuals.

The middle age group showed a higher prevalence (7.1%) of DC in anterior teeth but here only one carious tooth was affected. In addition, the sample was low in the older age category. Young adult teeth displayed a higher frequency of DC, perhaps influenced by lower rates of attrition compared to the occlusal surfaces in the older adults. Four lesions in this age group were located in occlusal surfaces. The differences between age groups, however, were not statistically significant between the young adults and the 30-50 year-old adults ($x^2 = 0.703$; $p = 0.402$), and the young adults compared to the older adults ($x^2 = 0.585$; $p = 0.444$). The AMTL data were not reliable since only one case of AMTL is included in Table 6.1.7 despite the cases of AMTL being larger in this sample ($n = 48$). Nevertheless, there was a slightly higher percentage of AMTL in the younger adult category but this was not significant compared to the middle ($x^2 = 1.01$; $p = 0.314$) and the older ($x^2 = 0.298$; $p = 0.585$) age groups.

The location most affected by AMTL was the posterior mandible. The anterior teeth were most affected than the posterior teeth in maxillae, while in the mandible the posterior teeth were more affected than the anterior teeth. However, these differences were not statistically significant (Table 6.1.8) except for mandibles being more affected than maxillae ($p = 0.007$).

Table 6.1.8. AMTL crude prevalence rates according to anterior and posterior teeth in maxillae and mandibles*.

Teeth (location)	PUNIC RURAL ADULT SAMPLE				Statistical results	
	Females	Males	Total[1] (n/N)	Total (%)	Chi-square	Significance
Anterior maxilla	-	0/6	1/46	2.1	1.20	n.s.
Posterior maxilla	-	0/9	0/56	0		
Anterior mandible	8/48	0/62	14/206	6.7	2.03	n.s.
Posterior mandible	7/28	3/85	33/304	10.8		
All maxilla	-	0/15	1/102	0.9	7.19	p<0.05
All mandible	15/76	3/147	47/510	9.2		
All anterior	8/48	0/68	15/252	5.9	1.82	n.s.
All posterior	7/28	3/94	33/360	9.1		

* Codes: anterior teeth = incisors and canines; posterior teeth = premolars and molars; n.s. = not statistically significant; [1] = the total prevalence also includes those adult dentitions that could not be sexed.

Females were more affected (16.6%) than males (0%) with regard to anterior teeth. This difference was significant ($x^2 = 10.4$; $p = 0.001$). The same applied with regard to the posterior teeth, where females (25.0%) had significantly ($x^2 = 10.5$; $p = 0.001$) higher frequencies than males (3.1%).

A summary of these results in relation to the different caries correction factors is provided below in Section 6.1.1.5.2.3.

6.1.1.5.2.1.2 The Punic urban sample

A total of 80 permanent subadult teeth (<15 years) were present. A total of 17 teeth could not be ascribed to the subadult or adult age group. Teeth identified as belonging to adults accounted for 205 teeth. Only the adult sample was considered when comparing contexts and periods, and also when analysing AMTL rates.

In order to understand the preservation bias in this sample, the adult data were analysed pooling upper and lower dentitions (Table 6.1.9). Subadult individuals were not included because an estimate of expected teeth is difficult in view of the different ages at which different teeth form.

Table 6.1.9. Number of teeth present, lost *ante-mortem*, lost *post-mortem* and generally missing*.

Permanent dentitions	**PUNIC URBAN (MNI = 42 adults)**		
	Anterior teeth	**Posterior teeth**	**Total**
Total teeth expected for 42 complete adult dentitions (a)	504	840	1344
Teeth preserved *in situ* (in sockets) (b)	35	66	101
Teeth found loose/isolated (adults) (c)	41	75	116
Teeth found loose/isolated (unaged) (d)	9	6	15
Teeth lost *ante-mortem* (e)	0	3	3
Total teeth present and lost *ante-mortem* (f) = (b) + (c) + (d) + (e)	**85**	**150**	**235**
Total Sockets present (g)	86	165	251
Teeth missing *post-mortem* (h) = (g) – (f)	1	15	16
Number of teeth not present (i) = (a) – (f)	**419**	**690**	**1109**
Percentage of teeth missing (j) = (i)/(a)	83.1%	82.1%	82.5%
Number of teeth for which status (AMTL, PMTL) is unknown (no sockets preserved) (k) = (i) – (h)	418	675	1093

* Codes are provided in Table 6.1.3.

Although the proportion of missing teeth was lower than that obtained from the rural sample, the rates were nevertheless high[101].

The prevalence of DC according to tooth type is presented in Table 6.1.10. Permanent teeth from subadult individuals exhibited four carious lesions in four different teeth. The carious tooth from the upper first molar corresponded to a 3-4 year-old individual. Those carious lesions in the upper and lower second molars came from individuals aged between five and ten years.

[101] It was possible to calculate here the rates of missing teeth in various published Punic sites from Ibiza. At *Can Marines* (Gómez, 1989), the author estimated a minimum number of 28 individuals according to the number of crania. At this site there were only two fragmented mandibles and a total of five teeth present. The expected number of teeth at this site, assuming all adults had full dentitions (n = 32 teeth), would have been 896 (28 x 32). Since only five teeth were present, the number of missing teeth was therefore 891, which accounted for 99.4%. At *Cas Jurat* (González-Martín and Lalueza, 1992) the authors estimated a minimum number of 15 individuals according to the number of crania. At this site there was only one mandible present. The expected number of teeth at this site would have been 480 (15 x 32). The authors stated that a total of 55 teeth were present while 30 had been lost *ante-mortem*. These figures added up totalled a number of 85 teeth that were not lost *post-mortem*. The number of missing teeth was 395, which accounted for 82.2%. At *Ca n'Eloi* (González-Martín and Lalueza, 2001) the authors found a total of 16 adult crania and two mandibles. Considering the minimum number of individuals was sixteen, the total expected teeth would have been 512. The total number of teeth present was 56 and the number of teeth lost *ante-mortem* was 11. Therefore from the total of 512 teeth, all but 67 were lost *post-mortem* (445/512, 86.9%).

Table 6.1.10. Number of permanent teeth present in the Punic urban sample and affected with DC*.

PUNIC URBAN PERMANENT DENTITION					
Maxilla	**Unaged**	**Subadult**	**Female**	**Male**	**Total Adults[2]**
I1	0/2	0/9	0/3	0/3	0/11
I2	0/3	0/10	0/3	0/3	0/10
C	0/1	0/5	0/4	0/4	1/13 (7.6)
P1	-	-	0/4	0/4	1/12 (8.3)
P2	-	-	0/3	0/4	0/12
M1	0/2	1/6 (16.6)	0/1	0/5	0/8
M2	-	2/7 (28.5)	1/3 (33.3)	0/6	1/10 (10.0)
M3	-	-	0/3	1/4 (25.0)	1/10 (10.0)
Mandible	**Unaged**	**Subadult**	**Female**	**Male**	**Total Adults[2]**
I1	0/1	0/9	1/3 (33.3)	0/5	1/11 (9.0)
I2	0/2	0/6	0/3	0/5	0/11
C	0/1	0/5	0/3	0/7	0/14
P1	0/3	-	0/5	0/7	0/16
P2	0/1	-	0/4	0/5	0/15
M1	0/1	0/11	0/4	0/7	1/19 (5.2)
M2	-	1/12 (8.3)	2/4 (50.0)	0/7	2/18 (11.1)
M3	-	-	0/3	0/5	1/15 (6.6)
TOTAL[1]	**0/17**	**4/80 (5.0)**	**4/53 (7.5)**	**1/81 (1.2)**	**9/205 (4.3)**

* The numerical figures (n/N) represent the number of teeth with DC/number of teeth observed. Percentages are indicated in brackets in cases where DC was present. [1] = crude (uncorrected) DC prevalence rates; [2] = these rates include teeth from the female and male samples, as well as those from unsexed adult individuals.

From this data, the most affected tooth in the adult sample was the lower second molar (11.1% crude DC rate), while the upper second and third molars only had a slightly lower rate (10.0%). From all the carious teeth observed (n = 9), molars were the most affected (66.6%).

Posterior teeth were more affected by DC than anterior teeth, and mandibular and maxillary teeth were similarly affected. No differences between groups were statistically significant (Table 6.1.11).

Table 6.1.11. Dental caries crude prevalence rates according to anterior and posterior teeth in maxillae and mandibles*.

Teeth (location)	PUNIC URBAN ADULT SAMPLE				Statistical results	
	Females	Males	Total[1] (n/N)	Total (%)	Chi-square	Significance
Anterior maxilla	0/10	0/10	1/34	2.9	0.340	n.s.
Posterior maxilla	1/14	1/23	3/52	5.7		
Anterior mandible	1/9	0/17	1/36	2.7	0.241	n.s.
Posterior mandible	2/20	0/31	4/83	4.8		
All maxilla	1/24	1/33	4/86	4.6	0.022	n.s.
All mandible	3/29	0/48	5/119	4.2		
All anterior	1/19	0/27	2/70	2.8	0.549	n.s.
All posterior	3/34	1/54	7/135	5.1		

* Codes: anterior teeth = incisors and canines; posterior teeth = premolars and molars; n.s. = not statistically significant; [1] = the total prevalence also includes those adult dentitions that could not be sexed.

Females had higher frequencies of DC in anterior (5.2%) and posterior (8.8%) teeth than male teeth (0% and 1.8% respectively) but the differences were not statistically significant (respectively $x^2 = 1.38$; $p = 0.240$; and $x^2 = 2.10$; $p = 0.147$). The most common type of lesion was pit and fissure caries (4.6% of teeth observed), which also accounted for 40% (4/10) of all the lesions in this sample (Table 6.1.12).

Table 6.1.12. Location of cavities in the adult dentition*.

Adult	PUNIC URBAN ADULT SAMPLE						
	Anterior teeth			Posterior teeth			
	Gross	Coronal	CEJ	Gross	Pit/fissure	Coronal	CEJ
Female	1/19	0/17	0/17	1/34	2/22	1/32	0/33
Male	0/27	0/19	0/27	0/54	0/22	0/24	1/53
Total[1]	1/70	0/54	1/68	1/135	4/86	1/99	2/132
%	1.4	0	1.4	0.7	4.6	1.0	1.5

*Codes: CEJ = cemento-enamel junction; [1] = the total is the sum of the female sample, the male sample and those unsexed specimens.

In this sample, gross lesions were not too common. The CEJ was the site of carious attack in one anterior tooth and two posterior teeth.

The age factor in caries prevalence could also be investigated. Table 6.1.13 presents the DC and AMTL distribution according to age groups.

Table 6.1.13. Distribution of DC and AMTL in adults according to age and sex*.

PUNIC URBAN ADULT SAMPLE												
	FEMALE TEETH				MALE TEETH				TOTAL ADULT TEETH[1]			
AGE	Anterior		Posterior		Anterior		Posterior		Anterior		Posterior	
	DC	AM	DC	AM	DC	AM	DC	AM	DC	AM	DC	AM
15-30	0/7	0/8	0/14	0/16	-	-	-	-	0/23 (0)	0/24 (0)	2/49 (4.0)	0/49 (0)
30-50	0/3	0/7	2/11	2/15	0/19	0/18	1/37	1/28	0/22 (0)	0/25 (0)	3/53 (5.6)	3/48 (6.2)
50+	1/9	0/5	1/9	0/4	0/8	0/14	0/17	0/7	1/17 (5.8)	0/9 (0)	1/28 (3.5)	0/25 (0)

*Codes: DC = dental caries (figures given as the number of cases with DC/number of teeth observed); AM = tooth lost *ante-mortem* (figures given as the number of cases with AMTL/number of sockets observed); [1] = these rates include teeth from the female and male samples, as well as those from unsexed adult individuals.

Carious lesions in anterior teeth only appeared in teeth from the older age category, although this difference was not significant in relation to the rate (0%) obtained in the younger adult category ($x^2 = 1.31$; $p = 0.252$) and the 30-50 year age group ($x^2 = 1.25$; $p = 0.263$). All age groups revealed carious lesions in posterior teeth, the middle category showing the highest. The differences between age groups were not significant when the younger age group was compared to the middle ($x^2 = 0.123$; $p = 0.725$) and older ages ($x^2 = 0.011$; $p = 0.915$). Neither was the difference significant ($x^2 = 0.155$; $p = 0.694$) between DC in the middle and older age groups. Amongst the

sockets observed, only three cases of AMTL were present, and these were confined to the middle age category. However, the difference was not significant when compared to the younger ($x^2 = 2.97$; $p = 0.085$) and older ($x^2 = 1.53$; $p = 0.216$) age groups.

The most affected location for AMTL was the posterior mandible. However when compared to rates from other locations in the dentition the differences were not significant (Table 6.1.14).

Table 6.1.14. AMTL crude prevalence rates according to anterior and posterior teeth in maxillae and mandibles*.

Teeth (location)	PUNIC URBAN ADULT SAMPLE				Statistical results	
	Females	Males	Total[1] (n/N)	Total (%)	Chi-square	Significance
Anterior maxilla	0/10	0/10	0/35	0	N/A	N/A
Posterior maxilla	0/16	0/25	0/61	0		
Anterior mandible	0/15	0/26	0/51	0	1.46	n.s.
Posterior mandible	2/24	1/35	3/104	2.8		
All maxilla	0/26	0/35	0/96	0	1.84	n.s.
All mandible	2/39	1/61	3/155	1.9		
All anterior	0/25	0/36	0/86	0	1.55	n.s.
All posterior	2/40	1/60	3/165	1.8		

* Codes: anterior teeth = incisors and canines; posterior teeth = premolars and molars; n.s. = not statistically significant; [1] = the total prevalence also includes those adult dentitions that could not be sexed; N/A = not applicable (no differences to be compared).

In the posterior teeth, females had more AMTL (5%) than males (1.6%) but the difference was not significant ($x^2 = 8.58$; $p = 0.354$). Amongst those teeth observed, the ratio of anterior to posterior teeth was 0.51 (86/165), which is near the normal 0.60.

The corrected caries rate taking into account the DC and AMTL data is undertaken in Section 6.1.1.5.2.3, where this context is compared to the rural sample.

6.1.1.5.2.2 The Late Antiquity-Early Byzantine sample

Subadult permanent teeth accounted for a total of 368 specimens. A total of 72 cases could not be assigned to a subadult or adult age group. These cases did not have DC. Only the adult sample was considered when comparing contexts and periods.

A table was devised to understand the proportion of teeth missing *post-mortem*. Table 6.1.15 examines the number of permanent teeth in adults obtained for the Period 2 sample, as well as those missing *post-mortem*. Upper and lower, left and right permanent teeth are considered together.

Table 6.1.15. Number of teeth present, lost *ante-mortem*, lost *post-mortem* and generally missing*.

Permanent dentitions	**PERIOD 2 (MNI = 106 adults)**		
	Anterior teeth	**Posterior teeth**	**Total**
Total teeth expected for 106 complete adult dentitions (a)	1272	2120	3392
Teeth preserved *in situ* (in sockets) (b)	216	392	608
Teeth found loose/isolated (adults) (c)	57	109	166
Teeth found loose/isolated (unaged) (d)	29	43	72
Teeth lost *ante-mortem* (e)	27	94	121
Total teeth present and lost *ante-mortem* (f) = (b) + (c) + (d) + (e)	**329**	**638**	**967**
Total Sockets present (g)	380	638	1018
Teeth missing *post-mortem* (h) = (g) – (f)	51	0	51
Number of teeth not present (i) = (a) – (f)	**943**	**1482**	**2425**
Percentage of teeth missing (j) = (i)/(a)	74.1%	69.9%	71.4%
Number of teeth for which status (AMTL, PMTL) is unknown (no sockets preserved) (k) = (i) – (h)	892	1482	2374

* Codes are provided in Table 6.1.3.

The sample size is much larger for this period and the preservation and recovery was much better than for the Punic samples.

The percentage of teeth present and with dental caries has been broken down in Table 6.1.16 according to tooth type and upper and lower dentition.

Table 6.1.16. Number of permanent teeth present in the Period 2 sample and affected with DC*.

PERIOD 2 PERMANENT DENTITION					
Maxilla	**Unaged**	**Subadult**	**Female**	**Male**	**Total Adults[2]**
I1	1/2 (50.0)	0/18	0/10	0/17	0/34
I2	0/5	0/20	0/7	0/15	1/29 (3.4)
C	0/7	1/12 (8.3)	1/7 (14.2)	0/16	2/37 (5.4)
P1	0/7	1/12 (8.3)	0/5	0/18	1/31 (3.2)
P2	0/3	0/7	0/8	1/17 (5.8)	1/37 (2.7)
M1	1/7 (14.2)	6/45 (13.3)	1/9 (11.1)	3/18 (16.6)	5/38 (13.1)
M2	0/4	4/35 (11.4)	1/8 (12.5)	3/16 (18.7)	6/40 (15.0)
M3	-	-	1/8 (12.5)	2/16 (12.5)	5/38 (13.1)
Mandible	**Unaged**	**Subadult**	**Female**	**Male**	**Total Adults[2]**
I1	0/6	0/30	0/11	0/27	0/46
I2	1/8 (12.5)	0/28	0/14	0/32	1/61 (1.6)
C	0/3	0/24	1/13 (7.6)	3/38 (7.8)	4/66 (6.0)
P1	1/7 (14.2)	0/10	4/17 (23.5)	3/35 (8.5)	7/67 (10.4)
P2	0/2	0/7	5/17 (29.4)	5/37 (13.5)	12/65 (18.4)
M1	2/5 (40.0)	2/66 (3.0)	4/18 (22.2)	7/31 (22.5)	12/65 (18.4)
M2	0/2	7/54 (12.9)	6/19 (31.5)	7/34 (20.5)	22/72 (30.5)
M3	-	-	3/13 (23.0)	7/26 (26.9)	13/48 (27.0)
TOTAL[1]	**6/72 (8.3)[3]**	**21/368 (5.7)**	**27/184 (14.6)**	**41/393 (10.4)**	**92/774 (11.8)**

* The numerical figures (n/N) represent the number of teeth with DC/number of teeth observed. Percentages are indicated in brackets in cases where DC was present. [1] = crude (uncorrected) DC prevalence rates; [2] = these rates include teeth from the female and male samples, as well as those from unsexed adult individuals; [3] = the total count from all the teeth listed equals 68 teeth, but there were 4 teeth that could not be ascribed to a specific tooth type due to distortions caused by taphonomic factors. These four teeth have only been added to the total.

The crude prevalence of subadult permanent teeth with DC was 5.7% (21/368). Among the adult teeth, all teeth were affected except the first incisors. Molars were

mostly affected, especially in the lower jaw. The highest DC rate was 30.5% obtained from the lower second molar.

Posterior teeth were significantly more affected than anterior teeth in the maxillae (p = 0.50), the mandibles (p = 0.000) and overall (p = 0.000) after pooling mandibles and maxillae. Mandibular teeth were significantly more affected (p = 0.008) than maxillary teeth (Table 6.1.17). The ratio of anterior to posterior teeth was 0.54.

Table 6.1.17. Dental caries crude prevalence rates according to anterior and posterior teeth in maxillae and mandibles*.

Teeth (location)	PERIOD 2 ADULT SAMPLE				Statistical results	
	Females	Males	Total[1] (n/N)	Total (%)	Chi-square	Significance
Anterior maxilla	1/24	0/48	3/100	3.0	3.83	p = 0.50
Posterior maxilla	3/38	9/85	18/184	9.7		
Anterior mandible	1/38	3/97	5/173	2.8	22.9	p<0.001
Posterior mandible	22/84	29/163	66/317	20.8		
All maxilla	4/62	9/133	21/284	7.3	6.93	p<0.05
All mandible	23/122	32/260	71/490	14.4		
All anterior	2/62	3/145	8/273	2.9	26.5	p<0.001
All posterior	25/122	38/248	84/501	16.7		

* Codes: anterior teeth = incisors and canines; posterior teeth = premolars and molars; n.s. = not statistically significant; [1] = the total prevalence also includes those adult dentitions that could not be sexed.

Females had higher frequencies (3.2%) of DC in anterior teeth than males (2.0%) but the difference was not significant (x^2 = 0.234; p = 0.629). No significant difference was found (x^2 = 1.08; p = 0.299) between females and males with regard to posterior teeth, despite female teeth displaying more DC (20.4%) than male teeth (15.3%).

The most popular locations for carious attacks were the occlusal surfaces of premolars and molars (Table 6.1.18). Occlusal surfaces were affected in 8.3% of cases by pit and fissure caries. The CEJ region in posterior teeth was also more affected than other areas with a prevalence of 6.9% of the teeth observed. Considering all lesions, pit and fissure caries were the most prevalent (33/104, 31.7%).

Table 6.1.18. Location of cavities in the adult dentition*.

Adult	PERIOD 2 ADULT SAMPLE						
	Anterior teeth			Posterior teeth			
	Gross	Coronal	CEJ	Gross	Pit/fissure	Coronal	CEJ
Female	1/62	0/47	1/59	3/122	5/102	2/115	18/116
Male	0/145	0/125	1/135	7/248	23/192	6/221	9/238
Total[1]	2/273	0/236	6/258	16/501	33/394	14/459	33/474
%	0.7	0	2.3	3.1	8.3	3.0	6.9

*Codes: CEJ = cemento-enamel junction; [1] = the total is the sum of the female sample, the male sample and those unsexed specimens.

When age groups were compared, this Period 2 sample probably yielded a more reliable estimate since the number of teeth observed was larger than the Period 1 sample. The trend was clear towards an increase of DC and AMTL with age (Table 6.1.19). Therefore some age bias was likely to be present in the overall caries rate.

Table 6.1.19. Distribution of DC and AMTL in adults according to age and sex*.

