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A Smile From the Past: Exploring a Fixed Bone Dental Bridge From Eighteenth/Nineteenth Century Porto (Portugal)

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ABSTRACT

This paper presents the first documented case of a fixed bone dental bridge in Portugal. This item was recovered alongside the remains of a young adult individual of indeterminate sex from the 19th century burial site of the 3rd Order of Our Lady of Carmo in Porto, Portugal. Despite the remains being mostly complete and well preserved, the maxilla is edentulous and the mandible is missing, with only two loose mandibular teeth recovered. The cranium, the two lower teeth, cervical vertebrae and dental bridge underwent detailed macroscopic examination with the latter also undergoing macro stereomicroscopy, multiscale x-ray, micro-CT imaging, x-ray diffraction, and ZooMS analyses. The bridge, which measures 24 mm long× 6 mm wide × 12 mm tall, is made from bone and likely sourced from the *Bovidae* family. It features three rudimentary "teeth" of increasing size with two perforations at each end. Internally, a cuboid-shaped object composed of lead compounds, primarily pyromorphite and cerussite, can be observed on the top right corner. Given its design, overall width, and the loss of the maxillary dentition, it is most likely that the bridge covered the labial surface of the lower right incisors and canine and was secured to the adjacent teeth through wire or thread. However, the possibility of it serving as a prosthetic substitute should not be discounted.

1 | Introduction

The finding of dental bridges in archaeological contexts assists our understanding of the history of oral medicine and development of prosthetic dentistry. While the ability to tailor rudimentary forms of teeth from various materials, such as wood, ivory and precious metals demonstrates skill and knowledge, the development of dental prostheses (e.g., bridges, crowns, and dentures) exemplifies the improvement in dental replacement techniques over time (Ionescu et al. 2023).

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Alongside demonstrating skill, dental bridges may also reflect affordability and status. Therefore, the context in which they are found allows us to explore the social and cultural dynamics that may have existed and shaped their use. Ultimately, a dental bridge in its archaeological context illustrates not only personal health concerns, but also societal values around aesthetics and dental appearance, creating a bridge between function and socio-cultural identity. Throughout history some prosthetics have served purely functional purposes, others aesthetic ones and the remainder a mixture of both (Becker 1994; Colleter et al. 2023; Seguin et al. 2014). They enhance functional capabilities, such as chewing, biting, and speaking, by acting as proxies for missing teeth, while contributing to a more favorable appearance (Colleter et al. 2023; Marin 2023). As aptly noted by Ionescu et al. (2023, 150), a "smile with missing teeth is hardly irresistible."

This paper introduces a fixed bone dental bridge recovered from a 19th century burial site associated with the 3rd Order of Our Lady of Carmo hospital burial ground in Porto, Portugal, which was in operation between 1801 and 1869. The practice of dental care in Portugal was of slow growth, and therefore any new finds are essential to complement and inform on its history. To date, four studies have been published: two in archaeological contexts (Cunha et al. 2017—gold wire ligature; Gomes 2023—possible ivory dental bridge) and two in contemporaneous collections of human remains (Table S1) (Carvalho et al. 2018; Wasterlain 2006).

The ligature was found in situ and associated with the remains of an adult female (late 15th century–radiocarbon dating) from the Convento de Santa Clara a Velha in Coimbra (Cunha et al. 2017). The wire circled the left upper lateral incisor and canine roots 1 mm below the cervical margin and was tied by twisting the wire on the vestibular/mesiodistal area of the canine. The skeleton displayed ante-mortem tooth loss, caries and severe periodontal disease. The bridge was found out of context among ceramics and other materials attributable to the 16th–17th centuries, dug from a well at the Convento de Santana in Lisbon (Gomes 2023). It is described as being fragile, measuring 25 × 5 × 11 mm and contains what appears to be the upper central incisors and partial lateral ones. Gomes proposes that it was fixed to the adjacent teeth or held in place with a metal wire. Despite no tests being performed, Gomes suggests that the bridge is made from elephant ivory. Lastly, Wasterlain's (2006) and Carvalho et al.'s (2018) studies are historically relevant, as they coincide with the formalization of Portuguese dentistry. Although the total number of prostheses found is unclear, crowns, complete and partial dentures, and inlays made from various materials were documented.

