1 **A matched comparison of the implant and functional outcomes of cemented**

2 **and cementless Unicompartmental Knee Replacements. A study from the**

3 **National Joint Registry for England, Wales, Northern Ireland and the Isle**

4 **of Man and Patient Reported Outcome Measure Databases**

5

6 Hasan R Mohammad, Andrew Judge, David W Murray

7

8 **Qualifications, appointments and roles of the authors**

9 [1,2] Mr Hasan R Mohammad - MRCS, MRes (Dist), DPhil (Oxon), Academic Research
10 Fellow in Orthopaedics.
11 [1,2] Professor Andrew Judge – BSc, MSc, PhD. Professor of Translational Statistics.
12 [1] Professor David W Murray – MD, FRCS. Consultant Orthopaedic Surgeon and Professor of
13 Orthopaedic Surgery.
14
15
16 **Institutional address**

17 1. Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences
18   University of Oxford, Nuffield Orthopaedic Centre, Oxford, OX3 7LD, United Kingdom
19 2. Musculoskeletal Research Unit, Bristol Medical School, University of Bristol, Level 1
20   Learning and Research Building, Southmead Hospital, Westbury-on-Trym, Bristol, BS10
21   5NB, United Kingdom.
22

23 **Corresponding author:**

24 Name: Mr Hasan Raza Mohammad

25 Email: hasanmohammad@doctors.org.uk

26 Tel: +44 (0) 7841 873 244

27

28 **Word count (including abstract):** words

29

30

31 **ABSTRACT**

32 **Background:** Unicompartmental knee replacement (UKR) is an effective treatment for end-

33 stage medial compartment osteoarthritis but there can be problems with fixation. The

34 cementless UKR was introduced to address this and has been shown in a matched study to

35 decrease the incidence of aseptic loosening. It is unknown how its functional outcomes

36 compare to the cemented version. We performed a matched comparison of the clinical and

37 functional outcomes of cementless and cemented UKRs.

38

39 **Methods:** 14,764 Oxford UKRs between January 2009 and December 2018 were identified

40 by the National Joint Registry for England and Wales (NJR) with linked patient reported

41 outcome data. 3,453 cemented and 3,453 cementless UKRs (n=6,906) were propensity score

42 matched, based on patient, surgical and implant factors.

43

44 **Results:** The 10 year cumulative implant survival for cementless and cemented UKRs were

45 93.0% (95% CI 90.0-95.1) and 91.3% (95% CI 89.0–93.0) respectively with this difference

46 being significant (HR 0.74; p=0.02). The postoperative Oxford Knee Score (OKS) was

47 significantly (p=0.001) higher for the cementless 39.1 (SD 8.7) compared to the cemented

48 38.5 (SD 8.6) UKR. The cementless group gained 17.6 OKS points (SD 9.3) postoperatively

49 compared to the cemented group of 16.5 points (SD 9.6) with a difference of 1.1 points

50 (p<0.001). The differences in OKS points gained after surgery was highest for surgeons with

51 volumes $\geq$ 30 UKRs/yr where the cementless group gained 1.8 points more than the

52 cemented group (p<0.001). The postoperative EQ-5D of the cementless group was higher

53 than the cemented with the difference being not significant (p=0.06) overall (respectively

54 0.808, SD 0.231 and 0.799, SD 0.232) but significant (p=0.02) for high volume surgeons ($\geq$ 30

55 UKRs/yr) (0.813, SD 0.236 and 0.797, SD 0.235; p=0.02).

56   **Conclusion:** The cementless UKR has improved ten-year implant survival and postoperative

57   functional outcomes compared to the cemented. The improvement in functional outcome was

58   largest in the high volume surgeon group, in which the average improvement in OKS was

59   about 2 points.

60

61   Level of evidence: III

62   Abstract word count: 294 words

63

64

65

66

67

68

69

70

71

72

73

74

75

76

77

78

79

80

INTRODUCTION

The two main surgical treatments for end stage medial compartment osteoarthritis are total knee replacement (TKR) and unicompartmental knee replacement (UKR). Although UKR offers significant advantages over TKR including faster recovery and lower mortality[1-3], its revision rate is higher in the joint registries[4-6].

The most commonly used UKR is the mobile bearing Oxford UKR (Zimmer Biomet)[7]. The original design was cemented, but given concerns of misinterpreted radiolucent lines[8] a cementless version was introduced in 2004. Randomised controlled trials comparing cemented and cementless UKRs found that the prevalence of radiolucencies was markedly reduced with cementless implants[9]. However the trials were inadequately powered to assess revision and for changes in functional outcomes. Previous big data matched studies[10, 11] and a systematic review[12] have shown reduced revision rates for the cementless UKR compared to the cemented, but did not have data to compare functional outcomes. Therefore there is no consensus on how the functional outcomes of cementless and cemented compare. Furthermore there have been no studies to date with adequate power comparing both implant and functional outcomes in the same cohort.