PERIOD 2 ADULT SAMPLE												
	FEMALE TEETH				MALE TEETH				TOTAL ADULT TEETH			
AGE	Anterior		Posterior		Anterior		Posterior		Anterior		Posterior	
	DC	AM	DC	AM	DC	AM	DC	AM	DC	AM	DC	AM
15-30	1/41	0/62	11/94	3/108	0/73	0/92	15/144	0/164	1/153 (0.6)	0/205 (0)	36/335 (10.7)	9/371 (2.4)
30-50	1/5	2/10	11/18	3/23	0/48	0/54	13/73	13/88	1/55 (1.8)	2/66 (3.0)	30/102 (29.4)	16/117 (13.6)
50+	0/16	7/17	3/10	16/22	2/19	14/39	7/27	33/67	3/37 (8.1)	25/66 (37.8)	11/41 (26.8)	60/102 (58.8)

*Codes: DC = dental caries (figures given as the number of cases with DC/number of teeth observed); AM = toot lost *ante-mortem* (figures given as the number of cases with AMTL/number of sockets observed).

Older adults (>50 years) displayed significantly higher frequencies of DC in anterior teeth than young adults (x^2 = 7.38; p = 0.007) but not when compared to middle adults (x^2 = 1.91; p = 0.167). Young adults and middle adults did not show any significant differences (x^2 = 0.562; p = 0.453) with regard to DC in anterior teeth. Older adults displayed significantly higher frequencies of DC in posterior teeth than young adults (x^2 = 6.05; p = 0.014) but not when compared to middle adults (x^2 = 0.053; p = 0.817). Young adults had significantly lower prevalence rates than middle adults (x^2 = 14.5; p = 0.000) with regard to DC prevalence in posterior teeth.

Older adults also displayed significantly higher AMTL rates than young adults (x^2 = 61.5; p = 0.000) and middle adults (x^2 = 16.6; p = 0.000) when anterior teeth were considered. The difference between young and middle adults was also significant (x^2 = 6.07; p = 0.014). When posterior teeth were examined, older adults also display significantly higher values than younger (x^2 = 123; p = 0.000) and middle (x^2 = 23.9; p = 0.000) age groups. The difference between the young and the middle adults was also significant (x^2 = 19.8; p = 0.000), the latter group showing a greater prevalence.

Table 6.1.20 presents the distribution of AMTL with regard to the upper and lower jaw, anterior and posterior teeth. Significant differences were found with regard to the posterior mandible, which revealed higher frequencies of AMTL than the anterior mandible ($p = 0.001$). The overall count for posterior AMTL, including observations on mandibles and maxillae, also showed significantly higher AMTL rates than the overall count for anterior teeth ($p = 0.001$).

Table 6.1.20. AMTL crude prevalence rates according to anterior and posterior teeth in maxillae and mandibles*.

Teeth (location)	PERIOD 2 ADULT SAMPLE				Statistical results	
	Females	Males	Total[1] (n/N)	Total (%)	Chi-square	Significance
Anterior maxilla	1/37	8/66	13/137	9.4	0.606	n.s.
Posterior maxilla	4/53	17/114	27/216	12.5		
Anterior mandible	8/58	6/131	14/243	5.7	11.9	p<0.005
Posterior mandible	18/113	32/218	67/421	15.9		
All maxilla	5/90	25/180	40/353	11.3	0.131	n.s.
All mandible	26/171	38/349	81/664	12.1		
All anterior	9/95	14/197	27/380	7.1	10.7	p<0.005
All posterior	22/166	49/332	94/637	14.7		

* Codes: anterior teeth = incisors and canines; posterior teeth = premolars and molars; n.s. = not statistically significant; [1] = the total prevalence also includes those adult dentitions that could not be sexed.

Overall, the prevalence of AMTL in anterior female teeth (9.4%) was slightly higher than that in males (7.1%), although the difference was not significant ($x^2 = 0.419$; $p = 0.517$). Posterior AMTL was slightly more prevalent in males (14.7%) than females (13.2%) but the difference was also not significant ($x^2 = 0.155$; $p = 0.694$).

6.1.1.5.2.3 Corrected caries rates: comparisons between samples

Corrections factors for DC prevalence in adult permanent teeth were applied in order to achieve as much of a reliable estimate as possible of the caries rate in the population. The methods were explained in Section 6.1.1.4.3 and the steps to follow in such calibration were introduced in Table 6.1.1. All age groups and sexes were pooled in order to obtain meaningful results for which comparisons could be made between the different contexts and periods.

It is recalled that the uncorrected caries rate for the Punic rural sample is 2.3% (1/42) for anterior teeth, 10.1% (17/167) for posterior and 8.6% (18/209) for overall teeth. The urban context provided a frequency of 2.8% (2/70) for anterior, 5.1% (7/135) for posterior and 4.3% (9/205) for overall teeth. The corrected caries rates are provided in Table 6.1.21.

Table 6.1.21. Corrected caries rates for the Punic rural and urban contexts*.

STEP	PUNIC RURAL		PUNIC URBAN	
	ANTERIOR	POSTERIOR	ANTERIOR	POSTERIOR
A	15	33	0	3
B	0.50 (1/2)	0.20 (6/30)	0.25 (2/8)	0.066 (1/15)
C	7.5	6.6	0	0.198
D	1	17	2	7
E	8.5	23.6	2	7.2
F	42	167	70	135
G	57	200	70	138
H (CCF)	14.9%	11.8%	2.8%	5.2%
I (PCF)	5.5%	7.3%	1.0%	3.2%
J	**12.8%**		**4.2%**	

*For codes on each step see Table 6.1.1; CCF = caries correction factor (Lukacs, 1995); PCF = proportional correction factor (Erdal and Duyar, 1999; Duyar and Erdal, 2003).

From the above results, the Punic rural population had a relatively higher DC frequency than the urban population.

The corrected caries rates for the total Period 1 sample as well as the Period 2 sample are provided in Table 6.1.22. The original uncorrected frequencies for Period 1 were 2.6% (3/122), 7.9% (24/302) and 6.5% (27/414) for anterior, posterior and overall teeth respectively. The crude frequencies obtained for Period 2 were 2.9% (8/273) for anterior teeth, 16.7% (84/501) for posterior teeth and 11.4% (92/774) for the whole dentition. The corrected caries rates indicate a higher incidence of DC in Period 2.

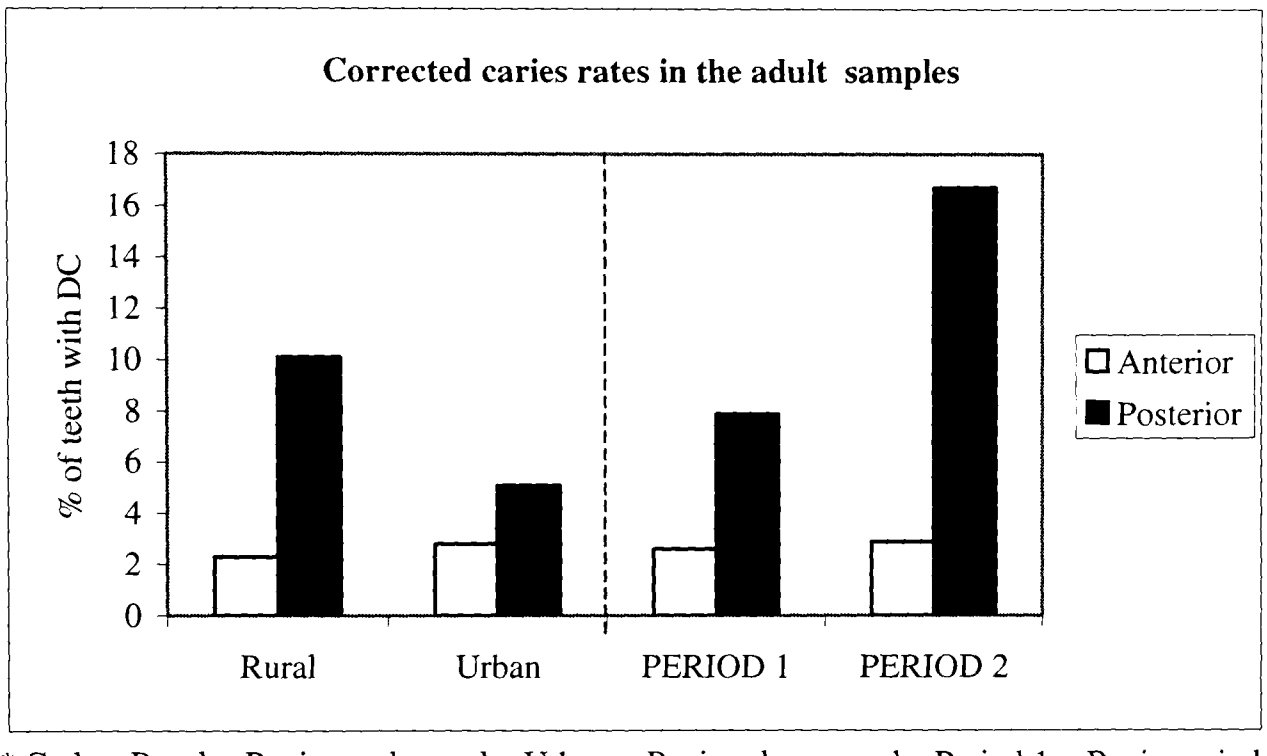
Table 6.1.22. Corrected caries rates for the Period 1 and Period 2 samples*.

STEP	PERIOD 1		PERIOD 2	
	ANTERIOR	POSTERIOR	ANTERIOR	POSTERIOR
A	15	36	27	94
B	0.30 (3/10)	0.155 (7/45)	0.176 (3/17)	0.571 (12/21)
C	4.5	5.58	4.752	53.674
D	3	24	8	84
E	7.5	29.5	12.7	137.6
F	112	302	273	501
G	127	338	300	595
H (CCF)	5.9%	8.7%	4.2%	23.1%
I (PCF)	2.2%	5.4%	1.5%	14.4%
J	**7.6%**		**15.9%**	

*For codes on each step see Table 6.1.1; CCF = caries correction factor (Lukacs, 1995); PCF = proportional correction factor (Erdal and Duyar, 1999; Duyar and Erdal, 2003).

The summary results for each context and period are illustrated in Figure 6.1 below. Only permanent teeth from adults were considered.

Figure 6.1. Corrected caries rates in the Ibizan samples*.



* Codes: Rural = Punic rural sample; Urban = Punic urban sample; Period 1 = Punic period; Period 2 = Late Antiquity-Early Byzantine period; Anterior = anterior teeth (incisors and canines); Posterior = posterior teeth (premolars and molars).

These results suggest that a higher incidence of DC was present in the Punic rural context as opposed to the urban area. When periods were compared, a higher incidence of DC was found in Period 2. Period 2 had the highest frequencies among all the samples. The Period 2 sample belonged to an urban context and with this consideration the frequencies for posterior teeth were over three times higher than the urban Punic sample.

Finally, mention can be made to permanent teeth belonging to individuals under the age of 15 years. No correction factors were applicable here because *ante-mortem*

tooth loss was unlikely. Correcting for *post-mortem* tooth loss was also excluded due to the fact that it was difficult to estimate how many teeth would have been erupted since this would have depended on the age of the individual and his or her dental development. Nevertheless, results were similar between Period 1 (urban dentitions) and Period 2. The uncorrected prevalence rates for Period 1 subadult permanent teeth were 5.0% (4/80) overall, 0% (0/44) for anterior and 8.6% (4/36) for posterior teeth. The DC rates in Period 2 were 5.7% (21/368), 0.7% (1/132) and 8.4% (20/236) for overall dentitions, anterior and posterior teeth respectively.

The implications of all these results are discussed below in Section 6.4.

6.1.1.5.2.4 Summary of key findings

Overall, corrected DC rates were relatively low, especially in the adult sample from the Punic urban site.

The deciduous sample in Period 1 (urban context only) and Period 2 exhibited similar frequencies of dental caries.

The adult Punic rural sample had a higher frequency of DC than the Punic urban sample. Overall corrected rates for Period 1 were lower than those in Period 2.

Generally speaking, in all samples DC and AMTL had predilection for the posterior mandible. DC was most common in the occlusal surfaces of posterior teeth. Anterior teeth were more affected by gross caries, except in Period 2 where CEJ lesions predominated. DC and AMTL were conditions present in all age groups. The small Period 1 samples did not show any significant differences according to adult age. However, the larger Period 2 samples did show significant differences with higher frequencies present in the older adults compared to the younger and middle adults.

Females tended to show a higher frequency of DC and AMTL than males but the differences were not significant except when the data on AMTL for the Punic rural context were considered.

6.1.2 Other indicators of oral pathology

Other conditions that allow an investigation into diet and the level of oral hygiene are briefly examined. These are dental calculus, periodontitis and periapical cavities. In addition, dental wear also deserves some attention in the reconstruction of diet. All these indicators are commonly used in combination with dental caries in a number of studies in order to reconstruct the diet of the population (e.g. Chimenos, 1990; Jurmain, 1990b; Littleton and Frohlich, 1993; Brothwell *et al.*, 2000). In addition, all these factors are interlinked. Dental caries and AMTL rates, for instance, may be influenced by dental attrition, periodontitis and calculus deposits, while periodontal disease may be influenced by dental calculus.

Each condition is analysed separately accompanied by a short review of definitions, aetiological factors and methods. Since the interest in this analysis was primarily oral hygiene and the diet of the population, only summary frequencies are given below rather than more detailed breakdowns such as, for instance, examining the prevalence of a condition according to tooth type.

6.1.2.1 Dental calculus

Dental calculus consists of an abnormal concretion (Ill. 6.3), basically mineralised plaque, which is associated with saliva. Plaque is a sticky matrix that includes living and dead organisms, protein and other food particles (Ortner and Putschar, 1985: 442). The aetiology of calculus is still poorly understood (Hillson, 1996; Lieverse, 1999). The presence of calculus is associated with poor oral hygiene and a diet high in carbohydrates (Hillson, 1996).

There are two types of dental calculus, supragingival and subgingival, the latter located below the gum level and less common today (see Hillson, 1996). Since calculus deposits occur more commonly in anterior teeth closer to salivary glands, separating tooth classes (anterior, posterior) during analysis was important.

Each tooth was observed and calculus was scored as present or absent. When present, dental calculus was observed as slight, moderate or considerable following

Brothwell (1987: 220). Taphonomic problems, such as caused by the type of archaeological deposit or the handling of teeth during excavation and post-excavation, may have contributed to any fragmentation, partial or complete removal of calculus. For this reason, it is not possible to estimate the real presence of calculus during the life of a particular individual (Chimenos *et al.*, 2001: 542). The frequencies therefore only represent a minimum.

These minimum frequencies were comparable between samples in Ibiza due to similar soil environments, similar excavation handling and handling by the same anthropologist (the current author). Prevalence rates were given. In addition, only teeth with considerable deposits were highlighted separately.

Table 6.1.23 presents the data for the Punic rural and Punic urban samples. The crude overall rate of teeth with calculus was 9.7% (18/184) in the rural sample and 36.5% (73/200) in the urban one. This difference was significant ($x^2 = 23.8$; $p = 0.000$). However, more reliably, when each tooth class was separated (anterior, posterior), the differences between contexts were not significantly different for anterior ($x^2 = 1.34$; $p = 0.247$) and posterior teeth ($x^2 = 3.56$; $p = 0.059$). Anterior teeth were more affected than posterior teeth, particularly noticeable in the rural sample where the difference was significant ($x^2 = 11.0$; $p = 0.001$). The difference between anterior and posterior teeth in the urban sample was not significant ($x^2 = 0.765$; $p = 0.382$). Mandibular teeth were significantly more affected than maxillary teeth in the urban sample ($x^2 = 3.94$; $p = 0.047$) but not in the rural sample ($x^2 = 1.35$; $p = 0.245$).

In the rural sample there were no deposits classified as 'considerable'. In the urban population only the anterior teeth had considerable deposits. This accounted for 27.5% (8/29) of teeth with calculus. Among the teeth with calculus, the difference between the numbers of teeth with considerable deposits was not significantly different ($x^2 = 2.61$; $p = 0.106$) between the rural context (0/10, 0%) and the urban (8/29, 27.5%).

Table 6.1.23. Dental calculus in the Punic samples*.

Calculus	PUNIC RURAL				PUNIC URBAN			
	F	M	T	%	F	M	T	%
Anterior maxilla	-	0/2	1/5	20	0/11	6/10	9/32	28.1
Posterior maxilla	-	0/6	0/24	0	0/14	9/22	11/49	22.4
Anterior mandible	0/1	5/15	9/33	27.2	1/9^{Cx1}	13/17^{Cx2}	20/36 ^{Cx8}	55.5
Posterior mandible	0/7	5/32	8/122	6.5	3/20	18/31	33/83	39.7
All maxilla	-	0/8	1/29	3.4	0/25	15/32	20/81	24.6
All mandible	0/8	10/47	17/155	10.9	4/29 ^{Cx1}	31/48^{Cx2}	53/119 ^{Cx8}	44.5
All anterior	0/1	5/17	10/38	26.3	1/20 ^{Cx1}	19/27^{Cx2}	29/68 ^{Cx8}	42.6
All posterior	0/7	5/38	8/146	5.4	3/34	27/53	44/132	33.3

* Codes: F = female sample; M = male sample; T = total sample (females, males and those unsexed); ^{C} = teeth with considerable calculus deposit. The number indicates the number of teeth with considerable calculus (e.g. Cx8 = eight teeth with calculus).

The rural female sample was only represented by eight teeth. In the urban sample, differences between sexes could be compared more reliably. Females had fewer anterior teeth with calculus (5%) than males (70.3%) and this difference was

significant (x^2 = 9.19; p = 0.002). This trend was also apparent in posterior teeth where 8.8% of female teeth had calculus compared to 50.9% of male teeth (x^2 = 8.72; p = 0.003). In addition, rural males had lower rates for anterior (29.4%) and posterior (13.1%) teeth than urban males who had 70.3% anterior teeth and 50.9% posterior teeth with calculus. The difference was not significant with regard to anterior teeth (x^2 = 2.25; p = 0.134) but proved significant with regard to posterior teeth (x^2 = 7.11; p = 0.008).

Table 6.1.24 compares the overall data for the Punic period (Period 1) with the data from the Late Antiquity-Early Byzantine period (Period 2).

Table 6.1.24. Dental calculus in Period 1 and Period 2*.

Calculus	PERIOD 1				PERIOD 2			
	F	M	T	%	F	M	T	%
Anterior maxilla	0/11	6/12	10/37	27.0	7/18 Cx1	17/40	33/85 Cx1	38.8
Posterior maxilla	0/14	9/28	11/73	15.0	15/37 Cx5	39/77 Cx1	73/174 Cx6	41.9
Anterior mandible	1/10 Cx1	18/32 Cx2	29/69 Cx9	42.0	27/37 Cx4	79/95 Cx15	125/166 Cx30	75.3
Posterior mandible	3/27	23/63	41/205	20.0	41/83 Cx4	89/153 Cx3	157/300 Cx8	52.3
All maxilla	0/25	15/40	21/110	19.0	22/55 Cx6	56/117 Cx1	106/259 Cx7	40.9
All mandible	4/37 Cx1	41/95 Cx2	70/274 Cx8	25.5	68/120 Cx8	168/248 Cx18	282/466 Cx38	60.5
All anterior	1/21 Cx1	24/44 Cx2	39/106 Cx8	36.7	34/55 Cx5	96/135 Cx15	158/251 Cx31	62.9
All posterior	3/41	32/91	52/278	18.7	56/120 Cx9	128/230 Cx4	230/474 Cx14	48.5

* Codes: F = female sample; M = male sample; T = total sample (females, males and those unsexed); ^{C} = teeth with considerable calculus deposit. The number indicates the number of teeth with considerable calculus (e.g. Cx8 = eight teeth with calculus).

In Period 1 anterior teeth had significantly more calculus than posterior teeth (x^2 = 8.07; p = 0.004), as well as more calculus in mandibles than in maxillae although here the difference was not significant (x^2 = 1.14; p = 0.285). In Period 2 the anterior teeth were significantly more affected (x^2 = 4.05; p = 0.044) and the lower jaw was more affected than the maxilla (x^2 = 8.10; p = 0.004). Overall, calculus in Period 1 affected 23.6% (91/384) of all the teeth observed, 36.7% anterior teeth and 18.7% posterior teeth. The overall teeth with calculus in Period 2 were 53.5% (388/725), and 62.9% of anterior teeth and 48.5% of anterior teeth. The difference between periods was significant when considering the overall teeth (x^2 = 39.0; p = 0.000), anterior teeth (x^2 = 6.43; p = 0.011) and posterior teeth (x^2 = 32.4; p = 0.000).

Overall, Period 1 female anterior teeth were significantly (x^2 = 7.83; p = 0.005) less affected (4.7%) than Period 1 male anterior teeth (54.5%). Posterior teeth were also significantly (x^2 = 7.21; p = 0.007) less affected in the female sample (7.3%) compared to the male sample (35.1%). In Period 2, females had slightly lower calculus in anterior teeth (61.8%) compared to males (71.1%), although the difference was not significant (x^2 = 0.300; p = 0.584). Posterior teeth followed the same pattern, with female teeth exhibiting lower (46.6%) frequencies than male teeth (55.6%) although the difference was also not significant (x^2 = 0.809; p = 0.368).

Comparing female teeth, the anterior female dentitions in Period 1 had less calculus (4.7%) than those in Period 2 (61.8%). The same pattern applied with regard to posterior female teeth between Period 1 (7.3%) and Period 2 (46.6%). These

differences were significant, both for anterior (x^2 = 9.26; p = 0.002) and posterior teeth (x^2 = 11.2; p = 0.001). Period 1 males exhibited fewer (54.5%) calculus deposits in anterior teeth compared to Period 2 male teeth (71.1%). However, this difference was not significant (x^2 = 0.858; p = 0.354). When posterior male teeth were compared between Period 1 (35.1%) and Period 2 (55.6%), the difference was significant (x^2 = 3.91; p = 0.048).

Finally, with regard to the teeth with calculus deposits, there was no real difference between those having considerable calculus: 20.5% (8/39) in Period 1 anterior teeth, 19.6% (31/158) Period 2 anterior teeth, 0% (0/52) Period 1 posterior teeth and 0.6% (31/158) Period 2 posterior teeth.