The present case was found in association with the remains of a young adult and a crucifix during the first excavation campaign (Vassallo et al. 2025). A significant number of secondary depositions along with 480 primary burials were recovered; they are being examined as part of the BeFRAIL project (Alves-Cardoso 2025). Based on site stratigraphy, the young adult was tentatively dated to between 1801 and 1834. By showcasing this case, this article aims to highlight the value of archaeological dental finds and contribute to the historical knowledge of prosthetic dentistry in Portugal and ultimately Europe.

2 | Methodological Approach

A multimethodological approach was employed to examine the human remains and dental bridge. A detailed macroscopic analysis of the remains following the guidelines provided in Buikstra and Ubelaker (1994) was performed, assisted where necessary by a low-powered magnifying lens.

To examine the bridge's macrostructure, macro stereomicroscopy was performed using a NIKON SMZ645 stereomicroscope coupled with a MOTICAM 10 MP digital camera. Following this, multiscale x-ray micro-CT imaging was used to explore the bridge's microstructure and compositional heterogeneities. The analysis was conducted using a laboratory desktop SkyScan 1172 μ-CT scanner (5-μm spot size; x-ray detector 1.3 MP, power 10 W–100 kV/100 μA), with a resolution of 13.57-μm pixel size. X-ray diffraction was performed to identify the respective compositions of the bridge and embedded object with a Philips X'Pert Pro X-ray diffractometer equipped with a Cu anode (Cu Kα radiation, wavelength 1.54 Å), operating at 40 kV/35 mA. Measurements were taken in the range of $5° \leq 2\theta \leq 100°$ with a step size of $0.05° 2\theta$ and a time per interval of 150 s (multichannel scan with combined step time). Data analysis was performed using X'PERT PLUS software, supported by the PDF4 database (International Centre for Diffraction Data 2025). Lastly, to identify the taxonomic origin of the dental bridge, Zooarchaeology by Mass Spectrometry (ZooMS) was performed. Normally, ZooMS involves drilling the bone to obtain a small amount of sample and its subsequent demineralization to facilitate the extraction of collagen (Buckley et al. 2009); however, collagen can also be extracted using a nondestructive approach by heating the bone in ammonium bicarbonate without demineralization (van Doorn et al. 2011). This approach is better suited for worked bone, because it preserves the visual acuity of the sample, and as such was chosen for analyzing the dental bridge. Briefly, the bridge was placed in 5 mL of 50 mM ammonium bicarbonate solution at 65°C for 1 h, and the liquid was decanted and concentrated to 200 μL using 10 kDa ultrafilters. To 100 μL of the resultant solution, 0.4 μg of trypsin was added for enzymatic digestion and incubated at 37 °C for 18 h. The resultant peptides were desalted using C18 ZipTips (Thermo Scientific, Pierce) and subsequently analyzed in triplicate using a Bruker Autoflex max MALDI spectrometer. The resultant ZooMS spectra were analyzed using mMass 6.0.2. Baseline correction was performed with Precision of 15 and Relative Offset of 25, following which peak picking was performed with a signal-to-noise threshold of 3. The peaks were identified based on the presence of the automatically identified peaks as well as visual identification of the spectra.