We aimed to use linked data from the National Joint Registry for England, Wales, Northern Ireland and Isle of Man (NJR) and Hospital Episode Statistics Patient Reported Outcome Measures (HES-PROMs) to compare both implant and functional outcomes of a single matched cohort of cemented and cementless Oxford UKRs.

MATERIAL AND METHODS

Data sources

A retrospective observational study was performed using linked data from the NJR and HES-PROMs database after ethical and legal approvals. The NJR is the world's largest arthroplasty register[13] and HES-PROMs started collecting PROMs for all NHS funded knee replacements from 2009 onwards. Preoperative and six month postoperative Oxford Knee Score (OKS)[14] and quality of life index EuroQol 5 Domain index (EQ-5D)[15, 16] are collected. The postoperative PROMs time point was selected by the programme to be close enough to surgery to provide timely feedback after the post-operative recovery period whilst avoiding influence of non-operative factors in the longer term. Research indicates most improvement in PROMs after joint replacement occurs in the first six months, with only minor improvement between six months, one year and thereafter[17-20].

Statistics

There were significant differences in baseline characteristics between cemented and cementless UKR groups (Table 1). Logistic regression was used to generate a propensity score representing the probability that a patient received a cementless UKR and were generated from patient demographics and surgical factors. All patient and surgical factors in Table 1 were used for matching which included preoperative OKS and EQ-5D. BMI was not used for matching given the large proportion of missing data but was well balanced between groups. This is a well-recognised approach[10, 11, 21-24]. Surgical factors included surgeon caseload, defined as the average number of UKRs performed per year as described previously [11, 25]. The algorithm used matched 1:1 on the logit of the propensity score with a 0.02-SD calliper width. Greedy matching without replacement was used given its superior performance for estimating treatment effects [26]. Standardized mean differences (SMDs) were

131   examined both before and after matching to assess for any imbalance between groups, with

132   SMDs of >10% suggestive of covariate imbalance[27]. After matching, 6,906 UKRs (3,453

133   cemented and 3,453 cementless) were included for analysis. Outcomes of interest were: (1)

134   10-year implant survival, (2) indications for revision, (3) OKS and (4) EQ-5D scores.

135

136   Cumulative survival was determined using the Kaplan-Meier method. The endpoint for

137   implant survival was revision surgery (any implant component removed, exchanged or

138   added). Implant survival rates were compared between groups, using Cox regression models,

139   with the proportional hazards assumptions assessed and satisfied in all analyses. A multi-

140   level frailty model was tested in the regression models to control for patient clustering within

141   surgeons. Additionally to account for clustering within the matched cohort a robust variance

142   estimator was used in regression models. The proportional Chi-squared test with Yate's

143   correction was used to compare the frequency of revisions for specific indications between

144   groups.

145

146   The OKS has 12 items relating to knee pain and function, presented as an overall score

147   between 0 and 48 [14]. The percentage of the possible change (PoPC) was calculated as

148   described previously[28]. This expresses the actual OKS change attained as a percentage of the

149   possible OKS change. The OKS was categorised into categories poor (<27), fair (27-33),

150   good (34-41) and excellent (>41) as described by Kalairajah et al[28]. Subscale analysis of the

151   OKS pain and functional components was also performed with each being scored out of

152   100[28]. The EQ-5D comprises five questions about mobility, selfcare, activities of daily living,

153   pain and anxiety/depression. These answers can be presented as a weighted overall index

154   from 1 (perfect health) to –0.594 (worst possible state) [15, 16]. Subgroup analyses of the

155   functional outcomes was performed in surgeons of different caseloads as described

156 previously. Low caseload defined as <10 UKRs/yr, medium caseload surgeons (10 to <30

157 UKRs) and high caseload surgeons (≥30 UKRs/yr). PROMs scores were not normally

158 distributed appropriate nonparametric tests were used. To compare post-operative scores and

159 changes in scores between groups the Mann Whitney test was employed.

160 All statistical analyses were performed using Stata (Version 15.1; StataCorp, TX, USA)

161 except propensity score matching, which was performed using R (Version 3.4.0; R

162 Foundation for Statistical Computing, Vienna, Austria). P-values of <0.05 were considered

163 significant, with 95% confidence intervals (CI) presented.

164

165 **<u>Ethical approval</u>**

166 This study was approved by the NJR Research subcommittee and had ethical approval from

167 the South Central Oxford B Research Ethics Committee (19/SC/0292). The linkage of the

168 datasets was approved by the Confidentiality Advisory Group (19/CAG/0054).