The key findings from these results are that rates for calculus were high in both periods, particularly when taking into account that the real number of calculus in the once living populations is underestimated in the archaeological material. There were no significant differences between rural and urban contexts in calculus prevalence. With regard to the real prevalence as confirmed by statistical analysis, the following statements were drawn:

- In the Punic urban context, females had more calculus than males.
- Rural males had more calculus than urban males in posterior teeth.
- Period 1 had lower calculus prevalence than Period 2.

- Period 1 females had less calculus than Period 1 males and also lower than Period 2 females.
- Males in Period 1 had lower calculus in the posterior teeth than males in Period 2.

6.1.2.2 Periodontitis

Since periodontitis is associated with an infection influenced by factors such as poor hygiene or calculus deposits (Brothwell, 1987: 218), it can also serve as an indicator of a population's oral health.

Periodontal disease is an inflammation starting in the soft tissues of the jaw (gingivitis) that eventually might lead to bone resorption (periodontitis) (Roberts and Manchester, 1995: 56). Metabolic problems (e.g. scurvy) and dental calculus may be some of the influential factors causing this inflammatory response that may lead to periodontitis (Ortner and Putschar, 1985: 442). Today, it is one of the most common dental diseases and a major cause of tooth loss in individuals over 40 years of age (Roberts and Manchester, 1995: 56).

In archaeological material what is observed is the distance between the cemento-enamel junction (CEJ) of the tooth and the alveolar crest of the mandible (Ill. 6.4). Recording of periodontal disease followed the schemes devised by Brothwell (1987: 220): absent, slight, medium and considerable. Chimenos and colleagues (2001:

542) propose that slight or moderate periodontal recession should be in the range of 3-6 mm, while over 6 mm it could be classified as considerable.

There are several problems in recording periodontitis in archaeological populations (Roberts and Manchester, 1995: 56-57). Firstly, an increase in the space between the CEJ and the alveolar crest may not always be a result of periodontal disease but could result from continuous tooth eruption through life. Secondly, and leading from the first problem, this continuous eruption to compensate for attrition has been often diagnosed as periodontitis and therefore periodontitis has been over diagnosed in skeletal populations. A third problem is that there is a need for standardisation in recording data and also in defining what constitutes periodontitis. Finally, care must be taken with *post-mortem* damage in the jaws because it may mimic bone resorption.

With regard to these problems, the definition followed is that by Roberts and Manchester (1995: 56) who indicate that a secure positive diagnosis of periodontitis would see inflammatory pitting or new bone formation in the jaw. Alveolar resorption can be identified as probably resulting from periodontal disease when no periapical cavity or tooth loss is present (Ortner and Putschar, 1981: 443).

To further counteract these problems only advanced periodontitis will be taken into account. In general, lower degrees of advanced periodontitis would suggest a good standard of oral health (Brothwell *et al.*, 2000: 253).

Most jaws in the Ibizan samples were found very fragmented *post-mortem* so that the sample size was limited. In case age might have influenced the presence of advanced periodontitis, data are presented first according to age groups and later pooled together (Tables 6.1.25 and 6.1.26). Upper and lower, anterior and posterior alveoli have been pooled here.

Prevalence rates reflected the proportion of alveoli (sockets) with advanced resorption among all the alveoli observed.

Table 6.1.25. Prevalence of advanced periodontitis in the Punic samples.

Periodontitis	**PUNIC RURAL**				**PUNIC URBAN**			
	F	**M**	**T**	**%**	**F**	**M**	**T**	**%**
15-30	0/3	0/22	0/63	0	-	-	1/17	5.8
30-50	-	0/10	2/43	4.6	5/7	25/33	31/55	56.3
50+	-	-	0/5	0	-	-	1/1	100
Adult (unaged)	-	-	0/1	0	-	-	-	-
TOTAL	0/3	0/32	2/112	1.7	5/7	25/33	33/73	45.2
%	0	0	1.7	-	71.4	75.7	45.2	-

* Codes: F = female sample; M = male sample; T = total sample (females, males and those unsexed).

The prevalence for the Punic rural sample was low at 1.7% (2/112) of alveoli with advanced recession. The Punic urban sample exhibited significantly ($x^2 = 35.4$; $p = 0.000$) higher frequencies (45.2%) of periodontitis. Although the female sample size was small, no real differences were found between sexes. In comparing males, however, significantly ($x^2 = 19.1$; $p = 0.000$) lower rates (0/32, 0%) were found in male from the rural environment. There were also variations according to age group,

although here only the young and middle adult categories are comparable due to the sample sizes. Young adults showed significantly lower frequencies than middle adults in the urban ($x^2 = 6.50$; $p = 0.011$) but not in the rural ($x^2 = 2.85$; $p = 0.091$) groups. Middle-aged adults (30-50 years) from the rural area had a significantly ($x^2 = 15.7$; $p = 0.000$) lower prevalence rate than the same age group in the urban area.

Table 6.1.26 contains the prevalence of alveoli with advanced recession for the overall Period 1 and Period 2 samples. No significant differences ($x^2 = 1.69$; $p = 0.193$) were found between the overall rate in Period 1 and that in Period 2. No significant differences ($x^2 = 0.194$; $p = 0.659$) were found between Period 1 males and females, but differences between the sexes were present in the Period 2 sample ($x^2 = 7.14$; $p = 0.008$). Comparing females from both periods no significant difference was found ($x^2 = 1.15$; $p = 0.284$), but with regards to males there were significantly higher prevalence rates in Period 1 ($x^2 = 17.9$; $p = 0.000$).

Table 6.1.26. Prevalence of advanced periodontitis in Period 1 and Period 2.

Periodontitis	**PERIOD 1**				**PERIOD 2**			
	F	**M**	**T**	**%**	**F**	**M**	**T**	**%**
15-30	0/3	0/22	1/80	1.2	4/52	6/145	19/259	7.3
30-50	5/7	25/43	33/98	33.6	12/12	10/64	22/77	28.5
50+	-	-	1/6	16.6	1/1	3/9	4/11	36.3
Adult (unaged)	-	-	0/1	0	-	5/9	5/13	38.4
TOTAL	5/10	25/65	35/185	18.9	17/65	24/227	50/360	13.8
%	50	38.4	18.9	-	26.1	10.5	13.8	-

* Codes: F = female sample; M = male sample; T = total sample (females, males and those unsexed).

In Period 1, between comparable samples, younger adults displayed significantly (x^2 = 21.3; p = 0.000) lower values than middle adults. The same trend between young and middle adults applied to Period 2 (x^2 = 17.8; p = 0.000). When younger adults (15-30 years) from both periods were compared, there was no significant difference (x^2 = 3.74; p = 0.053), and equally no significant differences were found between middle age groups (x^2 = 0.273; p = 0.601) and between older age groups (x^2 = 0.417; p = 0.519).

In summary, rates were not modest in all the contexts bearing in mind that only the alveoli with advanced resorption were scored as positive. Significant differences were found between Punic contexts where the urban sample exhibited higher rates of advanced periodontitis. No differences were found between the overall rates in Period 1 and Period 2. Males in Period 1 exhibited a significantly higher prevalence than males in Period 2. In Period 2, females exhibited significantly more periodontitis than males from the same period.

6.1.2.3 Periapical cavities

Periapical cavities have often, in anthropology, been erroneously referred as abscess cavities, since it is unlikely that abscess form these cavities in the majority of cases (Dias and Tayles, 1997). Apart from periapical abscess, other conditions resulting in cavities include periapical granulomata and apical periodontal cysts (Dias and Tayles, 1997).

The identification of a periapical cavity was diagnosed by the presence of a perforating fistula in a specific alveolar location. These lesions were distinguished from *post-mortem* damage by observing round (healed) edges indicative of an *ante-mortem* condition (Roberts and Manchester, 1995: 51). Prevalence rates were given by number of alveoli with cavities out of the number of alveoli observed (Table 6.1.27). Only adult jaws were examined. Teeth were grouped into anterior and posterior dental classes. Fragmentation *post-mortem* of maxillae and mandibles limited the number of observations.

Table 6.1.27. Presence of periapical cavities in all samples studied.

PERIAPICAL CAVITIES IN THE IBIZAN SAMPLES						
Population	**FEMALES**		**MALES**		**TOTAL ADULTS**	
	Anterior	**Posterior**	**Anterior**	**Posterior**	**Anterior**	**Posterior**
Punic rural	-	-	0/21	1/31 (3.2)	0/21	1/31 (3.2)
Punic urban	-	-	0/9	0/14	0/18	0/31
PERIOD 1	-	-	0/30	1/45 (2.2)	0/39	1/62 (1.6)
PERIOD 2	0/60	1/114 (0.8)	0/119	1/198 (0.5)	0/216	6/372 (1.6)

The prevalence of periapical lesions was low in all samples. The results in those groups where cavities are present (>0%) are within the normal range for archaeological sites from Spain (see Lalueza-Fox and González, 1999) as well as within the ranges obtained from sites dating from the Roman to Medieval periods in Britain (see Roberts and Manchester, 1995: 51-52). Higher prevalence rates, however, have been reported for other Punic sites in Ibiza (see Section 6.4).

From the samples analysed in this thesis, no cavities were found in anterior alveoli. In the Punic samples, only the rural series produced a periapical cavity, and the prevalence (3.2%) was not significantly different ($x^2 = 0.984$; $p = 0.321$) to that from the urban sample. Females and males had similar frequencies. Identical prevalence rates (1.6%) were found in the overall Punic sample (Period 1) compared to Period 2.

6.1.2.4 Dental wear

Dental wear may be studied at the macroscopic (macrowear[102]) and microscopic levels. Microwear is related to tooth striations on buccal surfaces (see Hillson, 1996; also see Spanish studies by Pérez-Pérez *et al.*, 1991a; Lalueza, 1992) and requires microscopy. Microwear might only record the pattern of meals just before death, rather than the result of many years of food consumption. This study focused on macrowear or dental attrition (Ill. 6.5).

Dental attrition can be defined as a 'physiological process, the wearing away of tooth hard tissue as a result of tooth-to-tooth contact during mastication and swallowing' (Langsjoen, 1998: 398). Abrasion and erosion[103] can also result in loss of occlusal surfaces (Langsjoen, 1998: 398).

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[102] With regard to macrowear, there are different types such as attrition, abrasion and erosion (see Hillson, 1996). Here, tooth wear was used to include any combination of these (after Larsen, 1997: 247). In any case, only attrition and abrasion were observed. Erosion was not studied. See footnote below.

[103] Langsjoen (1998: 398) defines dental abrasion as 'a wearing away of dental hard tissue by some abnormal mechanical process or abrasive material, and is considered pathologic'; while dental erosion would be the 'loss of tooth tissue by a chemical process that does not involve bacterial action'. While

Dental attrition provides direct evidence of behaviour during mastication (Smith, 1984). At a very general level, it can indicate the type of diet and subsistence economy, for instance differentiating hunter-gatherers from agriculturalists (Smith, 1984). Smith (1984) observed how hunter-gatherers had a relatively flat, even wear at an advanced stage, while agriculturalists were characterised by developing oblique wear. Farwell and Molleson (1993: 182) state that 'Molar teeth are particularly involved in the mastication of cereal foodstuffs and it is by monitoring the wear on these teeth that some indication can be gained of the importance and nature of cereal in the diet'.

Dental attrition can also be informative about food preparation techniques (Molnar, 1971). Cereals in the form of bread have a marked effect on dental wear (Farwell and Molleson, 1993: 182). Vegetables are in general more abrasive than meat, cooked foods will cause a more oblique wear plane than that caused by uncooked food, and the use of mortar stones to grind grain might leave stone particles in the food that will be abrasive for teeth (Polet and Orban, 2001). Low rates of wear in Europe today are a consequence of factory-processed foods (Mays, 2002).

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abrasion might be caused by the use of teeth as tools; enamel erosion can be caused, for example, by drinking herbal tea (e.g. see Brunton and Hussain, 2001).

Therefore, in this section, dental attrition is only generally described to gather information on the general diet of the population and possibly on food preparation techniques[104].

A word of caution is essential in that dental wear can be caused not only from masticating food, but also from other masticatory activities such as chewing hides, as can be clearly observed in Inuit examples from Greenland (see Ammitzbøll *et al.*, 1991). Other cultural factors affecting wear may be the inclusion of ashes in food, clenching objects, prolonged holding of objects such as a pipe or wind instruments, toothpick use and trauma (Townsend *et al.*, 1994)[105]. Bruxism, the involuntary grinding or clenching of teeth (e.g. while sleeping), might also wear enamel.

Wear on each tooth was recorded using four methods in order to provide as much detailed recording as possible. Wear in all teeth was drawn and in some cases it was photographed. Each wear pattern on a tooth was classified primarily according to one of the stages devised by Smith (1984) as well as those created by Brothwell (1981). Smith's method is applicable to all teeth in the dentition. Brothwell's chart is only applicable to molar teeth but it has the advantage that it visually shows the plain or angle of dental wear. It was also thought appropriate to convert the diagrams on

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[104] In addition, dental wear is related to the development of dental caries. A reduction in dental wear correlates with an increase in dental caries (Hillson, 2001; Larsen, 1997a: 252). Understanding the degree of attrition was therefore important in order to further understand the prevalence of dental caries.

[105] No prevalence rates were made for extramasticatory wear, for instance where teeth were used as 'tools' (Larsen, 1997: 258). However, when noticed it was recorded. Some examples of extramasticatory wear have been found. In the Period 2 dentitions labial wear in anterior teeth was found in specimen AR33-B (Ill. 6.6, Ill. 6.7). This wear pattern seems to have been activity-induced. Another example of this is canine AR33-H. *Ante-mortem* chipping seems evident in a second molar (AR33-L-N/G-H) and one premolar (AR33-K/D). In a right second premolar (AR33-M-C) there seems to be a pattern related to a tool similar in dimensions and shape to a toothpick.

attrition found in Hillson (1996) and to number each wear pattern from zero (no wear) to stage five, six, or seven depending on the diagram. Hillson's diagrams cover anterior and posterior teeth and it was thought useful in order to back-up and confirm any patterns that had been recorded using Smith's diagram. Additionally, recording was also undertaken for molar teeth based on the charts by Li and Ji (1995), which have the advantage to score separately every quadrant of the tooth as well as incorporating recording stages of enamel wear prior to exposure of dentine. Smith's (1984) method would have been sufficient, particularly when drawings were taken of each tooth, but the opportunity was taken to apply these other methods and these were employed in case access to this skeletal material is restricted in the future.

In the results shown below, all dental wear classifications were based on Smith's (1984) stages. For statistical purposes the teeth were finally classified into: no dentine exposed, slight, moderate and heavy wear. These three last categories corresponded with the following stages in Smith's diagram (1984): slight corresponded to stages 1-4, moderate to stages 5-6 and heavy to stages 7-8.

Notes were also made on any prominent angle in molars caused by wear as well as the type of wear (e.g. flat, 'cupped'). For instance, agriculturalist show cupped wear and higher angles of occlusal wear than hunter-gatherers (Smith, 1984).

In this thesis, the study of wear was limited. Wear was not used for comparisons between samples, but only to learn about the proportion of anterior and posterior teeth

with slight, moderate and heavy wear. The reason that did not allow any reliable comparisons between periods was primarily imposed by problems in age determination. Age is a major determinant of dental attrition (e.g. see Boldsen, 2005) and Farwell and Molleson (1993: 182) rightly state that 'Although the wear patterns are an extremely crude reflection of the amount of attrition and the grades by no means represent equal amounts of loss of crown height, they can be used to estimate rate of wear if the grade typically reached by a given age is determined. The age must of course be estimated by independent criteria such as tooth development'. Unfortunately, in the adult category age-at-death could only be estimated through dental wear and not by other independent criteria due to the disarticulated nature of the assemblages[106].

Although a certain percentage of teeth would have slight, moderate and heavy wear correlated with age, the study of wear regardless of age did provide an indication about its possible influence on caries rates. This study also provided general impressions about wear patterns, such as whether anterior teeth were more affected than posterior teeth or whether molars had an oblique angle of wear in the rural population.

Results relating to dental wear focused on the degree of wear in anterior and posterior dentitions. In addition, some information was obtained on the type of wear (e.g. oblique, 'cupped'). Only individuals older than 15 years of age (adults) were considered.

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[106] It is also useful to see whether the opposing tooth of that one observed is functionally present or not, since if it had been lost during life the attrition rate of the tooth observed would have declined (Boldsen, 2005: 170). Opposing teeth are difficult to match, however, in disarticulated assemblages where fragmentation was high.

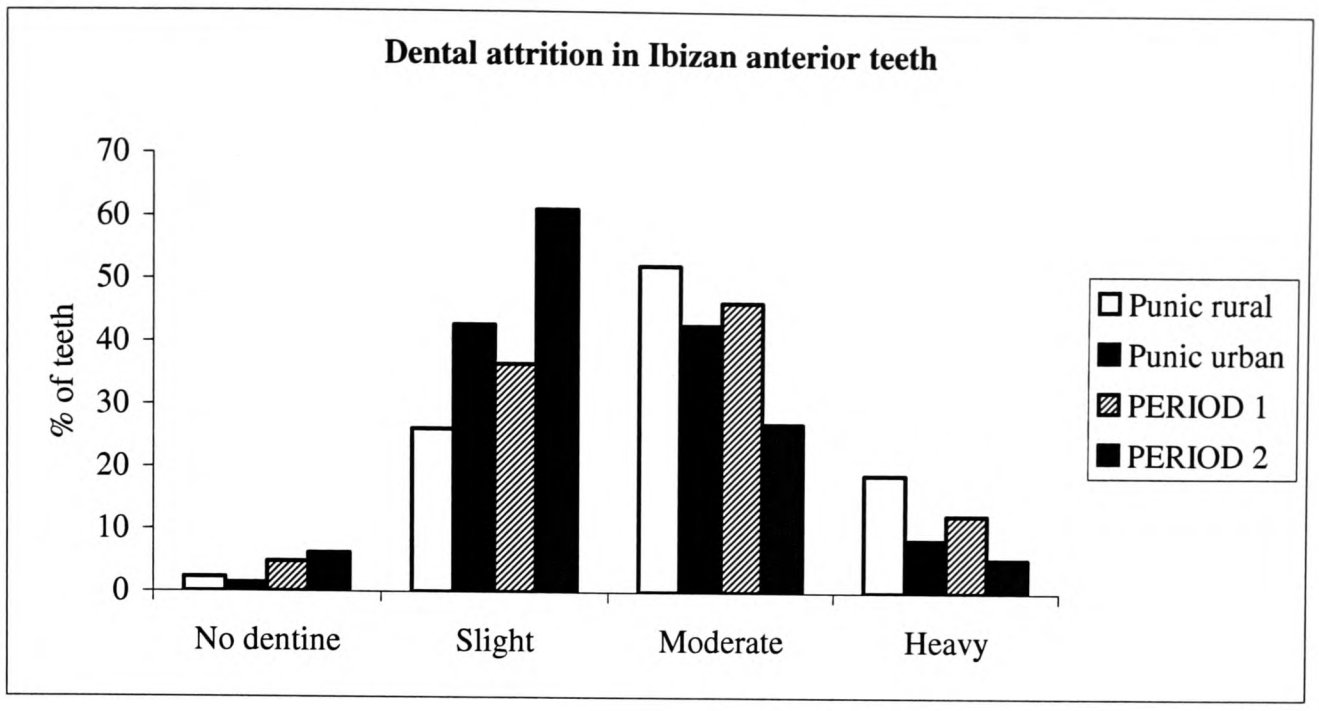
Table 6.1.28 provides the distribution of anterior and posterior teeth according to the amount of dentine exposed, classified into the following groups as stated previously: no dentine exposed, slight, moderate and heavy.

Table 6.1.28. Number of teeth distributed according to stage of dental wear.

Samples	**Total teeth observed**	**Degree of wear**			
ANTERIOR TEETH		**No dentine**	**Slight**	**Moderate**	**Heavy**
Punic rural	42	1	11	22	8
Punic urban	70	1	30	30	6
PERIOD 1	112	2	41	52	14
PERIOD 2	258	16	158	70	14
POSTERIOR TEETH	**Total teeth observed**	**No dentine**	**Slight**	**Moderate**	**Heavy**
Punic rural	166	4	77	45	40
Punic urban	130	30	54	20	26
PERIOD 1	296	34	131	65	66
PERIOD 2	457	57	310	71	19

These dental counts were converted into percentages of teeth in each category. These proportions are illustrated in Figures 6.2 and 6.3 for anterior and posterior teeth respectively.

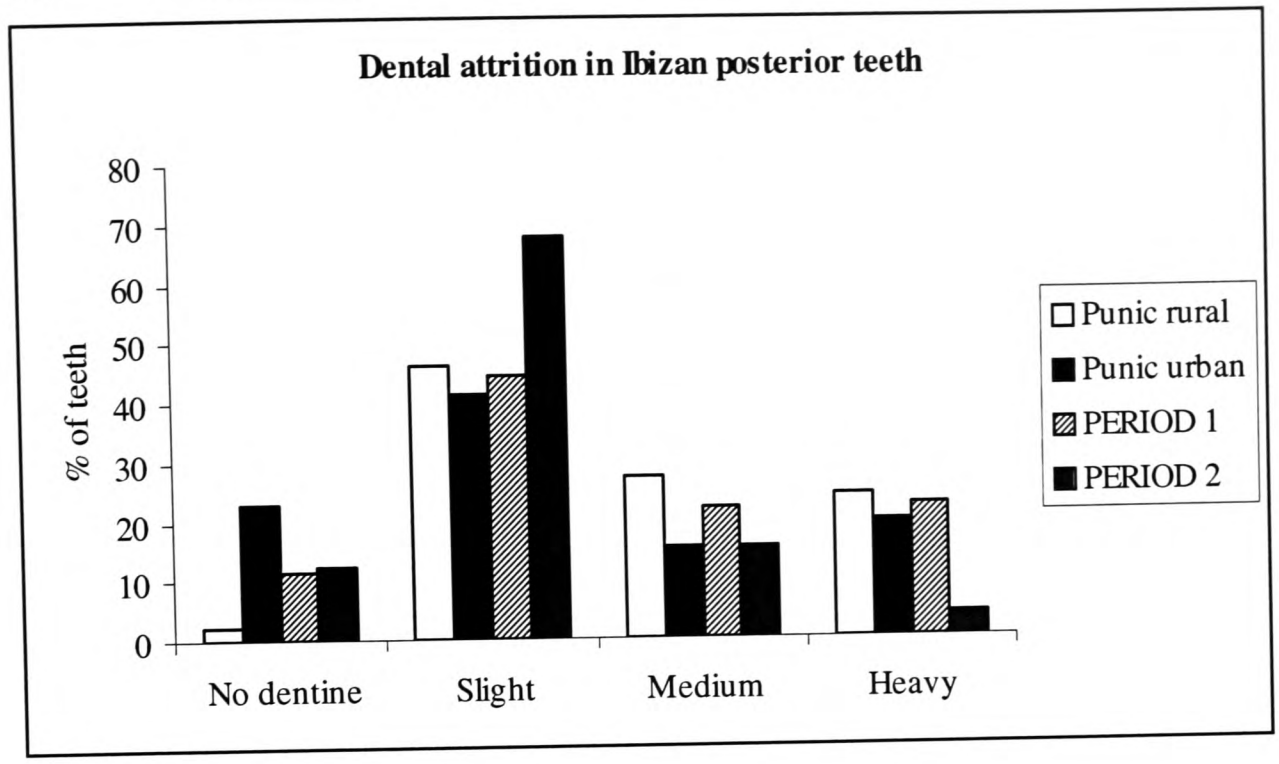
Figure 6.2. Proportion of anterior teeth with different degrees of wear.