3 | Results

3.1 | Analysis of the Human Remains

The skeletal remains are generally well preserved, mostly complete and belong to a young adult of indeterminate sex (Vassallo et al. 2025). While the neurocranium is intact, the mandible and most facial bones are missing. The maxilla is largely preserved except for the right side where the molars would be. All maxillary teeth were lost ante-mortem, with alveolar resorption

nearly complete, except in the anterior region, where some sockets remain visible. The palate shows some porosity that is mostly located on the right anterior portion of the median palatine suture. The right maxillary sinus fragment also exhibits porosity with a changed morphology: The bone tissue appears slightly enlarged. Only two teeth were recovered, namely, a lower left first or second molar and a lower left first premolar. The former, although preserving its form, displays considerable taphonomic changes to the roots and enamel, severe occlusal dental wear and an indentation just below the crown on the distal interproximal side (Figure 1) (Vassallo et al. 2025). The left first premolar shows similar taphonomic changes to the root along with a single horizontal band on the enamel (linear enamel hypoplasia). No degenerative changes were observed in the temporomandibular joint, nor were any other morphological alterations associated with biomechanical stress detected. All cervical vertebrae display degenerative changes, namely, porosity, eburnation, and/or osteophytic growth (Vassallo et al. 2025).

3.2 | Analysis of the Dental Bridge

The dental bridge is dark brown-beige in color, measures 24 × 6 × 12 mm and is composed of three rudimentary U-shaped "teeth" of increasing size (Figure 2). Two holes are present at each end. It appears as if most of the superior surface has been polished down.

Multiscale micro-CT imaging revealed a dense cortex along with cancellous bone. It also revealed a radiolucent area that extends down most of the tallest "tooth" along with a cuboid-shaped object with high x-ray opacity embedded above it; the latter's surface being visible macroscopically (Figures 2 and 3). A small, dispersed amount of the object is also visible through micro-CT imaging, extending superiorly toward the central "tooth" (Figure 3) and directly below the cuboid-shaped object (for video, see Pereira et al. 2025). A linear crack/fissure is also visible, both macroscopically and through the micro-CT examination (Figure 3). This crack/fissure runs diagonally

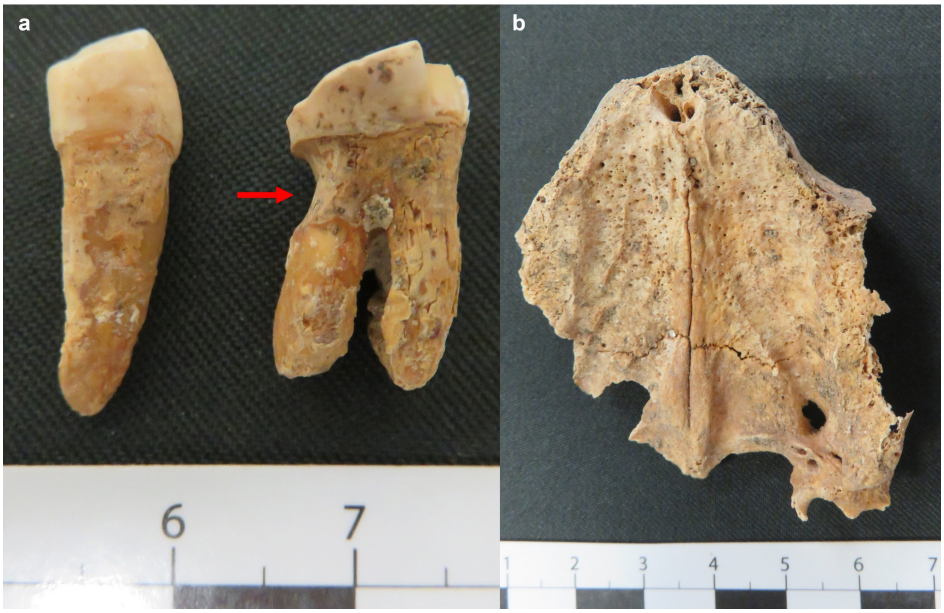

FIGURE 1 | Mandibular teeth and edentulous maxilla. (a) permanent lower left first premolar (left) and a permanent lower left first or second molar (right). The red arrow points toward an indentation on the mesial surface of the molar. (b) inferior view of the maxilla. Note the nearly complete alveolar resorption and the porosity on the palate. [Colour figure can be viewed at wileyonlinelibrary.com]