169

170

171

172

173

174

175

176

177

178

179 **RESULTS**

180 Between 1st January 2004 and 31st December 2018, 50,926 medial Oxford UKRs were

181 recorded in the NJR dataset[13]. From these 14,764 Oxford UKRs were successfully linked to

182 the HES-PROMs dataset[29] using pseudo anonymised identification numbers (Figure 1) as

183 described previously. There were significant differences in the baseline characteristics of the

184 unmatched cohort (Table 1). After matching there were 6,906 UKRs (3,453 cemented and

185 3,453 cementless) for analysis and the groups were well balanced for all co-variates (Table

186 1). In the matched cohort, the mean follow-up for both cemented and cementless implants

187 was 4 years (SD 2.2).

188

189 **Implant survival and indications for revision**

190 The 10-year cumulative implant survival rates were 93.0% (CI 90.0-95.1) and 91.3% (CI

191 89.0-93.0) for cementless and cemented respectively (Figure 2). Cementless UKRs had a

192 significantly higher implant survival compared with cemented UKRs (HR=0.74, CI 0.58-

193 0.95; p=0.02).

194

195 The most common reasons for revision in the cemented group were aseptic loosening (n=38,

196 1.10%), pain (n=24, 0.70%) and osteoarthritis progression (n=43, 1.25%) (Table 2). In the

197 cementless group the most common reasons for revision were osteoarthritis progression

198 (n=25, 0.72%), pain (n=15, 0.43%) and dissociation (n=31, 0.32%) (Table 2). The only

199 significant differences in revision indication were aseptic loosening and arthritis progression

200 which were both significantly lower in the cementless group (0.35% vs 1.10%, p<0.001) and

201 (0.72% vs 1.25%, p=0.03) respectively.

202

203

204 **<u>Oxford Knee Score</u>**

205 The mean preoperative OKS for the cementless and cemented groups were 21.5 (SD 7.6)

206 and 22.0 (SD 7.7) with no significant differences in baseline characteristics (SMD=0.02) given

207 patients were matched on preoperative scores. Both groups showed statistically significant

208 improvements in their six month postoperative scores (p<0.001) to 39.1 (SD 8.7) and 38.5

209 (SD 8.6) respectively. The six month OKS was significantly higher in the cementless group

210 (p=0.001). The cementless group gained 17.6 points (SD 9.3) postoperatively whereas the

211 cemented group gained 16.5 points (SD 9.6) with the difference of 1.1 points being

212 statistically significant (p<0.001). The PoPC was 66.7% (SD 31.5) and 63.0% in the

213 cementless and cemented groups with this difference being significant (p<0.001).

214

215 Subgroup analyses of postoperative OKS and changes in OKS in surgeons of different

216 caseloads showed larger differences between fixation groups in higher surgeon volume

217 groups (Table 3). There were no significant differences (p=0.87) in changes in OKS

218 postoperatively between cementless and cemented groups in low caseload surgeons (<10

219 UKRs/yr). However there were significant differences of 0.9 (p=0.003) and 1.8 (p<0.001) in

220 medium (10 to <30 UKRs) and high (≥30 UKRs/yr) caseload surgeons (Table 3). Surgeons

221 with volumes ≥30 UKRs/yr had the highest postoperative OKS with values of 39.8 (SD 8.3)

222 and 38.2 (SD 9.2) for cementless and cemented groups with this difference being significant

223 (p<0.001). They also had the highest PoPC with values of 68.7% and 62.0% respectively with

224 significant differences between fixation groups (p<0.001) (Table 3).

225

226 The proportion of poor, fair, good and excellent scores showed no difference between

227 fixation groups preoperatively. Post operatively in the high caseload group (≥30 UKRs/yr)

228   there were significantly more excellent scores (55.5% vs 47.7%, p=0.04) and fewer poor

229   scores (8.5% vs 11.8%, p=0.01) in the cementless group compared to the cemented. No

230   differences were observed between fixation groups in the low (<10 UKRs/yr) and medium

231   (10 to <30 UKRs) caseload groups postoperatively (Table 4).

232

233   There were no significant differences in the post-operative pain or function components of

234   the OKS between fixation groups in the low or medium caseload surgeons. However in the

235   high caseload surgeons both the pain and function components of the OKS were significantly

236   higher in the cementless UKR group (Table 5).

237

238

239

240

241

242

243

244

245

246

247

248

249

250

251

252

253 **EQ-5D score**

254 The mean preoperative EQ-5D index for the cementless and cemented groups were 0.474

255 (SD 0.294) and 0.489 (SD 0.288) with no significant differences in baseline values

256 (SMD=0.06) given matching on preoperative scores. Both groups showed a statistically

257 significant improvement in their six month scores ($p<0.001$) to 0.808 (SD 0.231) and 0.799

258 (SD 0.232) respectively. Although the postoperative scores were not significantly different

259 ($p=0.06$), the cementless group gained 0.332 (SD 0.312) points postoperatively, which was

260 significantly ($p=0.004$) more than the 0.310 (SD 0.306) gained by the cemented group.

261 Subgroup analyses did not show significant differences in EQ-5D between fixation groups

262 with surgeon volumes <10 and 10-30 UKR/year. However, with surgeon volumes > 30 the

263 improvement in EQ-5D was significantly higher ($p=0.02$) with cementless than cemented

264 fixation (Table 6).