This trend in adults was more or less similar for all samples where peaks were present in the slight and medium categories. In the Punic rural sample, and the overall Period 1 sample, there were more anterior teeth with moderate wear. The Punic urban sample displayed equal number of teeth with slight and moderate wear. Teeth from Period 2 revealed a higher percentage in the category of slight dentine exposure. As explained earlier, no attempts were made to compare periods since the ages of the individuals to which these teeth belonged were only known through dental wear in the majority of cases.

In relation to posterior teeth, all samples had a higher proportion of premolars and molars with slight wear. The other categories showed a more even distribution.

Figure 6.3. Proportion of posterior teeth with different degrees of wear.



The low frequency of heavy wear would suggest a limited consumption of hard fibrous food. This peak in slight wear might be influenced by lower attrition in premolars and in third molars that may have erupted late in life.

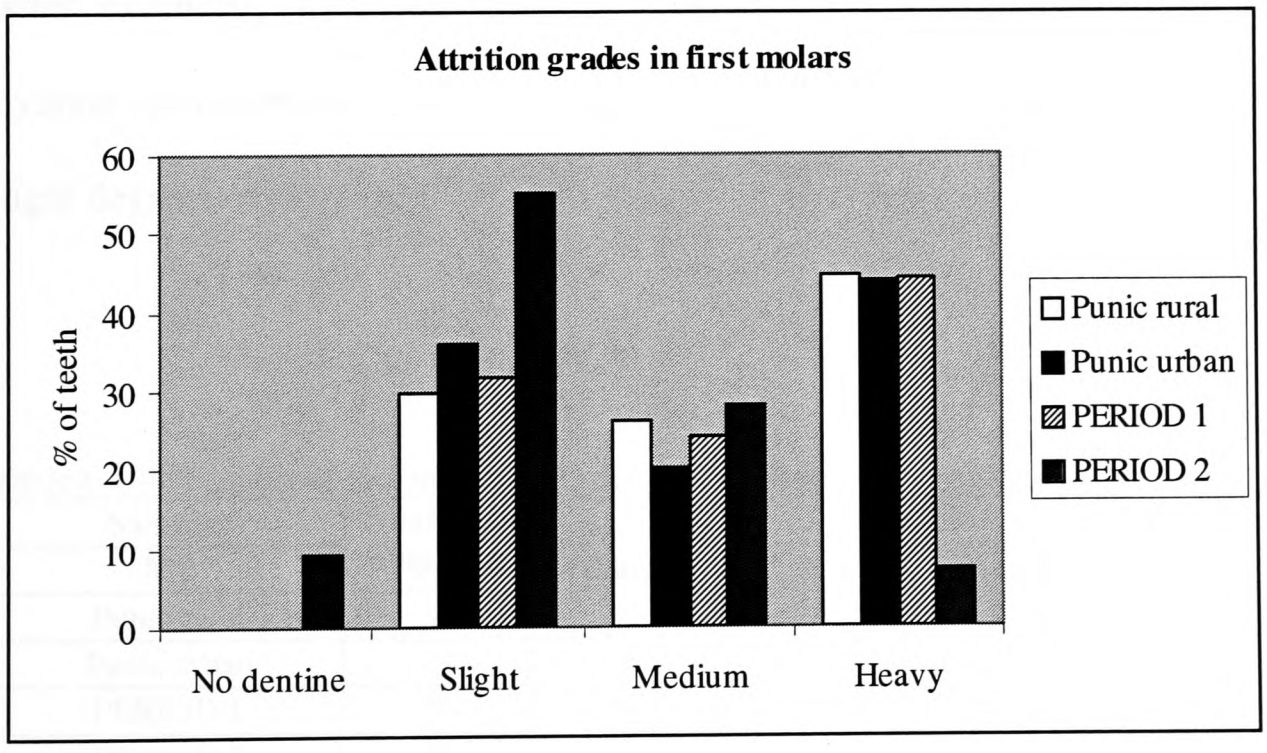
It was thought that the first molar could be examined in more detail since it is the first permanent tooth to erupt, when the individual is about six years of age. Table 6.1.29 and Figure 6.4 provide data, respectively, on the number and percentage of first molar teeth observed in each wear category.

Table 6.1.29. Number of first molars distributed according to stage of dental wear.

Samples	Total teeth observed	Degree of wear			
M1		No dentine	Slight	Moderate	Heavy
Punic rural	54	0	16	14	24
Punic urban	25	0	9	5	11
PERIOD 1	79	0	25	19	35
PERIOD 2	96	9	53	27	7

All samples except for Period 2 revealed high levels of heavy wear (Figure 6.4). Period 2 showed a peak in the category of slight wear. In this period there was also a small percentage of first molars with no dentine exposed.

Figure 6.3. Proportion of first molars with different degrees of wear.



Hence, it is may be that the higher frequency of dental caries in Period 2 is partly influenced by the lower degree of attrition in this sample.

Finally, the number of first molars with oblique wear or cupped wear could be estimated (Table 6.1.30). It is recalled that oblique and cupped wear is common in agriculturalists consuming agrarian diets based primarily on grain-based foodstuffs.

Only the most noticeable cases were considered. Out of 54 first molars in the rural context, four teeth were characterised by oblique wear and six by cupped wear. No cupped wear was found in the urban sample, but oblique wear was found. All characteristics pointing towards an agricultural diet point to the Punic period where the percentages are higher than that in the Late Antiquity-Early Byzantine sample, despite this latter exhibiting a higher frequency of caries which should reflect higher carbohydrate consumption. The remaining wear patterns tended to be more or less even with slight degrees of sloping.

Table 6.1.30. Number of first molars (M1) distributed according to type of wear.

Samples	**Total teeth observed**	**Type of wear**			
M1		**Oblique**	**%**	**Cupped**	**%**
Punic rural	54	4	7.4	6	11.1
Punic urban	25	5	20	0	0
PERIOD 1	79	9	11.3	6	7.5
PERIOD 2	96	3	3.1	2	2

The tooth with the steepest oblique plane was an upper first molar (PCHN-6) from a rural individual aged 30-50 years according to the pattern of dental wear. This tooth had an oblique angle of around 45 degrees, sloping in a linguo-buccal direction. The second steepest wear plane (c. 60 degrees) was present in a lower first molar from an older adult (PCHN-H10-M4). In the rural area, the deepest cusps were present among all the samples. A lower first molar from a rural male individual (PCHN-H10-M53) aged 30-50 years, displayed a cuplike structure with a depth of 3.29 mm measured from the highest point of the enamel to the deepest point of the cup. This was followed by another rural tooth, a lower second molar from a 30-50 individual (PCHN-H10-M50), with a cup deeper than 1.5 mm.

The implications of all of these results are discussed in Section 6.4.

6.2 Stable isotope analysis

Results were available from stable isotope analysis undertaken on samples from Ibiza. This method also aided in the reconstruction of the diet of the Ibizan populations[107].

6.2.1 Background

Analyses of stable isotopes have been a useful source of information in reconstructing diet. These chemical analyses have contributed to understanding the diffusion of maize agriculture in the USA (Vogel and van der Merwe, 1977) and the importance of marine resources in European hunter-gatherers (Tauber, 1981). Studies have also been undertaken on fossil hominids dated as early as the Pliocene (Sponheimer and Lee-Thorpe, 1999) as well as the more recent Neandertals (Richards *et al.*, 2000).

Without entering into too much detail about bone composition, a bone is constituted of water, an inorganic part (c.70%) and an organic part (c.30%). In the organic part there is collagen, which is a protein composed of amino-acids and

[107] These data did not derive from work undertaken particularly for this thesis, since chemical analyses requires specialists in this field. The results used here come from unpublished preliminary data. The information presented here derives from work undertaken in collaboration with Drs. M.P. Richards and B.T. Fuller, formerly at Oxford. Dr. Mike P. Richards is head of the project that was funded by the *British Academy*. Ibizan samples ranging from Prehistory to Medieval times were analysed. Ben Fuller undertook the analyses and has helped me often during long discussions over emails. I thank them both for allowing me to include these results in this thesis. Published results have been given for the Punic rural site (Márquez-Grant *et al.*, 2003).

elements (carbon, hydrogen, oxygen, nitrogen and sulphur). The carbon and nitrogen stable isotopes are the most used in palaeodietary studies (see Vogel and van der Merwe, 1977; Tauber, 1981; Schwarz and Schoeninger, 1991; Katzenberg, 2000; Mays, 1998, 2000b), although recently sulphur has also been used (Richards *et al.*, 2001, 2003).

A chemical element can have distinct varieties of atoms, with different atomic masses. Atoms are particles with a nucleus generally composed of protons and neutrons and that is surrounded by electrons. The variations within a same element are a result of the different number of neutrons since the amount of protons and electrons is the same. The combinations of protons and neutrons (e.g. 6, 7 or 8 neutrons in carbon) are called isotopes. Isotopes can be radioactive (e.g. ^{14}C) or stable (e.g. ^{12}C and ^{13}C). In palaeodietary studies when ^{13}C is used, its value represents the ratios of $^{12}C/^{13}C$ in a sample relative to that of a standard reference.

In the Ibizan material, values from two stable isotopes have been examined: ^{13}C and ^{15}N. The quantity of ^{13}C can provide some indication as to the quantity of terrestrial (e.g. cereals, meat, milk) and marine protein (e.g. fish, shellfish, sea mammals) in the diet. This stable isotope also allows for a distinction between C_3 plants (most species, over 95% on earth) and C_4 such as maize. These are distinguished by way of different photosynthesis (e.g. see Crawley, 1997). Usually a $\delta^{13}C$ value of 20‰ represents a diet based on C_3. By contrast values of -12‰ would represent C_4 plants. However, in

Europe and template zones, C_4 plant species are scarce so it is assumed that a value of -12‰ represents marine protein.

Values obtained from ^{15}N provide information about how much meat (animal protein) or fish was consumed in the terrestrial or the marine diet. For instance, in a marine diet (as inferred from the $\delta^{13}C$ values) a range of +7‰ and +8‰ probably represent shellfish, while higher values will represent fish and much higher, circa +20‰, will probably indicate consumption of sea mammals (e.g. seals). With regard to terrestrial protein, there is a tendency for herbivores to be between +3‰ and +6‰ and carnivores between +7‰ and +10‰. The values will depend on many factors such as geographical region, climate, time depth and weaning in cases where children are analysed.

There are several advantages to using stable isotopes. The first is that it provides a record of an individual's diet during many years. Bone remodelling might be completed every seven to ten years, so that stable isotopes can provide information on the amount of protein an individual has consumed over a number of years. The other advantage is that it can be applied to any teeth or bone, and only a maximum sample size of 250 g is generally required. In addition, not only does it provide direct evidence for the diet of the population in general, but also for the diet of a particular individual. The analysis however requires some dental or skeletal destruction, appropriate equipment and finance. It only indicates protein consumption and not which foodstuffs were consumed. Nevertheless, its advantages surpass its disadvantages.

6.2.2 Materials and methods

A total of 38 left ulnae representing 38 different adults in the Punic rural sample were submitted for analysis. A total of 12 individuals from the Punic urban sample were submitted although, due to poor preservation, only eight yielded any collagen. The fragments from these eight individuals belonged to two subadults and six adults from site VR47.

Samples for Period 2 only included those from the site HLL and came from 36 burial contexts representing over 63 different individuals. These individuals include all age and sex groups. In addition, seven samples from Period 2 rural individuals were also analysed: three individuals from *Can Fita* and three from *Ca na Martina*.

The methods for extracting collagen and for analysis were carried out according to the protocol followed by the Research Laboratory for Archaeology and the History of Art at the University of Oxford (B. Fuller, pers. comm.). Different laboratories have different protocols, but in general removing soil, dissolution, freezing, cleaning with distilled water, further dissolution in acid, heating, filtering and freezing in nitrogen liquid are some of the stages the samples went through (B. Fuller, pers. comm.). A mass spectrometer measured the C and N contents comparing them with a standard value. Delta (δ) measured the deviation in the isotopic proportion and the result was expressed in parts per thousand (‰).

6.2.3 Results[108]

The carbon and nitrogen isotope data are summarised (mean values) by archaeological site in Table 6.2.1, while the individual samples are plotted in Figure 6.2.1. Despite differences in sample size, there was little variation in $\delta^{13}C$ results, ranging from -18.5‰ (Punic rural) to – 19.0‰ (Period 2). There was more variation in $\delta^{15}N$ mean values, with the Punic rural producing the highest value (+12.5‰) and Period 2 (rural burials) showing the lowest (+10.2‰).

The individual values from each sample were tightly clustered around the mean in the Punic rural sample. There was more heterogeneity in the distribution among the remaining samples.

Table 6.2.1. Mean values and standard deviations (s.d.) from stable isotope analysis.

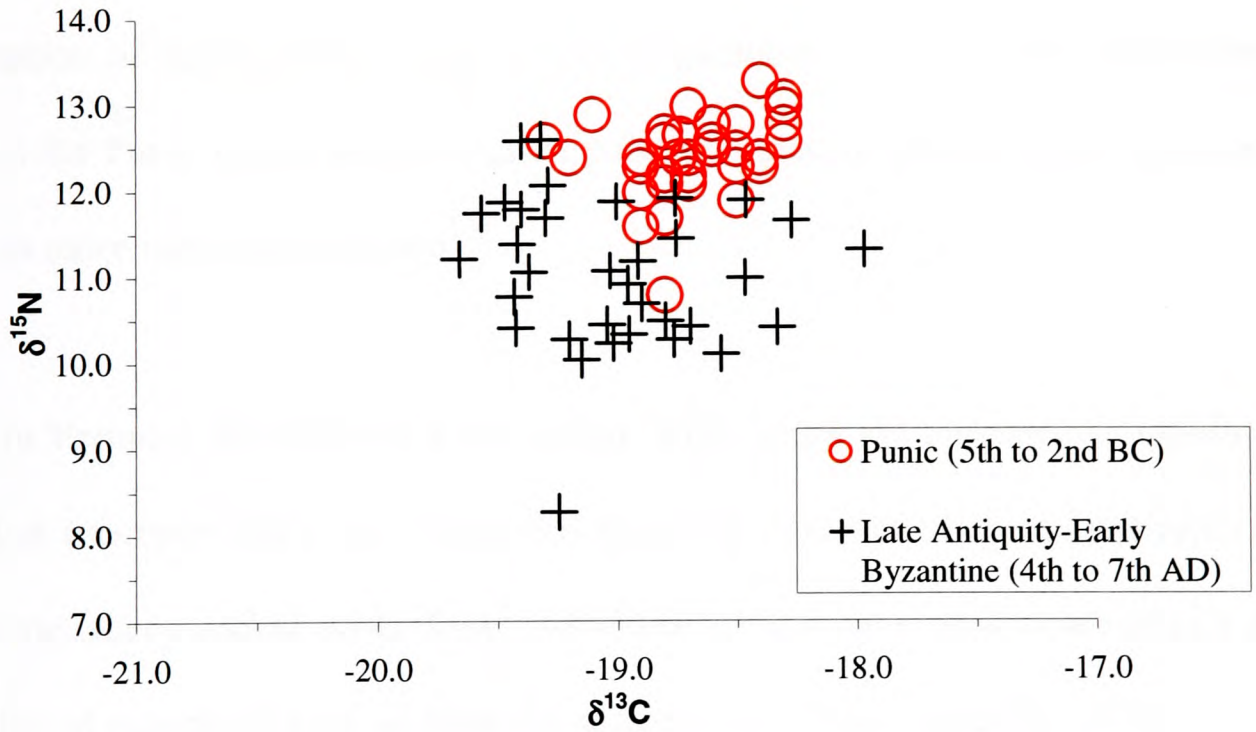
STABLE ISOTOPES (Preliminary results from January 2005)		
PERIOD 1	**$\delta^{15}N$**	**$\delta^{13}C$**
Punic rural (n = 38)	Mean = 12.5; s.d. = 0.46	Mean = -18.5; s.d. = 0.25
Punic urban (n = 8)	Mean = 11.3; s.d. = 0.71	Mean = -18.8; s.d. = 0.31
PERIOD 2	**$\delta^{15}N$**	**$\delta^{13}C$**
S'Hort des Llimoners (n = 63)	Mean = 11.1; s.d. = 1.04	Mean = -19.0; s.d. = 0.42
Can Fita + Ca na Martina (n = 7)	Mean = 10.2; s.d. = 0.60	Mean: -19.0; s.d. = 0.41

[108] The interpretation of the results has come from discussions with B. Fuller.

The carbon values indicated a diet relying on terrestrial protein. The nitrogen values, a higher meat consumption in Period 1. The Punic urban sample was small but suggested a different protein intake since it had a lower value than the rural sample.

Values for the Punic rural and the Late Antiquity-Early Byzantine site (HLL) are presented in Figure 6.2.1 (courtesy of B. Fuller).

Figure 6.2.1. Distribution of individual samples from Period 1 and Period 2.



The rural population seemed to have had a fairly homogeneous diet. The data also indicated that over many centuries, the Punic rural population had similar diets, assuming the individuals represent a cross-section of all the centuries of use of the

cemetery. It was difficult to say what the people were specifically eating. Section 6.3 provides information that will complement the gaps that stable isotope data could not fill. However, the population mainly consumed terrestrial diet, with little reliance on marine protein (which would have shown values nearer -13‰). Animal protein, either in the form of meat and in some cases milk, would have derived from cows, sheep, goat and perhaps pig and dog (see Section 6.3).

In addition, data from the Punic rural site seemed to indicate that more meat was consumed compared to Period 2, where more reliance on agrarian products seemed likely. If this were true, the higher prevalence of DC in Period 2 reflected a higher consumption of carbohydrate foods in this population. At present, the high nitrogen values in the Punic Ibizan sample cannot point to a precise animal but do indicate that there was more meat consumption[109].

In Period 2 the diet was more varied, with values not clustered as tightly as in the Period 1 sample. The type of meat that the population was likely to have eaten came from cattle, sheep and/or goat. Some individuals might have been consuming a small proportion of marine protein, as might be suggested for values near the -18‰.

One of the problems interpreting the Ibizan data is that there is a lack of faunal remains in the analysis. Although some stable isotopic data derived from fauna (see

[109] There are discrepancies among authors about the interpretation of high nitrogen values (B. Fuller, pers. comm.).

Section 6.4), these remains were not all contemporaneous with the human skeletal material.

It must be remembered that isotopic analysis only provides information on the proteinic diet (e.g. meat, fish, milk, cheese, eggs, cereals). The diet was likely to have incorporated carbohydrates and lipids, which are not properly represented in this analysis (B. Fuller, pers. comm.)[110]. A further problem is that illness (infections, fractures) can cause fluctuations in the stable isotopic values (B. Fuller, pers. comm.).

In spite of these limitations, the Ibizan populations seemed to have relied on land resources. Marine consumption was very limited. The Period 1 population showed a homogenous diet and consumed on average more meat than the Period 2 population.

[110]There are five different groups of nutrients: proteins, carbohydrates, fats (lipids), vitamins and minerals. All these nutrients are provided in maternal milk, only available in right proportions for babies.

6.3 Other sources of information

The data obtained from oral pathology and stable isotope analysis, alongside other sources of information such as artefactual data, faunal remains and documentary evidence provide a more complete picture of the diet of ancient populations.

A review of the literature has been undertaken here in order to obtain as much information as possible about the diet in the population. These sources can be used to reject or confirm any interpretations derived from the previous dietary analysis on human remains. Most importantly, they may shed light on the specific foodstuffs that were consumed[111].

6.3.1 The evidence

Diodorus of Sicily wrote how Ibiza's production in Punic times was noted by its wool, wine and oil (Tarradell and Font, 1975: 258). From this brief statement, there is already some evidence for sheep, vines and olive tree cultivation.

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[111] Human remains may also reveal some deficiencies of certain vitamins. In the Ibizan samples there was no clear identification of scurvy (e.g. vitamin C deficiency) but two adult cases of osteomalacia (vitamin D deficiency) were possible in a male humerus from HLL203.1 (Ill. 6.8) and a radius from AR33-D (Ill. 6.9), both from Period 2. Osteomalacia is an adult manifestation of rickets and is usually associated with malnutrition and poor living conditions (see Ortner and Putschar, 1981).

Agricultural organization in Ibiza was probably controlled from the city, *Eivissa*, perhaps starting in its immediate surroundings at the end of the sixth century BC, after which agricultural exploitation would have spread to the rest of the island (Sáez, 2001). The rural settlements would be self-sufficient and provide products for the town and abroad (Benito *et al.*, 2000: 306).