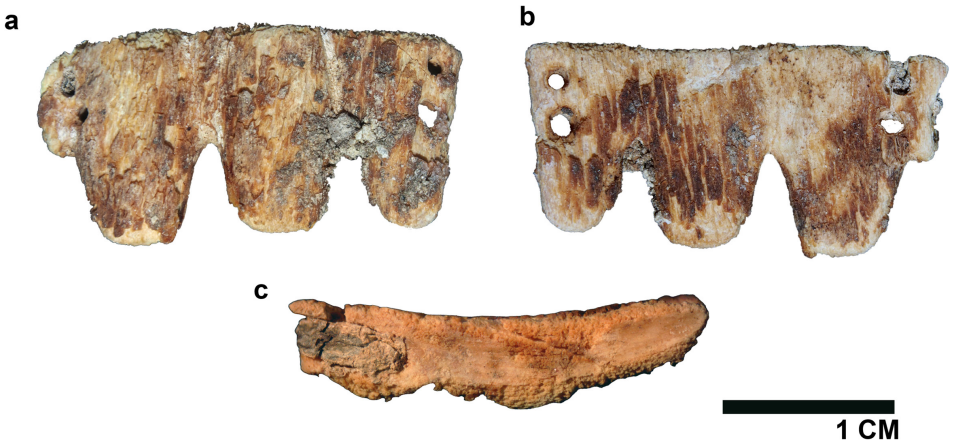

FIGURE 2 | Macro stereomicroscopic images of the dental bridge. (a) Anterior, (b) posterior, and (c) superior aspects. [Colour figure can be viewed at wileyonlinelibrary.com]