265

266

267

268

269

270

271

272

273

274

275

276

277

DISCUSSION

The early cementless UKR designs had poor clinical outcomes[30-33], but some newer designs have had improved outcomes[34-36]. Our study has shown for the first time that the cementless version of a UKR, the Oxford knee in this case, has both better implant survival and improved functional outcomes compared to its cemented version.

Our study found that implant survival was higher with the cementless implant at 10 years with a HR of 0.74 suggesting a 26% reduced risk of revision for the cementless UKR. This finding is consistent with a previous registry matched comparison of cemented and cementless UKR and with the New Zealand Joint Registry report[37]. The primary reason for this difference is that the rates of revision for aseptic loosening were much lower in the cementless group (0.3%) than the cemented group (1.1%). This demonstrated that for the Oxford knee cementless fixation is more reliable than cemented. A finding supported by randomised controlled trials[9, 38] which have shown a marked reduction in radiolucent lines with cementless fixation.

This study has shown that the postoperative OKS scores for cementless and cemented UKR are 39.1 and 38.5 with these differences being statistically significant. In addition the mean points gained after surgery were 17.6 and 16.5 points giving a mean difference of 1.1 points. Surgeons with volumes ≥30 UKRs/yr had higher postoperative OKS with values of 39.8 (SD 8.3) and 38.2 (SD 9.2) for the cementless and cemented UKR, with mean gains of 18.2 and 16.4 points after surgery giving a mean difference of 1.8 points. Although these differences are below the minimally clinically significant difference[39] they clearly show that functional outcomes in the cementless UKR are in fact better than the cemented version and that these differences are exaggerated in high caseload surgeons. Subgroup scale analysis of the

303   pain and functional components of the OKS confirmed this in the high caseload group. In

304   addition, for the high caseload surgeons the proportion of excellent scores (55.5% vs 47.7%)

305   was significantly higher for the cementless and the proportion of poor scores (8.5% vs

306   11.8%) was significantly lower.

307

308   A concern regarding cementless fixation is aseptic loosening, given there is no cement to

309   augment fixation. Early loosening is likely to present with pain and worse functional

310   outcomes. The exaggerated differences in high volume surgeons may relate to technical

311   challenges intraoperatively. The cementless version is less forgiving than the cemented

312   version relying on more accurate cuts given there is no cement to augment fixation. We

313   advise surgeons to avoid deep cuts, make the vertical cut is just medial to the tibial spine,

314   protect the posterior cortex, ensure the tibial trial can be inserted with finger pressure and

315   impact the tibial component with care and a light hammer. The Microplasty instrumentation

316   helps to achieve more accurate cuts and improve outcomes[22].

317

318   Our study found no significant difference in the postoperative EQ-5D scores between the

319   groups with mean values of 0.808 and 0.799 for the cementless and cemented groups. The

320   mean difference in index points gained was 0.022 which is below the MCID for the EQ-5D[40]

321   suggesting no real differences in overall quality of life between fixation groups. However

322   there could be other unaccounted confounders affecting quality of life such as mental

323   health.

324

325   When comparing both cementless and cemented UKR to TKR the functional and quality of

326   life results are superior. The mean OKS and EQ-5D for TKR reported from the similar

327 datasets[41, 42] are 36 and 0.750 respectively. Therefore for the OKS from our study the

328 cementless and cemented have higher scores by 3.1 and 1.5 points respectively. This

329 difference for the cementless UKR is above the MCID of the OKS[39] suggesting it clinically has

330 better functional outcomes than TKR. The EQ-5D is higher for both cementless and

331 cemented UKRs by 0.058 and 0.049 which is at the bottom end of the MCID for the EQ-5D[40]

332 which is believed to range between 0.03-0.54 points. This suggests superior functional

333 outcomes and quality of life for both cementless and cemented UKRs compared to TKR with

334 a larger difference when compared to the cementless version.

335

336 We believe that this is the first big data study which has shown using the same cohort that

337 both the implant and functional outcomes of the cementless Oxford UKR are superior to

338 cemented version. Our results may however relate to the design of the implant. As all

339 ligaments are preserved and there is an unconstrained mobile bearing the loads transmitted to

340 the bone implant interface are predominantly compressive with minimal shear or tension

341 which is ideal for cementless fixation. The results may therefore not apply to all types of

342 UKR and TKR. In fact big data studies suggest that cementless TKRs have worse functional

343 outcomes and higher revision rates than cemented TKRs[41, 43].

344

345 The main study limitation is that it is retrospective data from databases. Despite matching

346 there is potential for residual confounding and matching can reduce the generalisability of our

347 findings. There was a substantial proportion of BMI data missing so we did not match on

348 BMI. However, the BMI distribution between cemented and cementless UKR were the same

349 both before and after propensity matching. The only way to achieve perfect matching is with

350 a randomised trial. However to compare revision rates would require huge numbers and long

351 follow up which would be impractical; we believe propensity matching offers the next best

352 alternative.