Archaeobotanical studies in Spain reveal that olive domestication could have occurred in the Neolithic, and certainly in the Chalcolithic or Bronze Age (Terral and Arnold-Simard, 1996; Terral, 2000; Terral *et al.*, 2004). With the Greek, Phoenician and Roman civilizations the cultivation was intensified perhaps due to farming, new tools, new interests on the olive tree for food and fuel, as well as for commerce (Terral and Arnold-Simard, 1996: 184; Terral, 2000). The vine would have also been cultivated (Guerrero, 1995b; Olmos and Sánchez, 1995). Wine was traded as a luxury and a prestigious good and Ibiza could have been a re-distribution centre for this product in Punic times due to the island's strategic location (Guerrero, 1995b: 78, 97). Wine was much liked and its abuse resulted in drinking bans being present in Carthage (Lancel, 1995: 276; Charles-Picard and Charles-Picard, 1958: 150). Some Ibizan scarabs catalogued by Professor J. Boardman have the image of a wine cup (Olmos and Sánchez, 1995: figure 4)[112].

[112] Although few inferences can be made from these facts, the point here is that, as many sources should be used. The information obtained can be encountered in a variety of different sources. This would emphasize once again the need for a multidisciplinary approach in order to reconstruct the morbidity and diet of past populations.

In Punic times, apart from olives and oil, the inhabitants may have also consumed grapes, dates, figs, almonds, fruit and legumes, with cereal consumption still somewhat unclear from the evidence available (Sáez, 2001). Pliny refers to the quality of the figs in Ibiza (Ramon, 1995a: 49), while artefactual evidence does confirm oil production and some preparation of cereal using mills (Ramon, 1995a; Gómez, 1995b). Apiculture or bee-keeping has also been present in Spain since prehistoric times (Bonet and Mata, 1997). Honey had nutritional and antiseptic values, and was also used to sweeten food and drink (Bonet and Mata, 1997).

At *Ses Païsses de Cala d'Hort*, where the rural skeletal population studied here was buried, cereals would have been ground to make flour presumably for bread (Ramon, 1995a: 50). Fruits, legumes and other vegetables were likely present, alongside meat such as sheep, goat, pigs and birds (Ramon, 1995a: 50).

The potential value of fauna analysis is great although not exempt of limitations (Estévez, 1991; O'Connor, 1996). Only few studies have been undertaken in Ibiza, but the types of livestock that would be present include predominantly sheep and goat, although pigs, cows and wild fauna would have also been consumed (Saña, 1994; Riquelme, 2001; Morales, 2003).

Although there is regional variation, the predominance of sheep and/or goat is a pattern also present in the Iberian Peninsula (Franquesa *et al.*, 2000; Iborra, 2000; Riquelme, 2001). Around the sixth century BC pig consumption increased over beef

(Iborra *et al.*, 2003). This may have been a reflection of the low cost maintaining pig, not dependent on as much water as bovines and neither on fresh pastures (Iborra *et al.*, 2003: 49). Some dog remains from Ibiza reveal cut-marks that might suggest their consumption by humans (Saña, 1994). Dog consumption may have been common practice in prehistoric times (Riquelme, 2001: 116). Other contemporary sites in NE Spain also suggest possible dog consumption (e.g. Oliva, 2000). However, whether this animal was eaten sporadically or sacrificed habitually for consumption is unknown (Saña, 1994; Oliva, 2000: 164). Certainly, documentary evidence has shown that bans were imposed on dog consumption in the fifth century BC, which suggests that they were previously eaten (Saña, 1994: 72). For the Punic rural site, stable isotope analysis does not seem to suggest regular dog consumption as a general rule in the population (B. Fuller, pers. comm.).

The presence of pigs is also of interest. Documentary evidence exists stating that Phoenicians and Punic people did not eat pork, but the high representation of pig remains in habitat contexts from Punic Ibiza seems to suggest that they were eaten (Ramon, 1994b: 69; Morales, 2003: 120). In Cyrene (Libya) pigs were the most represented faunal remains in the sanctuary of Demeter and Persephone and may have been sacrificed for ritual feasting (Crabtree, 1990). In the Roman Empire in general, diet seems to have changed towards an increase in pork (King, 2001).

All these animals, in addition, would have been used for their 'secondary products' (see Sherratt, 1981): meat, milk, traction, bone implements, leather and wool

for clothing. In addition, if the Punic dog in Ibiza had similar characteristics to the Ibizan hound today, they were probably used in hunting smaller animals (McDonald, 1980: 16-17). There is also evidence for the presence of horses (Saña, 1994; Riquelme, 2001; Morales, 2003) perhaps used for transport. Apart from ritual purposes, whether ostrich eggs and ostriches were consumed remains unknown[113].

Particularly with regard to the rural site *Ses Païsses de Cala d'Hort*, domestic fauna is not abundant in the living dwellings dating from the Punic and early Roman period (Ramon, pers. comm.)[114]. However, in the Late Antiquity-Early Byzantine period there seems to be a massive presence of meat sources, especially goats as attested by the number of horns that have been found (Ramon, 1995a: 49).

In Roman times the south of Spain was exporting above all wine and oil (Saéz, 1987) and similarly this might have been the situation in Ibiza (Tarradell *et al.*, 2000: 200). Later, in the Late Antiquity-Early Byzantine period rural settlements gradually decreased their exploitation functions and there was abandonment or reduction in size

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[113] Ostrich eggs were a common feature of the grave-goods found in Punic tombs from Ibiza (see Astruc, 1957). Their presence in the tombs, however, is clearly for ritual purposes and do not guarantee that these animals or their eggs were consumed. Nevertheless, ostriches, present in Egypt since prehistoric times, may have been hunted for their feathers, nutritive and medical value amongst other interests (Laufer, 1926; Manlius, 2001).

[114] While analysing the human skeletal remains from the rural Punic necropolis, the present author came up with faunal remains. Although a specialised report would be required in the future, some of the specimens identified (following e.g. Hillson, 1992) were a pig jaw and two dog skeletons. In addition, there were bones from larger mammals. Unfortunately, due to the disturbance in the land throughout the centuries and without any radiocarbon dates, there was no guarantee that the bones related to the Punic period as they might be associated instead with the modern farmsteads that are located near the cemetery. At the tomb VR28/1102 a pig premolar was found. In AR33 several faunal remains were present including sheep/goat, pig (an atlas vertebra, a femur), a possible rib and humerus of a dog, a scapula of a bovid and some equine remains. In grave HLL820 another equine bone fragment was found. These bones await specialist zooarchaeological analysis.

of the settlement (e.g. see Ramon, 1995a). A general period of aridity and drought appears to have been present in the Mediterranean in AD 300-400 and AD 800, with maximum temperatures in the fourth century AD (Lamb, 1982: 132, 159-160). Whether this decrease in occupation in the rural areas relates to climate is unclear, but future work on Ibiza could address these biocultural issues. There was, however, some revival (reoccupation, rehabilitation) of some rural settlements in Byzantine times (see Ramon, 1994b; 1995a; González and Pacheco, 2002).

Seafood and fish, or its derivatives such as fish sauce, would have been present too in Ibiza since prehistoric and Phoenician times (Ramon, 2003a: 156), although in Punic times this activity would have only been secondary to that on the land (Ramon, 1995a). The industries related to salt, salted fish and fish sauces in Phoenician and Punic times are reviewed in detail elsewhere (García, 2001). The presence of fishing artefacts (Ramon, 1995a) and a fragment of ichthyofauna, *Thunnus thynnus* (Juan-Muns, 1994)[115], provide some evidence for probable fish consumption. *Garum* (fish sauce) would have been available to both rural and urban populations since Phoenician and Punic times in Spain (Curtis, 1991; Prowse *et al.*, 2004)[116]. The possible consumption of sea mammals such as whales (e.g. see Reese, 2005) may not be

[115] In the Roman wreck near *Sant Antoni* (Vilar-Sancho and Mañá, 1964, 1965) there was presence of amphorae with *garum* inside and some evidence of fish vertebrae, although the authors do state that these vertebrae may not necessarily be associated with the amphorae. Stronger evidence from Greece reveals fish scales from filleted fish in Punic amphorae originating from the area of the Strait of Gibraltar (Maniatis *et al.*, 1984), and may have travelled through Ibiza. A third century BC Punic vessel found near the island of *Cabrera*, off the coast of Majorca, included Ibizan amphorae (Cerdà, 1978). A later boat from the third century AD boat in the same area contained amphorae with products such as oil, olives, wine and *garum* (Guerrero *et al.*, 1987).

[116] It is worth noting in relation to consumption and the low reliance of fish according to the isotopic data, that the Greeks and Romans thought that people who depended on the sea were very poor since reliance on sea resources was a sign of need and poverty (Purcell, 1995: 134-135). However, the paradox also equates in that fish was also a symbol of wealth (Purcell, 1995; García, 2001).

forgotten either. The low reliance on marine protein has already been highlighted with regard to the stable isotope data (Section 6.2; see also Márquez-Grant *et al.*, 2003). However, this is also surprising in view that salt and salted fish were common foodstuffs and would have been commercialised throughout the Punic and Late Antiquity-Early Byzantine worlds.

Although it is a plausible hypothesis that salt industry in Ibiza was present in Punic times, there is as yet no conclusive evidence (Tarradell *et al.*, 2000: 201). The salt industry was at its peak in Punic times and the product was in demand for a variety of reasons including medicinal, dietary and religious (Fernández Uriel, 2000; see also García, 2001). Many salteries seemed to have ceased their activity in the third century AD although some may have lasted until the eleventh century AD (Curtis, 1991). The production and commerce of salted fish continued at a smaller level in early Byzantine times, with some Byzantine medical texts recommending the intake of salted-fish products (Curtis, 1991: 184, 189).

Extrapolating from other areas in Europe, in general people in Byzantine times had a diet based on bread, legumes, vegetables and perhaps some supplement such as cheese, olives, fruit, fish and wine (Karpozilos ad Kazhdan, 1991: 621-622). Adaptation to nutritional shortages may have come with religion or an ideological system emphasizing the importance of care (Martin *et al.*, 1985: 228). Christian hospitals were erected in Late Antiquity and in the Early Byzantine period (see Miller, 1985) and the poor and the sick may have been cared for. Basic care such as food and

water would allow weak people to fight and perhaps recover from disease (McNeill, 1976: 121-122). By contrast, religious motives may also affect diet, for example fasting (Grimm, 1995).

Meat was rarely eaten in Byzantine times, although meat consumption, especially lamb, increased in the seventh century AD (Karpozilos and Kazhdan, 1991: 621-622; Kazhdan et al, 1991: 1326). Analysis of trace elements from bones from seventh century AD Carthage has indicated a relatively high animal protein intake (Sandford *et al.*, 1988).

Little is known with regard to food preparation in Ibiza. Food preparation, as stated earlier, can affect the rate of dental attrition. Some mills and grinding stones have been found in some contexts (see Ramon, 1994b, 1995a). At the site of *Na Guardis* (Majorca), which is a factory founded by Ibizan merchants, a lot of Punic tableware receptacles have been found, most of them from Ibiza and these include artefacts such as pots, jars, pans and trays for cooking, baking and frying (Guerrero, 1995a, 1999; see also Ramon, 1994b).

Today, the problem of limited water resources as well as reduced rainfall has influenced the scarcity of natural pasture fields, therefore limiting the development of stockbreeding (Miguélez, 1989: 10). Ethnographic accounts of traditional rural families may provide further clues as to dietary patterns in the past. Interviews with older men and women from rural areas in Ibiza have shown the importance of cereals and pulses

as the basic staple in the diet (Marí, 2003). This was complemented with figs, olives and some dairy products that were regarded as energy foodstuffs (Marí, 2003). Interviews had also been conducted in 1986 on rural families that lead a more modern lifestyle (Gómez, 1989). In these latter cases, a high proportion of fats, especially in women, were consumed as well as an insufficient amount of carbohydrates, although the protein intake was adequate (Gómez, 1989).

6.4 Dietary reconstruction: overview and discussion

An overview of the diet in each period is presented. This is followed by an interpretation of the results within a wider geographical and chronological context.

6.4.1 Overview

Past populations in Ibiza relied mainly on land resources as indicated by stable isotope data. Vegetables and cereals were present in the diet as attested by documentary sources and artefactual evidence. In addition, dental caries and calculus indicate some reliance on carbohydrates. Dental wear, especially in the rural area, reveals cupped and oblique wear patterns characteristic of a diet based on cereal consumption and preparation techniques involving mills to grind the grain. However, the extent of consumption of agrarian foodstuffs such as cereals is still unclear. Moreover, meat consumption according to isotope data was high in the Punic period although faunal remains have not been abundant. Meat probably derived from sheep and goat. Pork may have also been consumed, especially since Late Antiquity. In relation to dental caries, children had similar frequencies in both periods and perhaps a similar diet was consumed during the growing years.

Consumption of marine protein seems to have been limited, despite documentary evidence indicating the popularity of salted fish and fish sauce. This low

reliance on marine protein may be associated with the low frequency of *torus auditivus* (Chapter 5).

In relation to the hypothesis, nutrition is not easily inferred. It cannot be confirmed whether the higher meat consumption in Period 1, lower caries and lower calculus rates overall and relatively good oral hygiene (e.g. one abscess) would reflect better health and better nutrition than in Period 2, where there was a greater reliance on carbohydrates. Furthermore, trade in Punic times must have provided the population with a variety of foodstuffs. The apparent abandonment or decline in settlements in Period 2 might have resulted in a lower presence of fresh foods.

When periods were compared in more detail, the pattern of protein consumption was very homogenous in the Punic rural population. This revealed that there was no sexual dimorphism in protein consumption assuming both males and females were present. In Period 2, the sample provided a more dispersed distribution. This distribution may reflect different socio-economic backgrounds as can be interpreted by comparing between some of the tomb types in the cemeteries. Variation in this period may have also been influenced by the presence of infants and children amongst the stable isotope data.

6.4.2 Discussion within a wider geographical and temporal context

Oral pathology in the Punic and Late Antiquity-Early Byzantine periods was higher than that found in Prehistoric or Islamic contexts from Formentera and Ibiza respectively. These differences relate to different subsistence technologies as well as cultural aspects. Attempts were made to compare the results obtained from this thesis with other sites in Ibiza (Table 6.4.1). Since methods of recording were different and the number of teeth was not always indicated, uncorrected rates could only be provided at present (including the uncorrected rates obtained in this thesis). These rates came from adult individuals.

Table 6.4.1. Crude (uncorrected) caries rates (DC) and *ante-mortem* tooth loss (AMTL) in skeletal populations from Ibiza[117].

Site	Period	DC (%)	AMTL (%)	Authors
Ca na Costa (Formentera)	Prehistoric (c.2100 BC)	0.7% (1/138)	0% (0/35)	Gómez and Reverte (1988), Gómez (1989)
TOTAL PREHISTORY		**0.7%**	**0%**	-
Can Marines	Punic rural	0% (0/5)	0% (0/26)	Gómez (1989)
Cas Jurat	Punic rural	10.9% (6/55)	20% (30/150)	González-Martín and Lalueza (1992)
Ca n'Eloi	Punic rural	8.9% (5/56)	7.5% (11/146)	González-Martín and Lalueza (2001)
PCHN	Punic rural	8.6% (18/209)	7.8% (48/612)	This study
VR47, VR28, PM01	Punic urban	4.3% (9/205)	1.1% (3/251)	This study
TOTAL PUNIC PERIOD		**7.1%**	**7.7%**	-
Skeletons CL-13/CIII, AE-5/II, PM-N/III	Roman (probably 1st BC-1st AD)	2.1% (1/47)	5.3% (3/56)	Data from Gómez (1989)
Skeletons VR28/807, VR28/109, VR28/1202	In same context as Roman material	0% (0/34)	0% (0/44)	Preliminary unpublished data (Márquez-Grant)
TOTAL ROMAN PERIOD		**1.2%**	**3.0%**	-
HLL AR33	Late Antiquity-Early Byzantine	11,8% (92/774)	11.2% (121-1071)	This study
Ca na Martina	Late Antiquity-Early Byzantine	3.5% (2/57)	0% (0/25)	Preliminary unpublished data (Márquez-Grant)
Can Fita	Late Antiquity-Early Byzantine	0% (0/12)	0% (0/12)	Unpublished (Márquez-Grant) and published data (Márquez, 2002)
TOTAL LATE ANTIQUITY-EARLY BYZANTINE PERIOD		**11.1 %**	**10.9%**	-
Puig des Molins	Islamic	2.9% (2/51)	0% (0/88)	Gómez (1989)
Es Soto	Islamic	5.4% (7/129)	0.7% (1/138)	Márquez Grant (1999a, 1999b)
TOTAL ISLAMIC PERIOD		**5.0%**	**0.4%**	-

Interestingly, all Punic rural sites revealed similar frequencies of DC except for *Can Marines* where only five teeth were recovered and the rate was lower.

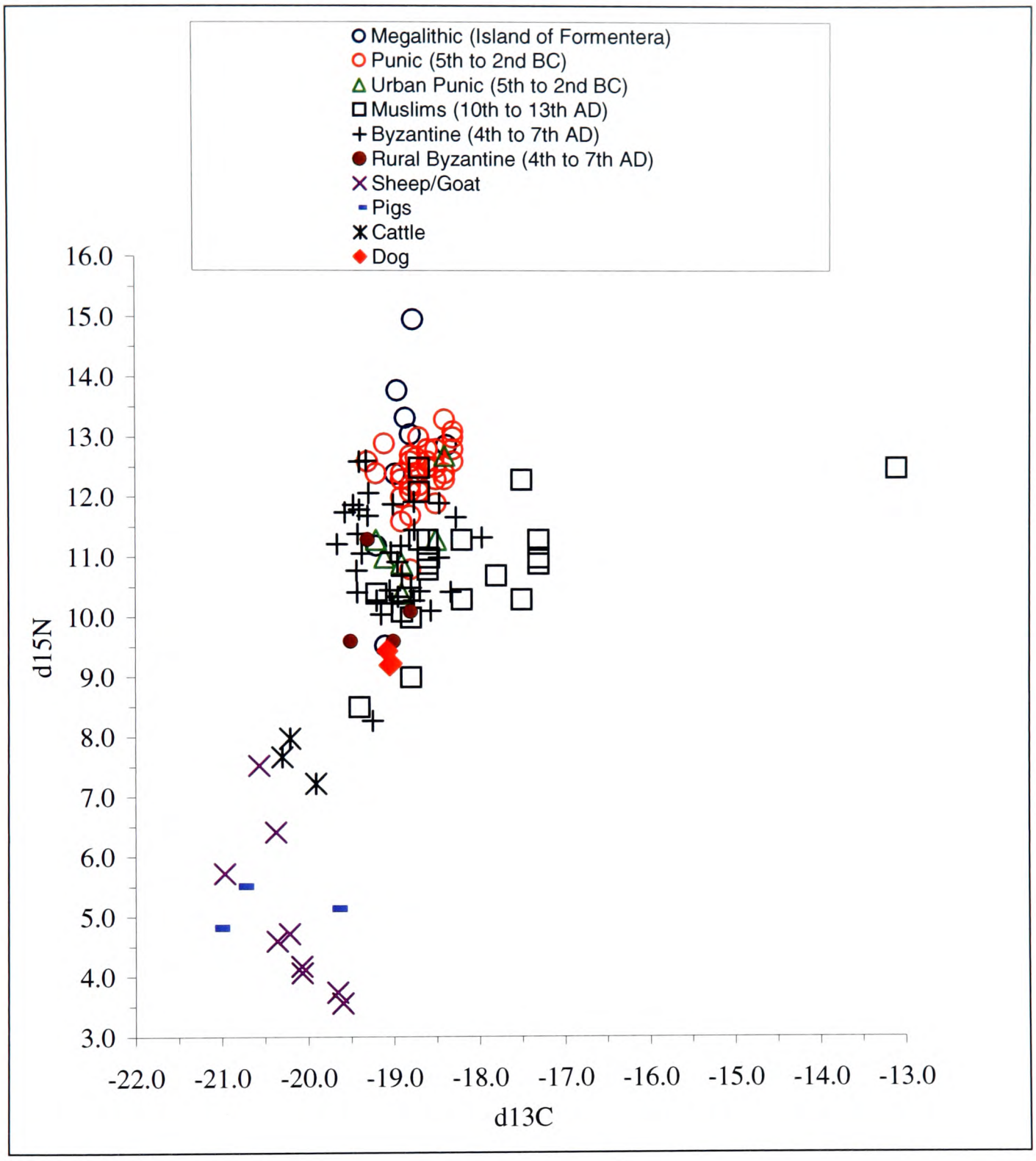
The purpose of showing this table with data from other sites served to show the differences between populations, with those in the Punic period and the Late Antiquity-Early Byzantine period showing more prevalence of DC and AMTL. These differences are most likely ling with different diet (Figure 6.4.1). Future projects will hopefully add

[117] I would like to thank Dr. Marta Fernández, odontologist for INSALUD (Ibiza) for providing me with data on dental caries observed on schoolchildren today but that were finally not employed here.

to this table and correct these caries rates accordingly. Despite these being crude rates, the interesting finding to point out was that the higher frequencies in these periods indicate consumption of carbohydrates and agricultural foodstuffs. This conclusion was reached when examining the stable isotope values from other periods (prehistoric, Islamic)[118]. Low prevalence of DC in the prehistoric sample would have been related to high meat consumption, while in the Islamic sample it might have been influenced by slightly more reliance on marine protein (Figure 6.4.1, courtesy of B. Fuller).

[118] Preliminary results. Work by M.P. Richards, B. Fuller and the present author. The preliminary data for the Islamic sample has been published (Márquez-Grant *et al.*, 2003).

Figure 6.4.1. Stable isotope values in different Ibizan samples.



The data from the prehistoric site, *Ca na Costa*, revealed the highest meat protein intake. The DC rate for this small prehistoric sample was low. The low levels of dental caries and the pattern of dental wear identify a diet based primarily on animal

protein, with a low component of starches and sugars (Gómez and Reverte, 1988)[119]. The type of meat providing the high values in these likely pastoralists has not yet been identified. From the evidence available, it seems probable that sheep/goat, some shellfish and birds (*Puffinus puffinus*) were consumed (B. Costa, pers. comm.). The Islamic groups from *Es Soto* in *Eivissa* (Márquez-Grant *et al.*, 2003; see also Márquez, 2003) also revealed lower levels of DC and their food source included more marine protein. In this sample, one individual had a diet mostly reliant on marine protein (plotted square with $\delta^{13}C$ value at -13‰).