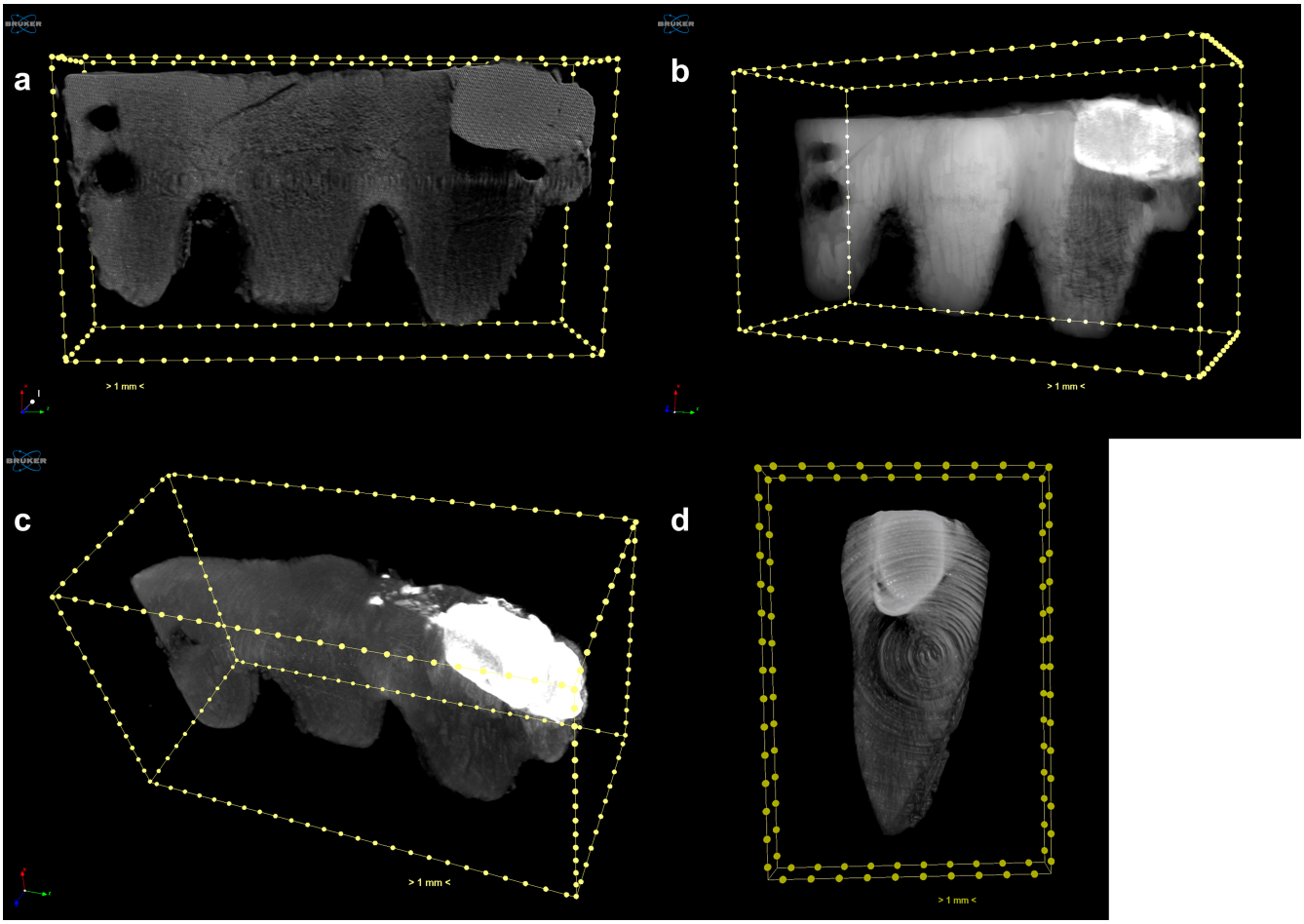

FIGURE 3 | Micro-CT slices of the dental bridge. A cuboid-shaped object, a small dispersed amount of the material, a linear crack/fissure and a radiolucent area are visible. (a) Posterior, (b) posterior, (c) supero-posterior, and (d) medial views. Ring artifacts visible in image d. [Colour figure can be viewed at wileyonlinelibrary.com]

from the central to the smallest "tooth" on the left and appears to extend to just above the mid-section of the bridge (Pereira et al. 2025).

The x-ray diffraction results confirmed the bridge's osseous origin through the identification of carbonate-hydroxyapatite (bone phosphate) crystals. It also detected three anomalous minerals, namely, a carbonate (cerussite) and a phosphate (pyromorphite), which are lead minerals, along with cassiterite, a tin ore mineral (Figure 4).

The ZooMS spectra showed several peaks identified to the family *Bovidae* (Figure 5), excluding the Caprinae subfamily (based on the presence of peaks at *m/z* 1192.8 and 1208.7; Buckley et al. 2009). This family encompasses a wide variety of herbivorous animals, of which *Bos* sp. and *Bison* sp. are the most common European representatives.

4 | Discussion

Based on the U-shaped appearance of the three rudimentary "teeth," their progressive increase in size from left to right and the edentulous maxilla, it is likely that the device was designed for the lower right incisors and canine. It features two holes at each end, which were likely used to secure it to the adjacent teeth with materials such as gold wires or silk threads (de Dumareille Vitry 1847; Harris et al. 1975). It is possible that the superior portion was smoothed down to increase the comfort and effectiveness of the device. The cause of the indentation on the lower left first or second molar is unclear and is unlikely to be associated with the device.

The results of the ZooMS analysis indicate that the dental bridge was made from a bone belonging to the family *Bovidae* (excluding Caprinae), possibly *Bos* sp. or *Bison* sp. However, *Bovidae* also includes many African antelopes, and owing to the well-documented interactions between 18th and 19th century Portugal and Africa (Casimiro et al. 2023), the possibility of the bone originating from some other antelope of the Bovidae family cannot be ruled out. The type of biomaterial selected for the device is uncommon and the least recommended according to 19th century Portuguese dental practices (de Dumareille Vitry 1847). The recovered device most closely resembles another lower bridge discovered in a 19th Dutch churchyard (Waters-Rist et al. 2013). This prosthesis, also consisting of three "teeth" and made from bone (species unknown), was recovered in situ with a young adult male who lived in the 1800s. Unlike the present case, the Dutch version is more anatomically correct, as it includes the gum line (attached gingiva). It replaced the permanent