353

354 In conclusion we found that the cementless UKR has improved ten-year implant survival and

355 postoperative functional outcomes compared to the cemented. This was primarily because the

356 risk of revision for aseptic loosening, significantly decreased in the cementless, suggesting

357 improved fixation. The effect size of superior functional outcomes for the cementless UKR

358 was largest in the high volume surgeon group.

359

360

361

362

363

364

365

366

367

368

369

370

371

372

373

374

375

	Unmatched			Matched		
	Cemented (n=8,774)	Cementless (n=5,777)	SMD	Cemented (n=3,453)	Cementless (n=3,453)	SMD
Covariate						
Age at surgery (yr)						
Mean (SD)	65.2 (SD 9.0)	66.0 (SD 9.0)	0.09	65.7 (SD 9.0)	65.8 (SD 8.9)	0.01
Gender						
Female	4,178 (47.6%)	2,437 (42.2%)	0.11	1,457 (42.2%)	1,485 (43.0%)	0.02
Male	4,596 (52.4%)	3,340 (57.8%)		1,996 (57.8%)	1,968 (57.0%)	
BMI (kg/m^2)*						
Mean (SD)	30.2 (SD 4.9, n=6,290)	30.3 (SD 5.0, n=5,013)	0.02	30.2 (SD 4.9, n=2,688)	30.4 (SD 4.9, n=2,961)	0.03
Primary diagnosis						
Primary OA	8,694 (99.1%)	5,716 (98.9%)	0.02	3,419 (99.0%)	3,415 (98.9%)	0.01
Other	80 (0.9%)	61 (1.1%)		34 (1.0%)	38 (1.1%)	
Surgical approach						
Medial parapatellar	8,014 (91.3%)	5,288 (91.5%)	0.007	3,194 (92.5%)	3,205 (92.8%)	0.01
Other	760 (8.7%)	489 (8.5%)		259 (7.5%)	248 (7.2%)	
ASA grade						
1	1,550 (17.7%)	1,028 (17.8%)	0.05	612 (17.7%)	589 (17.1%)	0.02
2	6,483 (73.9%)	4,179 (72.3%)		2,511 (72.7%)	2,526 (73.2%)	
3 or above	741 (8.5%)	570 (9.9%)		330 (9.6%)	338 (9.8%)	

Preoperative OKS	21.7 (SD 7.6)	21.5 (SD 7.6)	0.02	22.0 (SD 7.7)	21.5 (SD 7.6)	0.06
Preoperative EQ-5D	0.48 (SD 0.29)	0.48 (SD 0.29)	0.001	0.49 (SD 0.29)	0.47 (SD 0.29)	0.05
Year of surgery						
2009	808 (9.2%)	44 (0.8%)	1.13	41 (1.2%)	44 (1.3%)	0.08
2010	1073 (12.2%)	97 (1.7%)		91 (2.6%)	97 (2.8%)	
2011	1048 (11.9%)	154 (2.7%)		145 (4.2%)	152 (4.4%)	
2012	1142 (13.0%)	236 (4.1%)		241 (7.0%)	231 (6.7%)	
2013	999 (11.4%)	348 (6.0%)		316 (9.2%)	307 (8.9%)	
2014	1081 (12.3%)	610 (10.6%)		548 (15.9%)	486 (14.1%)	
2015	843 (9.6%)	789 (13.7%)		527 (15.3%)	553 (16.0%)	
2016	691 (7.9%)	1,122 (19.4%)		542 (15.7%)	630 (18.2%)	
2017	628 (7.2%)	1,195 (20.7%)		570 (16.5%)	526 (15.2%)	
2018	461 (5.3%)	1,182 (20.5%)		432 (12.5%)	427 (12.4%)	
Surgeon caseload <10 cases/year	2,735 (31.2%)	793 (13.7%)	0.54	674 (19.5%)	655 (19.0%)	0.01
10 to <30 cases/year	4,019 (45.8%)	2,434 (42.1%)		1,605 (46.5%)	1,616 (46.8%)	
≥30 cases/year	2,020 (23.0%)	2,550 (44.1%)		1,174 (34.0%)	1,182 (34.2%)	
Surgical approach						
Medial parapatellar	8,014 (91.3%)	5,288 (91.5%)	0.007	3,194 (92.5%)	3,205 (92.8%)	0.01
Other	760	489		259	248	