In general, all the populations exhibited values indicating low consumption of marine protein. This trend of low consumption of marine resources in islands is shared with some populations from the Canary Islands where stable isotope data are available (Tieszen *et al.*, 1992). In Majorca, trace element analysis on a 600 AD sample from Can Reinés revealed a mixed diet with more plants than meat consumption, and a low proportion of marine foodstuffs (Garcia and Subirà, 2001).

By contrast, similar trace element analyses on human remains from *S'Illot des Porros* (6th-2nd BC) in Majorca have concluded that the population had a high consumption of marine protein (fish, molluscs) and cereals (Subirà *et al.*, 1989; Subirà and Malgosa, 1992). The crude rate for carious teeth at this site was 4.54% (Malgosa and Campillo, 1991).

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[119] Two human samples have been analysed by Van Strydonck and colleagues (2002). The authors have indicated that the consumption of marine resources was limited (Van Strydonck et al., 2002: 193). In their stable isotopic analysis, the dates and values presented in Table 2 (page 83) for this site were: Dates = 3595+-35 BP and 3535+-40 BP; $\delta^{13}C$ = -18,69‰ and –18,79‰; $\delta^{15}N$ = +9,06‰ and +12,74‰.

Periapical cavities were low in the Ibizan populations studied here and the prevalence rates lie within a normal range for samples from Roman and Medieval Britain, between 1.2% and 2% approximately (Roberts and Manchester, 1995: 51-52). However, at the Punic sites of *Cas Jurat* and *Ca n'Eloi* in Ibiza, the authors found a total of 8% (n = 12) and 5.5% (n = 8) alveoli with periapical cavities respectively (González-Martín and Lalueza, 1992, 2001). A large project on oral pathology in Ibizan past populations should be one of the aims in future studies.

In summary, from this discussion, the percentage of DC in Period 1 and Period 2 seem to relate to consumption of agrarian foods, although more meat was consumed in Period 1.

7 CHAPTER SEVEN - CONCLUSIONS

The main conclusions of this research include a series of practical results from elements of the research, a number of key findings, a range of discussion points and ideas for further research. In addition it became clear that there were a number of difficulties associated with doing this particular study with the samples available, but even these difficulties highlighted useful pointers for doing similar research and these have been incorporated in the report. This chapter therefore provides a summary of the main findings related to the key chapters, comments on the research difficulties, comments on the outcome of the hypothesis and lastly ideas for further research.

7.1 Key findings

This section outlines the key findings and/or discussion points which arose in each part of the research.

7.1.1 Chapter 2: the skeletal samples

In Chapter 2, the osteological material was described. This included archaeological information on each site, the state of preservation of the skeletal remains and the demographic profile of the dead populations under study: the minimum number of individuals, their age and sex.

The key issues identified with these samples were:

- The disarticulated nature of most skeletal assemblages
- Limited and varying sample sizes
- Preservation bias between samples
- Underrepresentation of infants in the rural contexts

Nevertheless, overall each sample represented a cross-section of different age categories and sex and provided a representation of a Punic rural population, a Punic urban population and a Late Antiquity-Early Byzantine urban and/or extra-urban population.

Although these samples may appear small they were relatively large with regard to anthropological studies on Punic remains in the Western Mediterranean. In addition, for the first time in Ibiza, an insight into the lives of those people in the Late Antiquity-Early Byzantine period could be provided to complement the scarce archaeological data available for these centuries.

7.1.2 Chapter 3: Health status during growth

This chapter assessed the health status of individuals during their growth. In assessing this several factors were borne in mind: the genetic, cultural and environmental conditions affecting children.

Health status during growth was assessed through examining dental enamel defects, orbital lesions and stature. The main findings were:

- Enamel defects were present in high proportions (c.50% of teeth) in each sample. These defects reflected interruptions during growth primarily associated with malnutrition and infection. There were no significant differences between prevalence rates in Period 1 and Period 2. There were no significant differences between females and males.
- Orbital lesions (*cribra orbitalia*) were not low (c.20%) in Period 1. However, when additional data was included, Period 1 exhibited fewer lesions than Period 2. Females had fewer lesions than males.
- Mean stature was higher in Period 1 than Period 2 but the difference between periods was not significant.

7.1.3 Chapter 4: non-specific infections (periostitis)

In this chapter, lesions in tibiae associated with infectious pathogens were assessed. The key findings derived from this examination were:

- Rates were not low in either period.
- Subadults had more infectious lesions than adults although the difference was not statistically significant.

- The only difference between the Punic rural and Punic urban contexts was established when considering active lesions (disease still active at the time of death). The urban sample displayed more active lesions than the rural one.
- There were no differences between Period 1 and Period 2 except for females. Period 1 females exhibited more lesions than females in Period 2. No lesions were displayed on female bones from Period 2.

7.1.4 Chapter 5: patterns of activity

In Chapter 5 a number of parameters were considered in order to assess activity patterns: *ante-mortem* fractures, osteoarthritis, *torus auditivus* and squatting facets. The results showed the following trends:

- Accidental and violence-related trauma (fractures) was low in all samples. Trauma tended to occur predominantly in the forearm and the lower leg. Overall, there were no significant differences between females and males.
- Osteoarthritis: there were no marked differences between samples, except for some bone elements such as the vertebrae, which were less affected in the Punic rural sample. Patterns of osteoarthritis only differed slightly. The rural sample displayed a higher number and the most severe cases of eburnation. No significant differences were found between females and males. Further inferences were limited in view of the age bias, a factor that could not be controlled in the samples examined.

- The key finding from the analysis of *torus auditivus* was that the population in general was not regularly involved in exploiting the island's marine resources, a conclusion confirmed from the dietary evidence. There were also no significant differences between periods.
- With regard to squatting facets, both periods exhibited a high degree of squatting or hyperdorsiflexion. It could not be understood whether this reflected the living conditions (e.g. limited furniture) or resulted from occupational related postures. There were no significant differences between periods.

7.1.5 Chapter 6: diet, nutrition and subsistence economy

Dietary reconstruction was based on a variety of sources: oral pathology, stable isotope analysis, documentary sources, artefactual evidence and faunal remains amongst others. The information limited itself to only providing the general dietary and subsistence patterns (e.g. meat, cereal; agriculture). Some knowledge of nutrition was obtained through the examination of protein consumption. The information on oral pathology also provided insights into issues of morbidity. The results revealed the following patterns:

- Oral pathology: Children from Period 1 had similar frequencies to those from Period 2. The Punic rural sample exhibited a higher deterioration in oral health compared to its urban counterpart. Generally speaking, the overall Period 1 sample exhibited lower rates of oral pathology than the Period 2 population.

Differences between sexes were balanced equally, although in some occasions a trend towards increasing morbidity rates in females became more apparent.

- Diet, nutrition and subsistence strategies: there was a predominant reliance on terrestrial foodstuffs and little reliance on marine resources. In Period 1 there was greater meat consumption and the diet was more homogenous across the population compared to the population from Period 2.

7.2 Overall assessment of morbidity: limitations and conclusions

It was difficult to interpret morbidity from one single factor, partially due to the multifactorial aetiology of many of the conditions and partially due to the disarticulated nature of the assemblages, which limited the information that could be obtained. However, by combining all parameters, and considering other biocultural factors, a more appropriate picture was obtained.

The parameters studied interacted with each other but understanding this interaction was complex. For instance, malnutrition would be related to infection, which in turn would be related to growth disturbances. Nutrition would also relate to work capacity, work in turn related to bone strength, bone strength leading to less vulnerability to trauma. At the same time all these factors would be influenced by age, sex, socio-economic status, climatic factors affecting harvests and cultural factors such

as wars. This system could be likened to a large and complex family tree where all these factors would be, in a sense, 'relatives'.

In addition to these complications there were methodological ones too. These related to general problems in anthropology with regard to estimating age and sex, recording procedures and the non-specificity of the lesions. *Post-mortem* disturbances in the grave, problems with preservation, errors during excavation and post-excavation handling were other such complications. The samples studied for this research had their share of these complicating factors but nevertheless yielded a relatively great wealth of information on the island's past inhabitants. This work has provided a bioanthropological perspective on those periods, examining how the people themselves lived and more importantly how their bodies coped within their biocultural environment.

Despite the above limitations certain conclusions on morbidity could be arrived at. The first concerns childhood and adolescence. It appears that since Punic times up until Byzantine times, children were equally affected under similar environmental 'stressors', possibly linked to a complex interaction between nutrition and infection. Whether this nutrition was adequate or inadequate was difficult to assess since many teeth and skeletal elements were affected by the physiological insult(s), although at the same time many individuals survived the insult(s). Rates for *cribra orbitalia* showed significant differences between periods only when additional data was included. There might then be a slight difference with regard to pathogen load or iron-deficiency but

with regard to enamel defects, stature, periostitis and dental caries, no significant differences were detected.

In general, the data indicated that adults in both periods also led similar lifestyles despite different economic situations. Active periostitis affected both Period 1 and Period 2 populations. Osteoarthritis, particularly in the rural sample was severe. Trauma in all samples had a low prevalence. Some healed cranial wounds may have resulted from violent actions in Period 2.

The only clear and most conclusive differences observed between periods, however, appeared once oral pathology was considered. Oral pathology deteriorated in Period 2, this perhaps related to a poorer diet based on carbohydrates that conversely may have affected nutritional adequacy.

Differences between the sexes when present were minimal. This 'egalitarian' picture is also confirmed by similar funerary and burial treatment.

7.3 Hypothesis outcome and overall conclusions

The hypothesis to be tested was: *General prosperity in the Punic period in Ibiza should be reflected in the general well-being of the population, as evidenced by human skeletal remains.*

The first question to address here is therefore: Do the results indicate a general well-being in the Punic population with regard to the skeletal indicators of morbidity and were there any significant differences between Punic urban and rural populations?

The result is only partially affirmative. Nutrition seems to have been adequate and oral pathology was relatively low. In addition, trauma was also low despite the apparent intense economic productivity. When fractures were observed, their healed state reflected the care of victims. Moreover, the scale of the industry in Period 1 may have increased the risk of trauma, but low frequencies in this sample may be indicative of appropriate adaptation to coping with the hazardous occupational environments people may have worked in.

With regard to periostitis, linear enamel hypoplasia (LEH) and osteoarthritis, however, the answer is a negative one. The interpretation of the results from the first indicator is unclear. Periostitis limited itself to indicate that infectious pathogens were present over many years. The incidence of LEH in teeth from adults was also high although, whatever negative factor may have influenced growth, in many cases people were able to cope with these stressors and survive into adulthood. Osteoarthritis was common and in the rural population it was also severe in a number of cases, possibly reflecting heavy physical demands. Viewed differently, high levels of morbidity may also indicate overall health with regard to longevity. Relatively high frequencies of osteoarthritis especially in elbows and knees may not be surprising, however, in view of the intense agricultural and industrial productivity in Period 1.

With regard to differences between Punic rural and urban populations, the conclusions reached were:

- Overall the only significant differences between rural and urban samples were found in relation to periostitis, osteoarthritis and oral pathology.
- There were more lesions with active periostitis in the urban environment.
- Osteoarthritis affected the rural population more severely as evidenced by the number of cases with eburnation. Vertebrae were more affected in the urban population.
- Dental caries was more prevalent in the rural area, but calculus and periodontitis had higher rates in the urban population.

Trauma was low in both periods and no significant differences were found between trauma prevalence rates in the rural and urban populations.

The remaining question to be addressed here is: Did the results show a lower prevalence of disease in Period 1 than in Period 2?

If this answer is affirmative, then the hypothesis is confirmed that prosperity in Period 1 contributed to lower morbidity rates when compared to Period 2. Higher rates in Period 2 might reflect deteriorating living conditions, possibly associated with the

plagues and droughts in the Mediterranean, in combination with a local abandonment of rural settlements and reduced trade.

As concluded earlier, the only indication of significant differences between periods is oral pathology. *Cribra orbitalia* did show some differences when other published data were employed. However, the remaining comparisons did not reveal any statistically significant differences. Moreover, patterns of osteoarthritis are surprising due to their relatively high prevalence in Period 2 when economic activity seems to have declined. Thus, absence of any marked differences would suggest that life would have continued as usual with regard to skeletal health. With this regard, the prosperity in Period 1 would not lead to an improved general well-being of the population.

In the light of these conclusions it would seem that, despite a number of mitigating factors, the overall hypothesis can be largely rejected, based on the samples currently available in Ibiza at present. Future planned excavations will produce more material and it may be worthwhile to revisit this hypothesis then. Nevertheless the samples currently available did allow for a detailed analysis as described herein, and this analysis will help to promote awareness in Ibiza of the importance of not only studying skeletal material but also of establishing a research protocol that will be of benefit to future anthropological analysis on the island.

7.4 Further research issues

This study, in spite of the limited sample sizes, has been the largest palaeoepidemiological research yet in Ibiza. It is hoped that it can provide useful comparative data for other studies in neighbouring geographical regions. It is also hoped that this work has shown the potential value of human remains and therefore it is expected to provide a stimulus for further work on skeletal remains from the island.

This research has demonstrated the importance of anthropological studies and the need for further integration with other archaeological and scientific evidence from Ibiza. Part of this could include the integration of palaeoclimatological and palaeobotanical data.

There is also a need to establish a protocol of research on the island, so that all studies can be comparable. The dental and skeletal indicators researched here must continue to be studied employing a larger number of sites and including samples from other periods. In this way, a better understanding of the evolution of a pathological condition through time can be understood. In addition, close collaboration between archaeologists and anthropologists is needed before, during and after excavation.

The research avenues that will be followed by the author are:

- Create a database of all human remains on the island and monitor their state of preservation.

- If access is possible, continue to study human remains in order to increase the representativity of the overall sample for a determined period.
- Provide further insights into funerary practices by considering skeletal data.
- Undertake analyses of post-Islamic burials and show that a more complete picture of these periods can benefit from bioanthropological studies despite the wealth of documentary sources.
- Promote the biocultural approach among anthropologists and archaeologists. Many past publications have only presented the anthropological results in a descriptive manner, without discussing their implications with regard to the wider cultural, economic, political and social contexts.
- Invite and encourage other anthropologists to undertake research into the rich variety of archaeological evidence available in Ibiza.

BIBLIOGRAPHY

Abbreviations (those in *italics* refer to journals):

AA	*American Anthropologist*
AAEM	*Annals of Agricultural and Environmental Medicine*
AAnt	*American Antiquity*
ADC	*Archives of Disease in Childhood*
ADJ	*Australian Dental Journal*
AdML	*Annales de Médicine Légale*
AEM	*Archivo Español de Morfología*
AEA	*Archivo Español de Arqueología*
AHB	*Annals of Human Biology*
AIM	*Annals of Internal Medicine*
AJHB	*American Journal of Human Biology*
AJA	*American Journal of Archaeology*
AJDC	*American Journal of Diseases of Children*
AJIM	*American Journal of Industrial Medicine*
AJFMP	*American Journal of Forensic Medicine and Pathology*
AJPA	*American Journal of Physical Anthropology*
AJS	*The American Journal of Sociology*
AML	*Anales de Medicina Legal*
AN	*The American Naturalist*
AO	*Aula Orientalis*
AOB	*Archives of Oral Biology*
AOdS	*Acta Odontologica Scandinavica*
AOHNS	*Archives of Otolaryngology – Head & Neck Surgery*
AOS	*Acta Orthopaedica Scandinavica*
APL	*Archivo de Prehistoria Levantina*
APLARJR	*APLAR* (Asia Pacific League of Associations for Rheumatology) *Journal of Rheumatology*
AR	*Atmospheric Research*
ARA	*Annual Review of Anthropology*
ARC	*Archaeological Review from Cambridge*
ARD	*Annals of the Rheumatic Diseases*
AS	*American Scientist*
AT	*Antiquité Tardive*
AW	*Ancient World*
A&R	*Arthritis and Rheumatism*
BACAEP	*Butlletí de l'Associació Catalana d'Antropologia, Etnologia i Prehistòria*
BAR	British Archaeological Reports
BDJ	*British Dental Journal*
BibAR	*Biblical Archaeology Review*

BJIM	*British Journal of Industrial Medicine*
BJSM	*British Journal of Sports Medicine*
BNYAM	*Bulletin of the New York Academy of Medicine*
BSEAB	*Boletín de la Sociedad Española de Antropología Biológica*
BSEDECK	*Boletín Sociedad Española de Espeleología y Ciencias del Karst*
BSHNB	*Bolletí de la Societat d'Història Natural de les Balears*
CA	*Current Anthropology*
CA&N	*Child Abuse & Neglect*
CERF	*Cahiers d'Études et de Recherches Francophones*
COAS	*Clinical Otolaryngology & Allied Sciences*
CollAn	*Collegium Antropologicum*
CPAC	*Cuadernos de Prehistoria y Arqueología Castellonenses*
CR	*Caries Research*
CTI	*Calcified Tissue International*
EA	*Evolutionary Anthropology*
EEiF	Enciclopèdia d'Eivissa i Formentera
EG	*Estudios Geográficos*
EJA	*European Journal of Archaeology*
EJAnat	*European Journal of Anatomy*
EPS	*Earth and Planetary Science Letters*
EST	*Environmental Science and Technology*
FSI	*Forensic Science International*
GR	*Geographical Review*
HB	*Human Biology*
HE	*Human Evolution*
IA	*Iranica Antiqua*
IDJ	*International Dental Journal*
IJC	*International Journal of Cancer*
IJNA	*The International Journal of Nautical Archaeology* [earlier title: *IJNAUE*]
IJNAUE	*The International Journal of Nautical Archaeology and Underwater Exploration* [later title: *IJNA*]
IJO	*International Journal of Osteoarchaeology*
IP	*Indian Pediatrics*
IPrev	*Injury Prevention*
JA	*Journal of Anatomy*
JAS	*Journal of Archaeological Science*
JBS	*Joint Bone Spine*
JDR	*Journal of Dental Research*
JECS	*Journal of Early Christian Studies*
JECH	*Journal of Epidemiology and Community Health*
JEN	*Journal of Emergency Nurses*
JEM	*Journal of Emergency Medicine*
JFA	*Journal of Field Archaeology*
JFS	*Journal of Forensic Sciences*
JHE	*Journal of Human Evolution*

JIH	*Journal of Interdisciplinary History*
JMAA	*Journal of Mediterranean Anthropology and Archaeology*
JMA	*Journal of Mediterranean Archaeology*
JMS	*Journal of Marine Systems*
JoB	*Journal of Biogeography*
JoD	*Journal of Dentistry*
JOPM	*Journal of Oral Pathology and Medicine*
JRA	*Journal of Roman Archaeology*
JRS	*The Journal of Roman Studies*
JSAA	*Journal of the Society for American Archaeology*
JSG	*Journal of Structural Geology*
JT	*Journal of Trauma*
JTA	*Journal of Theoretical Archaeology*
JVS	*Journal of Vascular Surgery*
MCV	*Mélanges de la Casa de Velázquez*
MH	*Melita Historica*
MMW	*Münchener medizinische Wochenschriff*
NAH	*Noticiario Arqueológico Hispánico*
NB	*Nutrition Bulletin*
NEJM	*The New England Journal of Medicine*
NGRE	*National Geographic Research & Exploration*
OaC	*Osteoarthritis and Cartilage*
OEM	*Occupational and Environmental Medicine*
OJA	*Oxford Journal of Archaeology*
OM	*Occupational Medicine*
O&A	*Osteoarthritis & Rheumatism*
PBM	*Perspectives in Biology and Medicine*
PNAS	*Proceedings of the National Academy of Sciences*
PoBSR	*Papers of the British School at Rome*
PPP	*Palaeogeography, Palaeoclimatology, Palaeoecology*
PSM	*The Physician and Sportsmedicine*
PTRS	*Philosophical Transactions of the Royal Society*
QI	*Quaternary International*
QR	*Quaternary Research*
QSR	*Quaternary Science Reviews*
RA	*Revista de Arqueología*
RB	*Revue Biblique*
REAB	*Revista Española de Antropología Biológica* [later title: REAF]
REAF	*Revista Española de Antropología Física* [earlier title: REAB]
REML	*Revista Española de Medicina Legal*
RHAA	*Revista de Historia da Arte e Arqueologia*
RSF	*Rivista di Studi Fenici*
RSL	*Rivista di Studi Liguri*
SA	*Scientific American*
SEAEP	*Sociedad Española de Antropología, Etnografía y Prehistoria*
SJMSS	*Scandinavian Journal of Medicine and Science in Sports*

SR	*Social Research*
TA	*Tissue Antigens*
TGOTR	*The Greek Orthodox Theological Review*
TH	*The Holocene*
TK	*The Knee*
TMAEF	Trabajos del Museu Arqueològic d'Eivissa i Formentera [earlier title: TMAI]
TMAI	Trabajos del Museo Arqueológico de Ibiza [later title: TMAEF]
TP	*Trabajos de Prehistoria*
TSCPP	*Transactions and Studies of the College of Physicians of Philadelphia*
WA	*World Archaeology*
WRND	World Review of Nutrition and Dietetics
YPA	*Yearbook of Physical Anthropology*