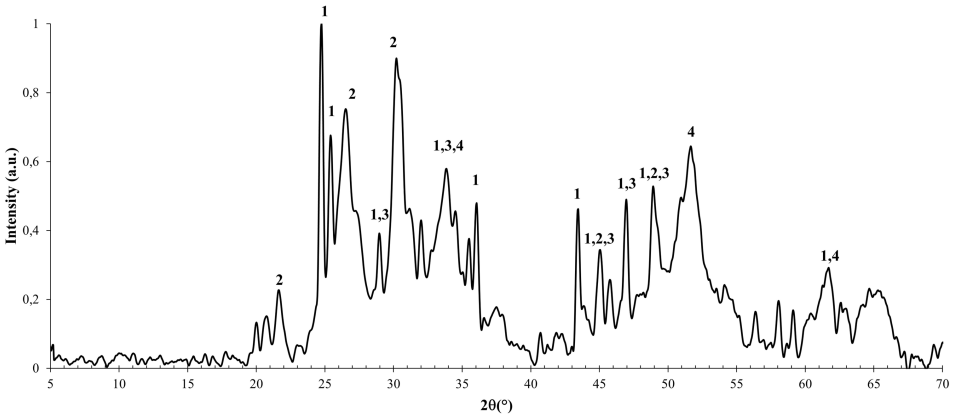

FIGURE 4 | X-ray diffraction pattern of the embedded material. Main peaks: (1) cerussite, (2) pyromorphite, (3) carbonate-hydroxyapatite, and (4) cassiterite.