	(8.7%)	(8.5%)		(7.5%)	(7.2%)	
Minimally invasive surgery						
0	4,571 (52.1%)	3,122 (54.0%)	0.04	1,822 (52.8%)	1,851 (53.6%)	0.02
1	4,203 (47.9%)	2,655 (46.0%)		1,631 (47.2%)	1,602 (46.4%)	
Femoral component size						
Ex small	13 (0.1%)	25 (0.4%)	0.12	8 (0.2%)	10 (0.3%)	0.01
Small	2,051 (23.4%)	1,472 (25.5%)		815 (23.6%)	815 (23.6%)	
Medium	4,741 (54.0%)	2,821 (48.8%)		1,731 (50.1%)	1,730 (50.1%)	
Large	1,954 (22.3%)	1,443 (25.0%)		891 (25.8%)	891 (25.8%)	
Ex-Large	15 (0.2%)	16 (0.3%)		8 (0.2%)	7 (0.2%)	
Tibial component size						
AA	47 (0.5%)	31 (0.5%)	0.38	18 (0.5%)	21 (0.6%)	0.03
A	1053 (12.0%)	204 (3.5%)		165 (4.8%)	181 (5.2%)	
B	1980 (22.6%)	1,141 (19.8%)		741 (21.5%)	736 (21.3%)	
C	2,447 (27.9%)	1,666 (28.8%)		1,026 (29.7%)	993 (28.8%)	
D	2,087 (23.8%)	1,508 (26.1%)		890 (25.8%)	910 (26.4%)	
E	924 (10.5%)	916 (15.9%)		464 (13.4%)	466 (13.5%)	
F	236 (2.7%)	311 (5.4%)		149 (4.3%)	146 (4.2%)	

Bearing size						
3	1,995 (22.7%)	1,951 (33.8%)	0.35	1,025 (29.7%)	999 (28.9%)	0.02
4	3,514 (40.1%)	2,405 (41.6%)		1,444 (41.8%)	1,456 (42.2%)	
5	1,880 (21.4%)	1,004 (17.4%)		668 (19.3%)	674 (19.5%)	
6	826 (9.4%)	296 (5.1%)		211 (6.1%)	221 (6.4%)	
7	364 (4.1%)	78 (1.4%)		65 (1.9%)	65 (1.9%)	
8 and 9	195 (2.2%)	43 (0.7%)		40 (1.2%)	38 (1.1%)	

379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410

411 **Table 2. Reasons for revision in matched cohort.** Comparisons between the frequency of

412 revision indications were conducted using the Chi squared test. * refers to revision

413 indications that were statistically significantly different between cementless and cemented

414 implants. Abbreviations: OA (Osteoarthritis), UKR (Unicompartmental Knee Replacement).

415

Revision indication	Cemented UKRs (n=3,453)	Cementless UKRs (n=3,453)	P value
Aseptic loosening*	38 (1.1%)	12 (0.35%)	<0.001
OA progression*	43 (1.25%)	25 (0.72%)	0.03
Pain	24 (0.70%)	15 (0.43%)	0.15
Other	18 (0.52%)	15 (0.43%)	0.60
Dislocation subluxation revision	8 (0.23%)	10 (0.29%)	0.64
Instability	15 (0.43%)	11 (0.32%)	0.43
Component dissociation	8 (0.23%)	10 (0.29%)	0.64
Malalignment	4 (0.17%)	4 (0.12%)	1.0
Infection	6 (0.17%)	9 (0.26%)	0.44
Periprosthetic fracture	2 (0.06%)	8 (0.23%)	0.06
Lysis	4 (0.12%)	4 (0.12%)	1.0

Wear	7 (0.20%)	5 (0.14%)	0.56
Stiffness	4 (0.12%)	1 (0.03%)	0.18

416 **Table 3. Comparison of OKS in fixation groups across difference surgeon caseloads**

417

Surgeon caseload	Cementless post op score	Cemented post op score	P value	Cementless change in score	Cemented change in score	P value	PoPC Cementless	PoPC Cemented	P value
<10 UKRs/ yr	38.2 (SD 9.1)	38.3 (SD 8.9)	0.82	16.6 (SD 9.4)	16.4 (SD 9.6)	0.87	63.1% (SD 33.9)	62.4% (SD 34.3)	0.65
10-30 UKRs/yr	39.0 (SD 8.7)	38.9 (SD 8.7)	0.38	17.6 (SD 9.2)	16.7 (SD 9.6)	0.003	66.6% (SD 31.3)	64.0% (SD 35.3)	0.08
>30 UKRs/ yr	39.8 (SD 8.3)	38.2 (SD 9.2)	<0.001	18.2 (SD 9.5)	16.4 (SD 9.6)	<0.001	68.7% (SD 30.2)	62.0 (SD 47.7%)	<0.001

418

419

420

421

422

423 **Table 4. Proportion of OKS scores compared between fixation groups across different**