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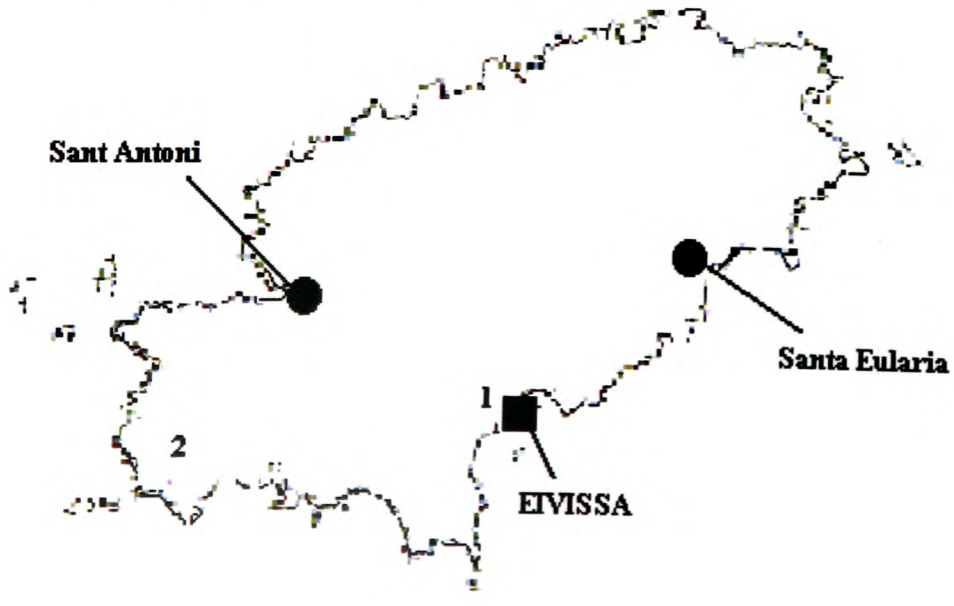
APPENDIX - ILLUSTRATIONS

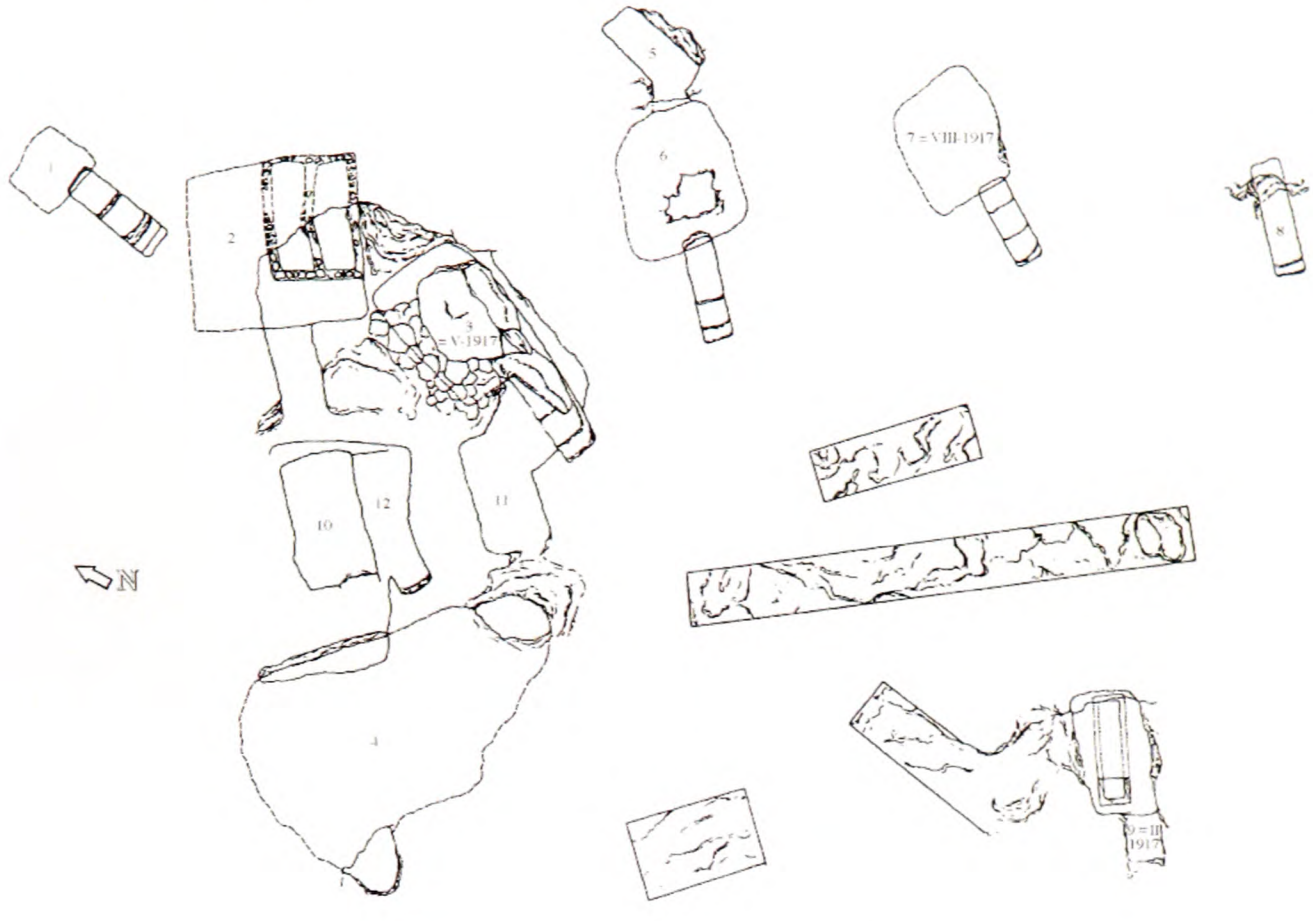
Ill. 1.1. Ibiza's location in the Western Mediterranean.



Ill. 1.2. Location of main sites on Ibiza. The capital *Eivissa* and two main towns (*Sant Antoni* and *Santa Eulària*) are indicated. 1 = the Punic and Late Antiquity-Early Byzantine urban sites are located in *Eivissa*. 2 = location of the Punic rural site (PCHN).



Ill. 2.1. Layout of the Punic rural cemetery (PCHN). Each number denotes a hypogeum. [Drawing provided by Dr. J. Ramon].

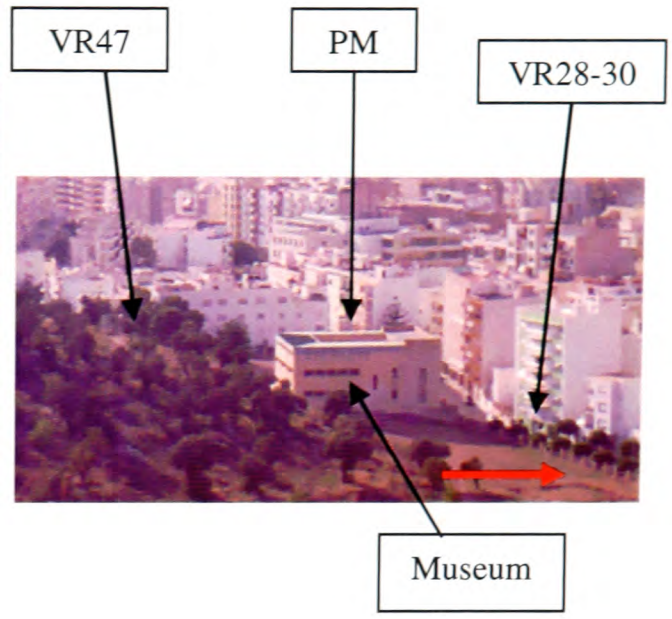


Ill. 2.2. Entrance to one of the smaller hypogea in PCHN Height of entrance c.0.50 m. [Photo: N. Márquez-Grant].

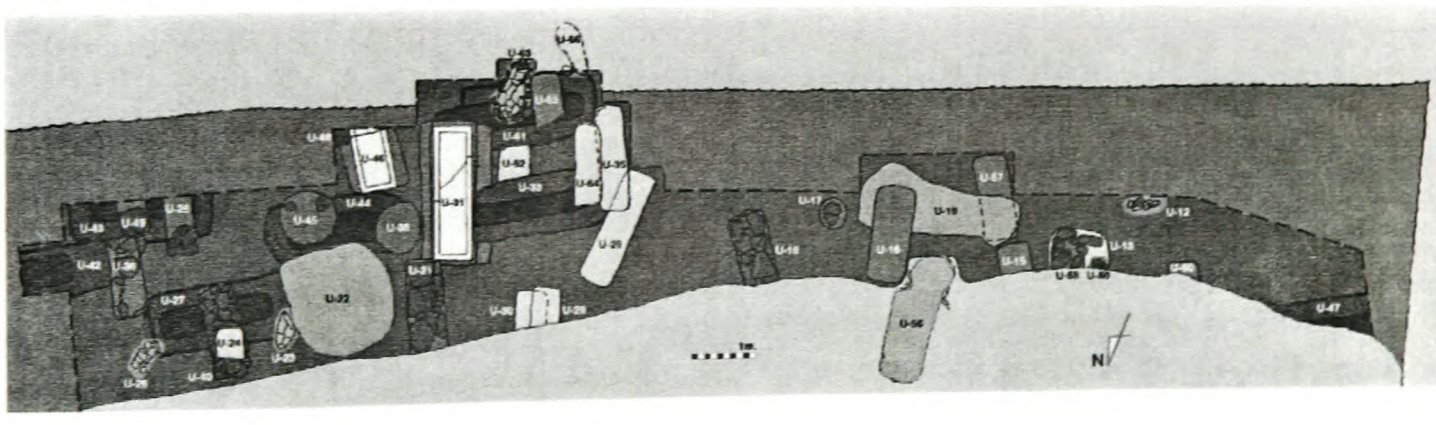


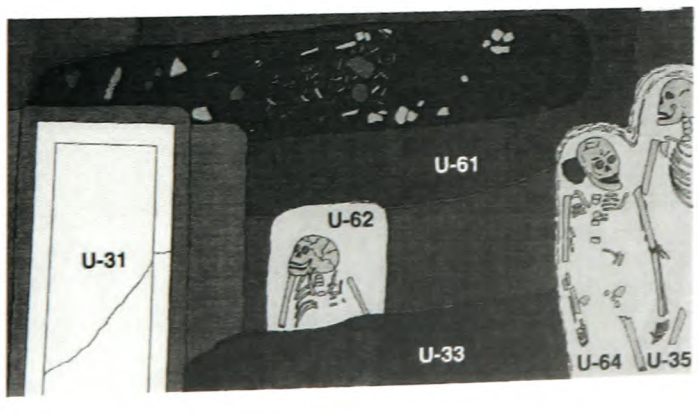
Ill. 2.3 (below left): *Puig des Molins* ('Windmill Hill'): the Punic urban cemetery (hill covered by trees). Part of the cemetery today is preserved within the museum's premises[1]. **Ill. 2.4** (below right): Arrows indicate approximate locations of the excavated sectors that provided material for this thesis. Sector PM (year 2000 and 2001 excavations) is located next to the museum building's eastern wall. Red arrow roughly denotes North. [Photos: N. Márquez-Grant].





Ill. 2.5. Excavation plan of VR47. [Drawing provided by Dr. J. Ramon].





Ill. 2.6 (left). Detailed view of some tombs from VR47 showing at least three fossae with adult inhumations. [Drawing provided by Dr. J. Ramon].

Ill. 2.7. Individual HLL819 from who samples were taken for radiocarbon dating. This skeleton belonged to a 20-30 year-old female. A facial reconstruction was included earlier in 'Acknowledgements'. [Photo: J. Ramon].



Ill. 2.8. View of cemetery AR33 during excavation. [Photo: J. Ramon].



Ill. 2.9. Site PCHN: Hypogeum with two sarcophagi. Originally this hypogeum would have had a roof but part of it and its walls have been damaged. Sarcophagi c.2 m long. [Photo: N. Márquez-Grant].



Ill. 2.10. Site PCHN: sector during excavation. Originally these tombs would have had roofs and walls but these have been destroyed. Level and trowel used for scale. Photo: N. Márquez-Grant

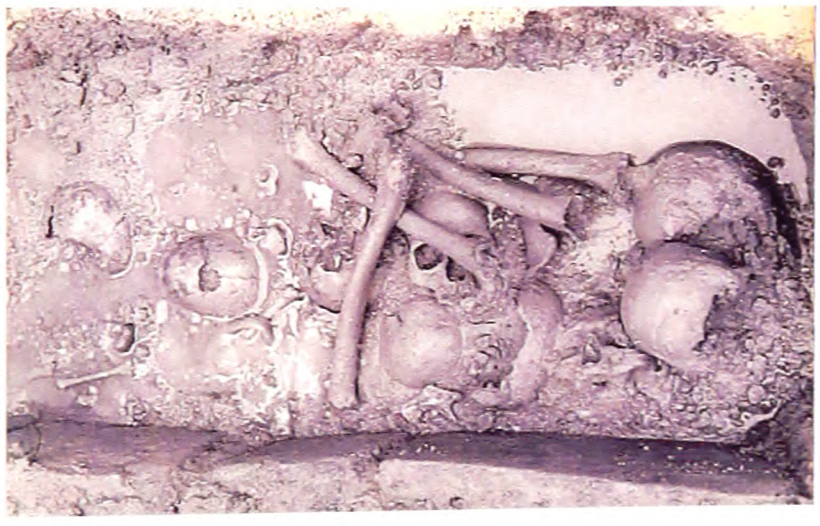




Ill. 2.11 (left). Site HLL: Disarticulated context (Tomb HLL902). [Photo: J. Ramon].



Ill. 2.12 (right). Site HLL: Tomb HLL820. In this tomb there was an adult male skeleton. On his abdominal area were placed at least five skulls from immature individuals. [Photo: J. Ramon]



Ill. 2.13 (left). Site AR33: Disarticulated tomb with secondary burials largely comprising skulls and long bones. [Photo: J. Ramon].



Ill. 2.14 (right). Skull VR28/709 was submitted for anthropological analysis in a block of earth. 'Mini-excavation' in the laboratory recovered the beads indicated by the arrows (includes a brown-coloured bead). [Photo: N. Márquez-Grant].

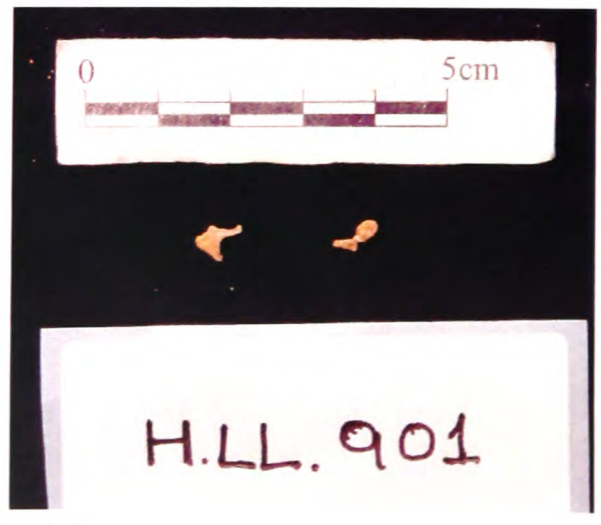
Ill. 2.15. Preservation was poor at site VR47. From this tomb (VR47/U15) not only was the skeleton poorly represented, but the bone surfaces themselves were also very weathered. [Photo: N. Márquez-Grant]



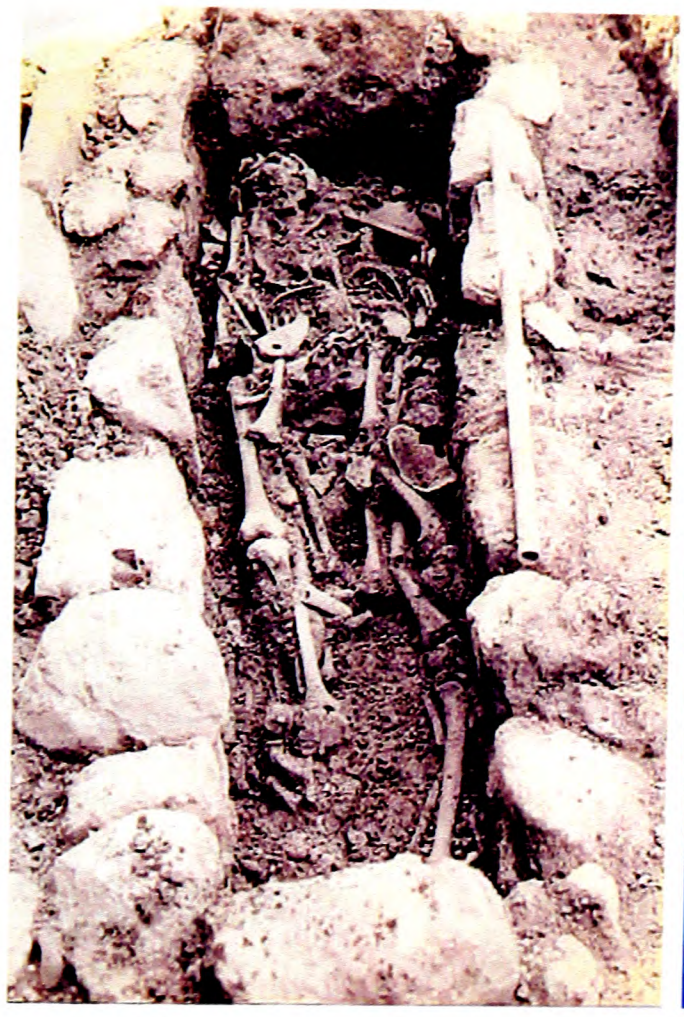
Ill. 2.16. Teeth were also in a bad state of preservation at site VR47. [Photo: N. Márquez-Grant]



Ill. 2.17. Good preservation in some skulls from site HLL allowed the recovery of ear ossicles as seen below. [Photo: N. Márquez-Grant].



Ill. 2.18 (left). Some skeletons in site HLL only yielded little information on age, sex and pathology such as this one (HLL214). [Photo: J. Ramon].



Ill. 2.19 (left). Many tombs in AR33 had many individuals. In this example at least two immature skeletons can be observed on top of a mature skeleton. [Photo: J. Ramon].

Ill. 2.20 (below). Preservation was good at AR33. Pictured below are complete femora that have been washed, dried and labelled and ready for analysis. [Photo: N. Márquez-Grant].



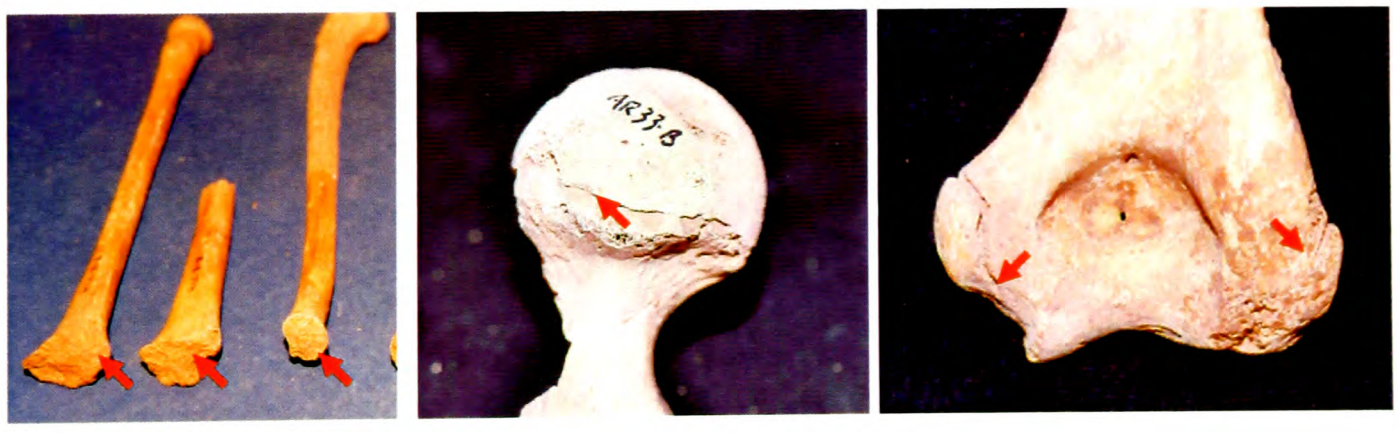
Ill. 2.21. Tooth formation was employed for estimating age-at-death in immature skeletons. In this case (HLL204) crown formation is almost complete and roots have not yet formed. The individual was estimated to be around 3-4 years. [Photo: N. Márquez-Grant].



Ill. 2.22. Dental development and dental eruption was examined in this individual AR33-H. The upper incisors have not erupted. This person was estimated to have died around the age of 7 years. [Photo: N. Márquez-Grant].



Ill. 2.23 (below left), **Ill. 2.24** (below centre), **Ill. 2.25** (below right). Three different stages of epiphyseal fusion. The first image (left) shows two radii and one ulna with unfused distal epiphyses (see arrows). This individual (HLL818) was estimated to be between 10 and 15 years old at the time of his or her death. The other two images show a semi-fused proximal epiphysis (AR33-B) of a femur and almost 3/4s fused epicondyles in the distal humerus (AR33-L). The skeletal ages for the individuals given by these two bones were 10-15 years. [Photos: N. Márquez-Grant].





Ill. 2.26 (left). Many adults were aged according to dental wear. In this picture, the mount of dentine exposed (darker areas, see arrow) indicated an age-at-death between 30 and 50 years for this individual. [Photo: N. Márquez-Grant].



Ill. 2.27 (right). Much *Ante-mortem* tooth loss indicated an older individual. In this example, all teeth had been lost during the person's life. The person was estimated to have been older than 50 years when he or she died. [Photo: N. Márquez-Grant].

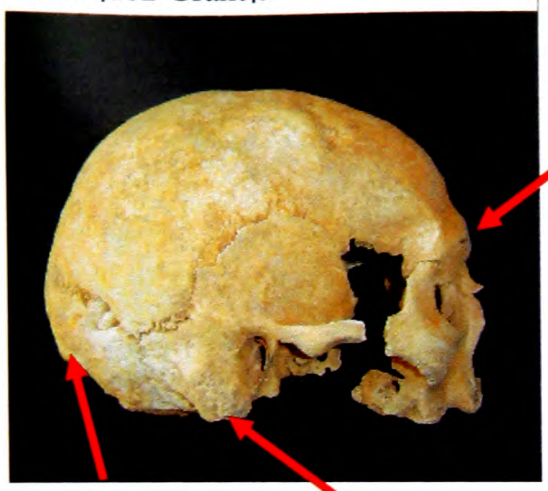


Ill. 2.28 (left). The surface of the pubic symphysis (pictured) was also employed to estimate the age-at-death. In this case (HLL818.1) the person was estimated to have died between the ages of 15 and 20 years. [Photo: N. Márquez-Grant].