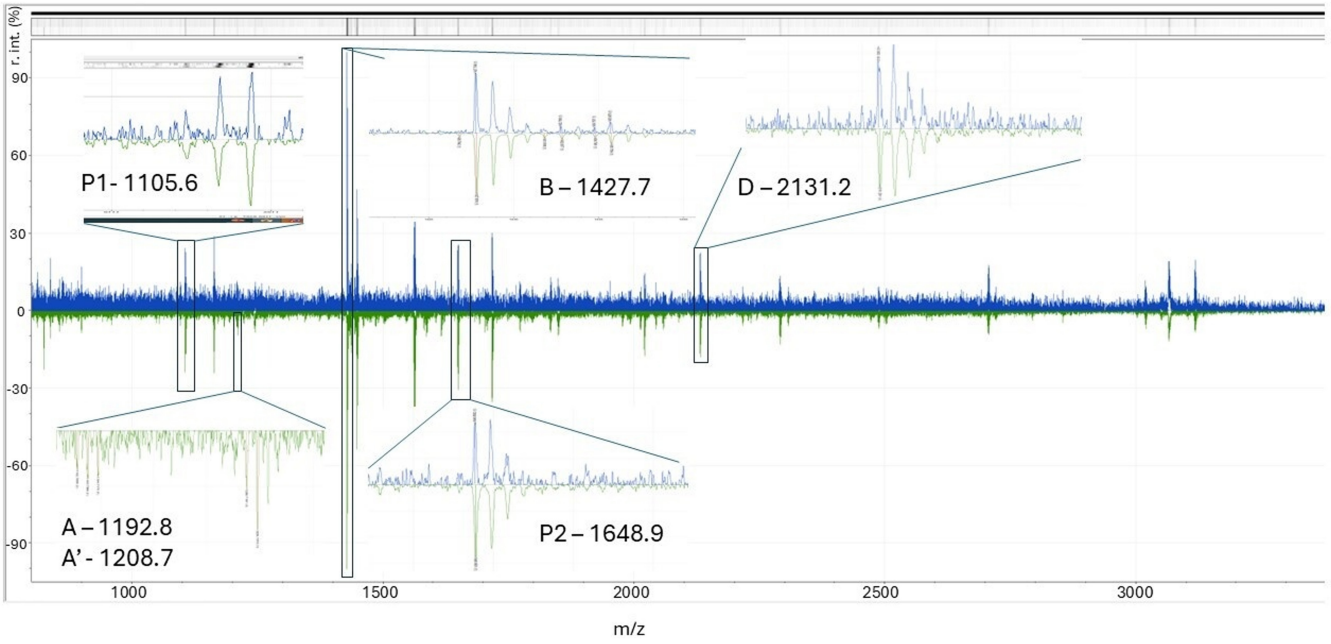

FIGURE 5 | MALDI spectra of two of the replicates analyzed for ZooMS showing the various peptide biomarkers used for taxonomic assignment along with their m/z values. Five of the eight commonly observed biomarkers are visible across both spectra. [Colour figure can be viewed at wileyonlinelibrary.com]

lower central and right lateral incisors and features small drilled holes on the inferior edge of the outer "teeth," through which it was anchored. The recovered device also resembles a possible upper bridge reported by Gomes (2023). The dimensions of both are strikingly similar, with the present case measuring 24 × 6 × 12 mm and the latter 25 × 5 × 11 mm. Nevertheless, they are composed of different materials (animal bone vs. possible elephant ivory) and were likely placed in the mandible and maxilla.

The presence of cerussite and pyromorphite minerals in the embedded object suggests that the original material was lead-based and underwent diagenetic transformations influenced by the microchemical conditions of the burial environment. Although the function of the object and radiolucent area are unclear, it is possible the former repaired, stabilized and/or added strength to the holes, while the latter contained the object. Despite lead's use over the past few centuries, lead and lead oxides are known to be cytotoxic (Marin 2023). High exposures can affect the central nervous system and lead to death (Marin 2023). However, it is unclear if the compound relates to the extensive tooth loss, and cranial and vertebral lesions. Briefly, the lesions consist of porosity at the palate and right maxillary sinus and considerable degenerative changes in all cervical vertebrae. The former may be a result of dental diseases/sinusitis and the latter degenerative disc disease (Vassallo et al. 2025).

The purpose of the recovered bridge can be considered through two different possibilities listed in order of probability: (1) It was placed over the labial surface of the lower right incisors and canine, and (2) it served as a prosthetic substitute for those teeth. Given its thin structure, the bridge may have functioned primarily as a cosmetic covering to hide discoloration, damage or dental diseases, such as caries. It is unlikely to have provided any additional benefits in terms of chewing or speaking because

this hypothesis presumes that the lower right incisors and canine were present. A second possibility is that it was designed to completely replace these teeth. However, if this was the case, it is unclear why the bridge is so thin, as it would likely not have been functional for chewing or biting. It may instead have had a cosmetic purpose or improved pronunciation, because missing teeth, particularly anterior ones, can negatively affect speech articulation (Bitencourt et al. 2019).

4.1 | Limitations of the Study

Presently, a definitive conclusion for the prosthesis' purpose cannot be reached because of the missing mandible, absence of most mandibular teeth, and lack of close-up in situ photos and documentation.

5 | Conclusion

The present study presents the first known example of a fixed bone dental bridge in the Portuguese archaeological record, highlighting the effectiveness of a nondestructive multimethodological approach in archaeological research. Although the exact purpose of this device remains unclear, it is likely that it was designed to cover several anterior mandibular teeth for aesthetic purposes. Further analysis of the remains recovered at the Carmo burial site may identify similar examples of prosthetic work, contributing to a clearer understanding of dentistry in 18th and 19th century Portugal.

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Ethics Statement

This study falls under the BeFRAIL project, which received a favorable evaluation from NOVA FCSH's Ethics Committee (Ref.: CE-NOVA_FCSH_2024/71).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** Published Portuguese archaeological and historical dental prosthetics.