424 **caseloads**

Fixation	Cemented	Cementless	Comparison (P value)
Preoperative			
Poor	2,467 (71.5%)	2,563 (74.2%)	0.30
Fair	752 (21.8%)	681 (19.7%)	0.09
Good	220 (6.4%)	196 (5.7%)	0.25
Excellent	14 (0.4%)	13 (0.4%)	0.41
Postoperative (1) Overall, (2) Low caseload, (3) Medium caseload, (4) High caseload			
Poor	1) 371 (10.7%) 2) 70 (10.4%) 3) 162 (10.1%) 4) 139 (11.8%)	1) 350 (10.2%) 2) 83 (12.7%) 3) 167 (10.3%) 4) 100 (8.5%)	1) 0.46 2) 0.25 3) 0.84 4) 0.01
Fair	1) 408 (11.8%) 2) 75 (11.1%) 3) 195 (12.2%) 4) 138 (11.8%)	1) 345 (10.0%) 2) 66 (10.1%) 3) 170 (10.5%) 4) 109 (9.2%)	1) 0.03 2) 0.58 3) 0.19 4) 0.07
Good	1) 982 (28.4%) 2) 217 (32.2%) 3) 428 (26.7%) 4) 337 (28.7%)	1) 948 (27.5%) 2) 199 (30.4%) 3) 432 (26.7%) 4) 317 (26.8%)	1) 0.49 2) 0.61 3) 0.97 4) 0.41
Excellent	1) 1,692 (49.0%) 2) 312 (46.3%) 3) 820 (51.1%) 4) 560 (47.7%)	1) 1,810 (52.4%) 2) 307 (46.9%) 3) 847 (52.4%) 4) 656 (55.5%)	1) 0.01 2) 0.89 3) 0.67 4) 0.04

425

426

Table 5. Comparison of the pain and functional components of the OKS between fixation groups in different surgeon caseloads

429

Caseload group	Cemented 1) Pain 2) Function	Cementless 1) Pain 2) Function	Comparison (p value) 1) Pain 2) Function
Low	1) 79.5 (SD 20.5) 2) 80.1 (SD 17.7)	1) 79.8 (20.8) 2) 79.4 (SD 18.3)	1) 0.51 2) 0.71
Medium	1) 81.0 (SD 19.8) 2) 80.8 (SD 17.5)	1) 81.7 (SD 19.5) 2) 80.8 (SD 18.0)	1) 0.24 2) 0.78
High	1) 80.0 (SD 20.7) 2) 83.6 (SD 18.8)	1) 79.2 (SD 19.0) 2) 81.9 (SD 17.2)	1) <0.001 2) <0.001

430

431

Table 6. Comparison of EQ-5D in fixation groups across difference surgeon caseloads

433

Surgeon caseload	Cementless post op score	Cemented post op score	P value	Cementless change in score	Cemented change in score	P value
<10 UKRs/yr	0.789 (SD 0.230)	0.787 (SD 0.242)	0.86	0.315 (SD 0.312)	0.298 (SD 0.307)	0.25
10-30 UKRs/yr	0.812 (SD 0.227)	0.806 (SD 0.226)	0.36	0.339 (SD 0.312)	0.307 (SD 0.303)	0.008
>30 UKRs/yr	0.813 (SD 0.236)	0.797 (SD 0.235)	0.02	0.332 (SD 0.313)	0.321 (SD 0.309)	0.35