Ill. 2.29 (right). Detailed view of the auricular surface in a right innominate bone (*os coxa*). The skeleton (HLL801.1) was estimated to have died between 30 and 50 years of age according to the texture of the surface. [Photo: N. Márquez-Grant].

Ill. 2.30. Male skull from site AR33. Location of traits observed for sex estimation (ignore scale through photograph). [Photo: N. Márquez-Grant].



Nuchal crest area

Mastoid process

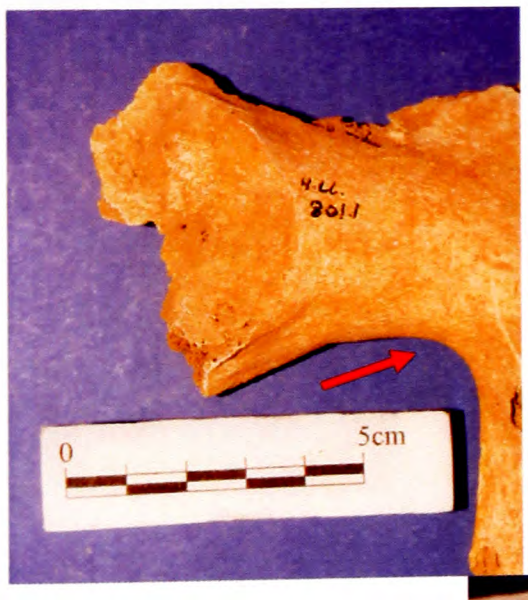
Glabella

Ill. 2.31. Female skull from site HLL. Location of traits observed for sex estimation (ignore scale through photograph). [Photo: N. Márquez-Grant].

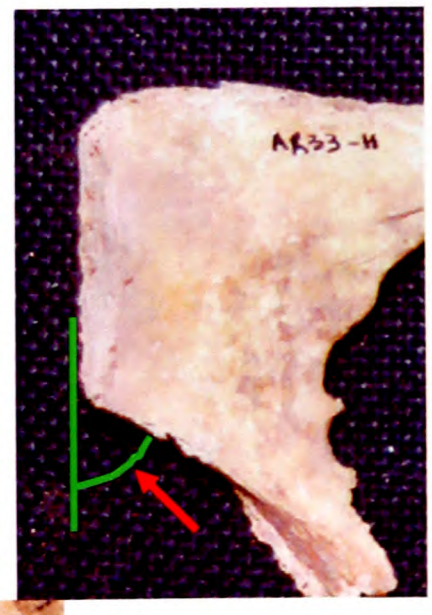


Mastoid process

Nuchal crest area



Ill. 2.32 (left), **Ill. 2.33** (right) and **Ill. 2.34** (below). Pelvic traits used in sex determination. These cases are typical of female traits: a wide sciatic notch (left), a wide sub-pubic angle (right) and the presence of one preauricular sulcus (below) on one or on both innominates. See arrows for locations. [Photos: N. Márquez-Grant].





Ill. 2.35. Individual stacked on top of another with his or her knees bent during interment that later collapsed duing decomposition of the corpse. [Photo: J. Ramon].





Ill. 3.1 (left) and **Ill. 3.2** (right). From these photos it is possible to identify linear enamel hypoplasia (LEH). The grooves indicated by the arrows are present in mandibular canines from site AR33. [Photos: N. Márquez-Grant].

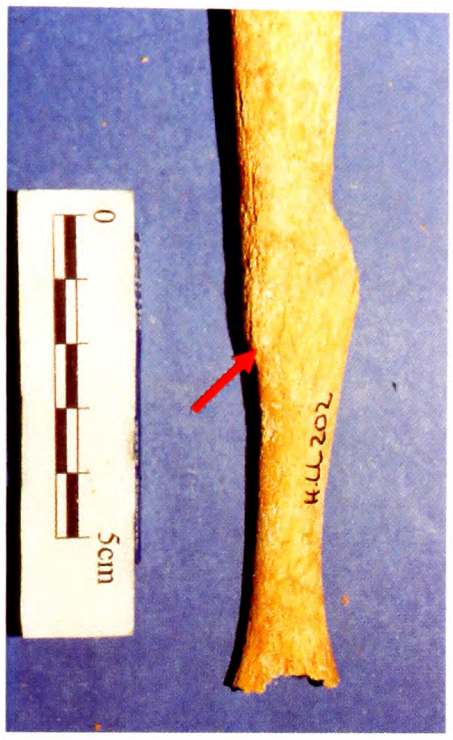




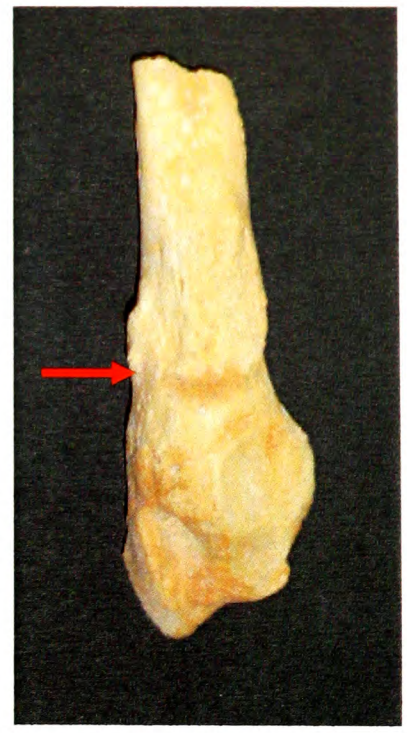
Ill. 3.3 (left). Left orbit with severe *cribra orbitalia.* Site HLL. [Photo: N. Márquez-Grant].



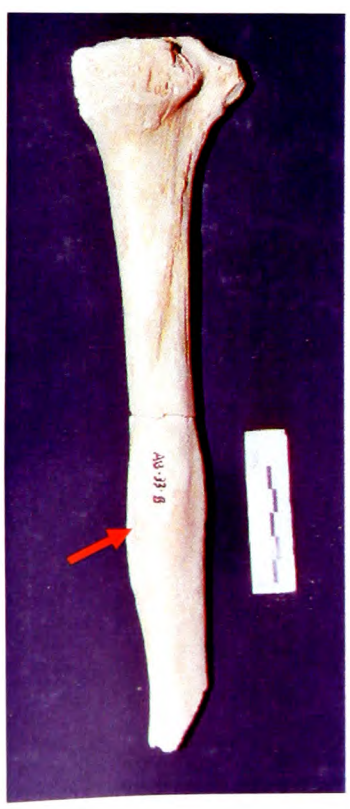
Ill. 4.1 (right). Tibia HLL201.1 displaying signs of periostitis on its surface: pitting and striae. [Photo: N. Márquez-Grant].



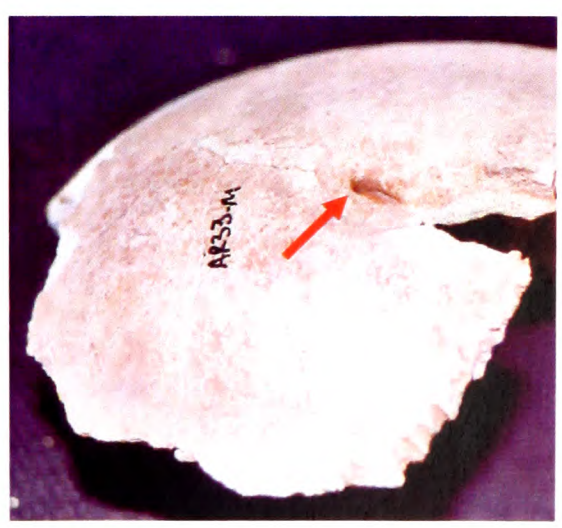
Ill. 5.1 (left). An example of a fracture. Trauma in this case was located in the distal third of an ulna (HLL202). [Photo: N. Márquez-Grant].



Ill. 5.2 (right). A Punic fibula with a healed fracture in the distal third (PCHN-H4). [Photo: N. Márquez-Grant].

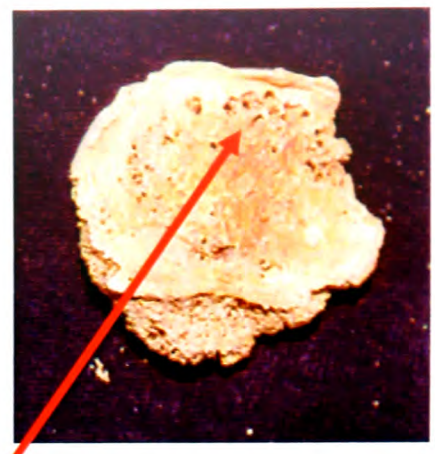


Ill. 5.3. (left), **Ill. 5.4** (below left) and **Ill. 5.5** (below right). Different types of trauma in different elements: in a tibia (Ill. 5.3) and a skull (Ill. 5.4) from Period 2, and ribs (Ill. 5.5) from the Punic rural site (PCHN-H7) showing massive callus formation. [Photos: N. Márquez-Grant].

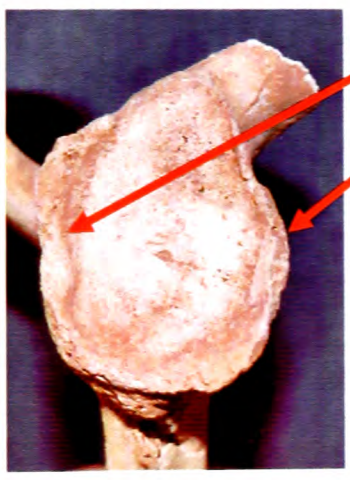


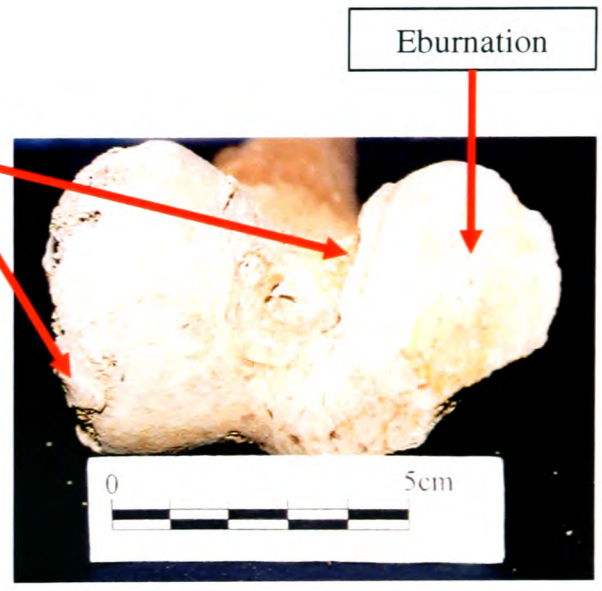






Ill. 5.6 (above left), **Ill. 5.7** (above right), **Ill. 5.8** (below left) and **Ill. 5.9** (below right). Criteria for scoring osteoarthritis. Examples come from a cervical vertebra, a patella, a scapula and a distal femur respectively. [Photos: N. Márquez-Grant].





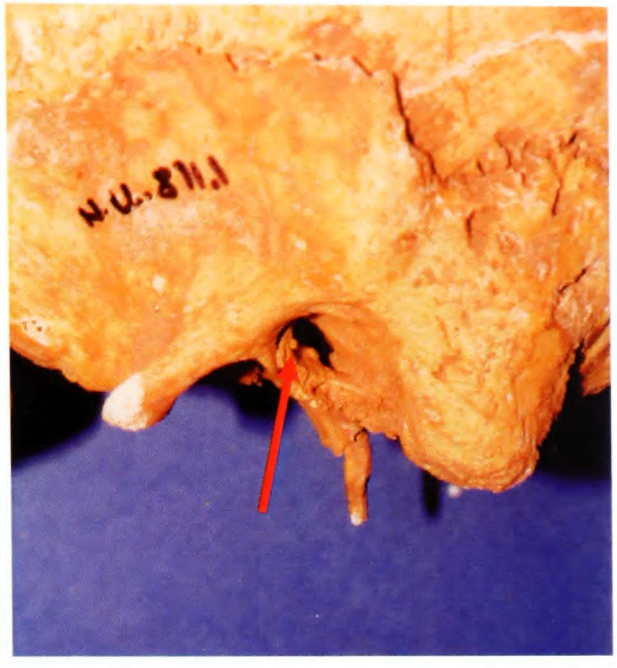


Ill. 5.10 (left). OA at the base of a first metacarpal. [Photo: N. Márquez-Grant].

Ill. 5.11 (right). OA in a distal humerus probably associated with trauma to the joint. [Photo: N. Márquez-Grant].



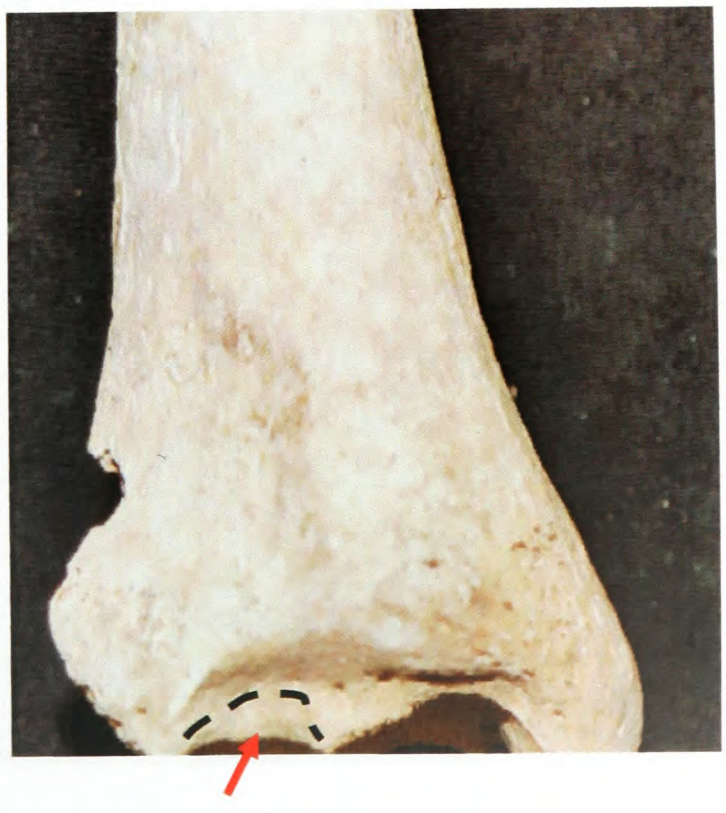
Ill. 5.12. Example of *torus auditivus* in a left temporal bone (HLL811.1). [Photo: N. Márquez-Grant].



Ill. 5.13. The most severe case found in the Ibizan material. Auditory exostosis in the right temporal of skull AR33-E-C1. [Photo: N. Márquez-Grant].



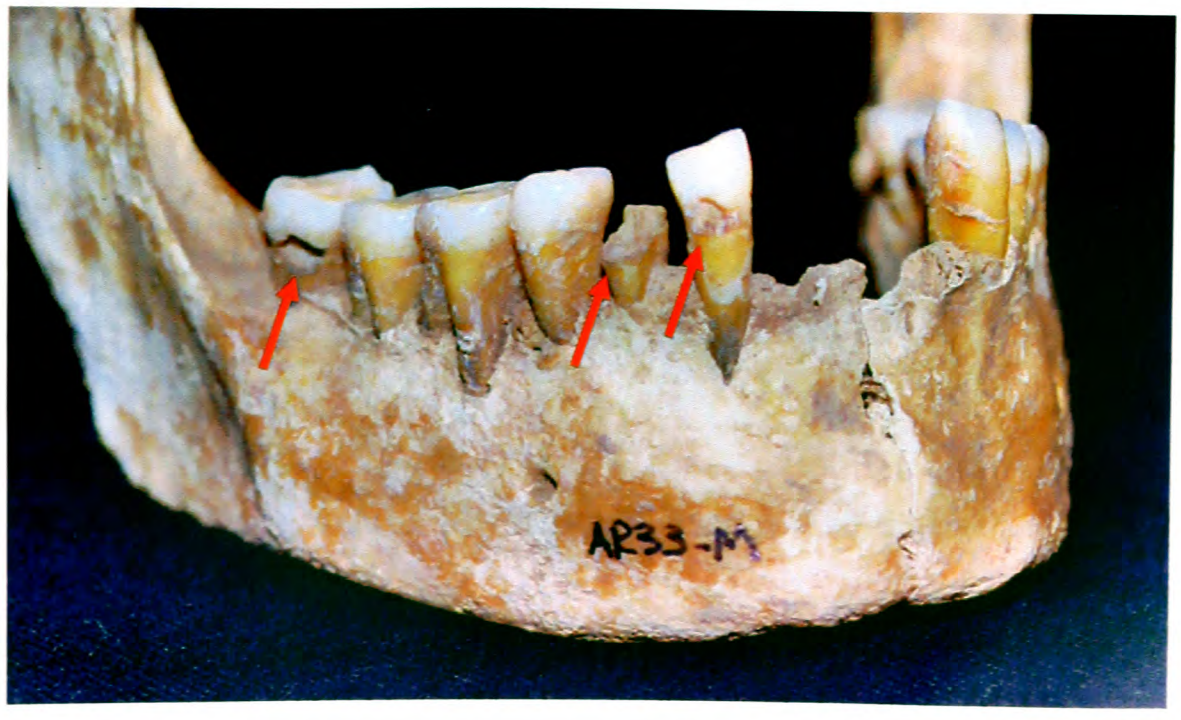
Ill. 5.14. Demarcated area indicates a lateral squatting facet in the distal epiphysis of this right tibia. [Photo: N. Márquez-Grant].



Ill. 6.1. Dental caries in three deciduous teeth and a permanent molar with a gross lesion. [Photo: N. Márquez-Grant].



Ill. 6.2. Mandible from Period 2 with dental caries at the cemento-enamel junction (CEJ) of the right canine and third molar, as well as a gross lesion in the first premolar (crown lost due to caries). [Photo: N. Márquez-Grant].





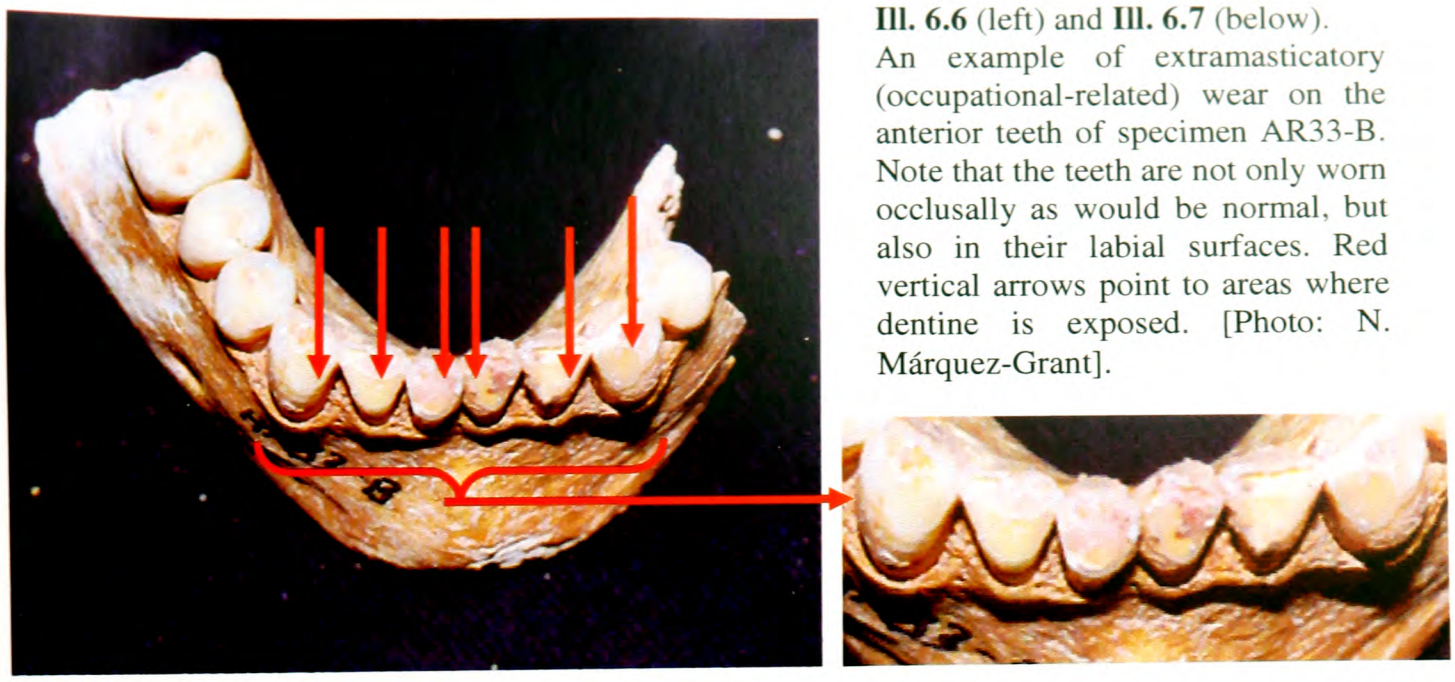
Ill. 6.3 (left). Upper molar tooth with considerable calculus. Site HLL. [Photo: N. Márquez-Grant].

Ill. 6.4 (right). Mandible from site AR33 with considerable bone recession (periodontitis) apart from other pathological conditions. [Photo: N. Márquez-Grant].



Ill. 6.5. Mandible from the Punic rural site (PCHN-H2) showing 'cup' wear in anterior teeth. First molars are worn considerably on a descending oblique wear plane with a lingual to buccal orientation. [Photo: N. Márquez-Grant].





Ill. 6.6 (left) and **Ill. 6.7** (below). An example of extramasticatory (occupational-related) wear on the anterior teeth of specimen AR33-B. Note that the teeth are not only worn occlusally as would be normal, but also in their labial surfaces. Red vertical arrows point to areas where dentine is exposed. [Photo: N. Márquez-Grant].



Ill. 6.8 (below left) and **Ill. 6.9** (below right). Possible and debatable cases of adult rickets (osteomalacia) as observed due to abnormal curvature in a humerus and a radius from Period 2. [Photos: N. Márquez-Grant].