447

448

449

451 **Figure 1. Data cleaning flowchart**

452

453

454

455

456

457

458

459

460

461

462

463

464

465

466

467

468
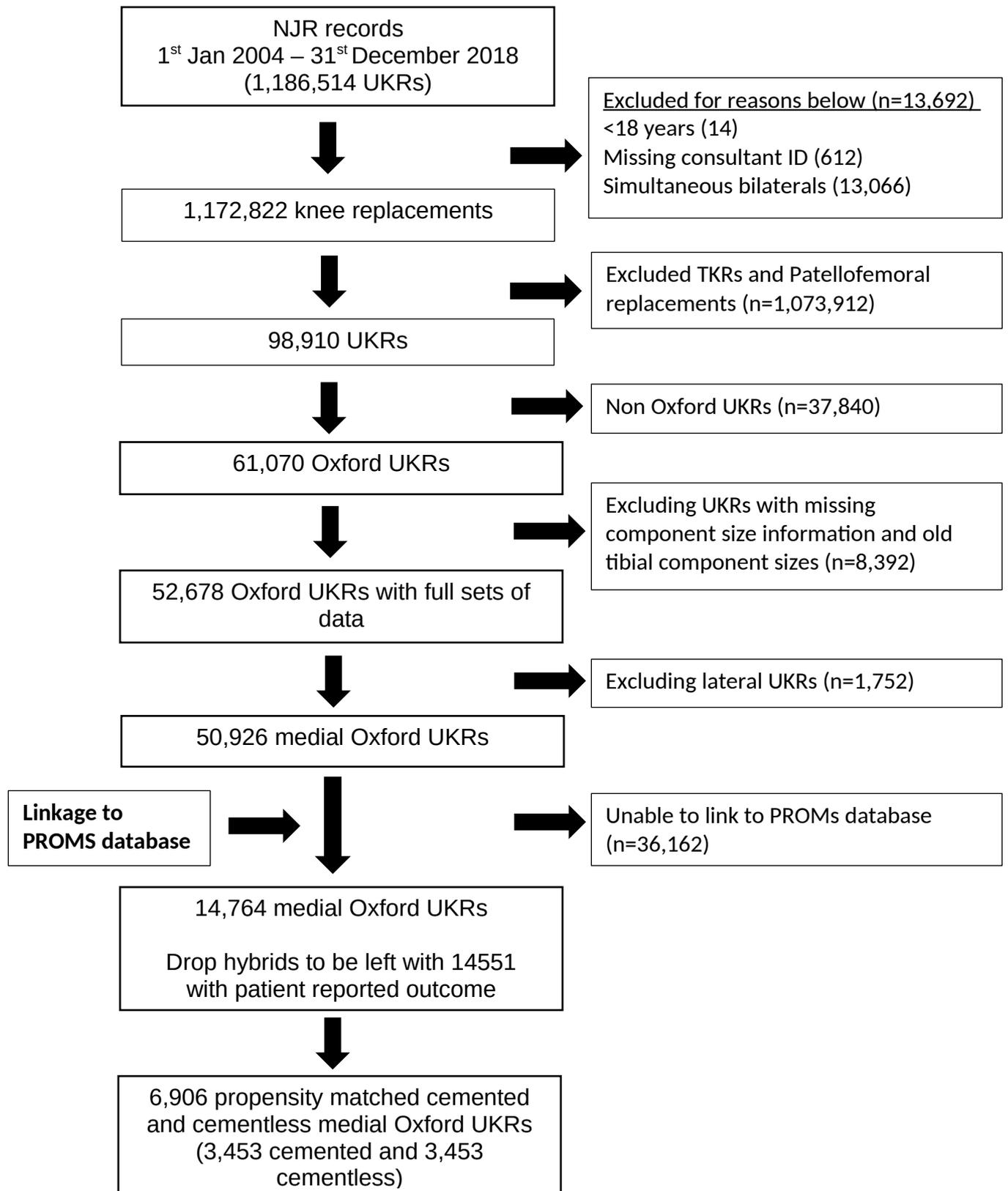
469

470

471

472


```
                 ┌─────────────────────────────┐
                 │        NJR records          │
                 │ 1st Jan 2004 – 31st December │
                 │      2018 (1,186,514 UKRs)   │
                 └─────────────────────────────┘
                              │          ┌──────────────────────────────────────┐
                              ▼ ────────►│ Excluded for reasons below (n=13,692)  │
                                         │ <18 years (14)                         │
                                         │ Missing consultant ID (612)            │
                                         │ Simultaneous bilaterals (13,066)       │
                 ┌─────────────────────────────┐
                 │ 1,172,822 knee replacements │
                 └─────────────────────────────┘
                              │          ┌──────────────────────────────────────┐
                              ▼ ────────►│ Excluded TKRs and Patellofemoral       │
                                         │ replacements (n=1,073,912)             │
                 ┌─────────────────────────────┐
                 │        98,910 UKRs          │
                 └─────────────────────────────┘
                              │          ┌──────────────────────────────────────┐
                              ▼ ────────►│ Non Oxford UKRs (n=37,840)             │
                 ┌─────────────────────────────┐
                 │      61,070 Oxford UKRs     │
                 └─────────────────────────────┘
                              │          ┌──────────────────────────────────────┐
                              ▼ ────────►│ Excluding UKRs with missing            │
                                         │ component size information and old     │
                                         │ tibial component sizes (n=8,392)       │
                 ┌─────────────────────────────┐
                 │ 52,678 Oxford UKRs with     │
                 │      full sets of data      │
                 └─────────────────────────────┘
                              │          ┌──────────────────────────────────────┐
                              ▼ ────────►│ Excluding lateral UKRs (n=1,752)       │
                 ┌─────────────────────────────┐
                 │   50,926 medial Oxford UKRs │
                 └─────────────────────────────┘
     ┌──────────────┐        │          ┌──────────────────────────────────────┐
     │ Linkage to   │───────►▼ ────────►│ Unable to link to PROMs database       │
     │ PROMS database│                  │ (n=36,162)                             │
     └──────────────┘        │
                 ┌─────────────────────────────┐
                 │  14,764 medial Oxford UKRs  │
                 │                             │
                 │ Drop hybrids to be left with│
                 │ 14551 with patient reported │
                 │         outcome             │
                 └─────────────────────────────┘
                              │
                              ▼
                 ┌─────────────────────────────┐
                 │ 6,906 propensity matched    │
                 │ cemented and cementless     │
                 │ medial Oxford UKRs          │
                 │ (3,453 cemented and 3,453   │
                 │ cementless)                 │
                 └─────────────────────────────┘
```

473

ACKNOWLEDGEMENTS

483

ETHICS, REGISTRATION, DATA SHARING PLAN, FUNDING AND POTENTIAL CONFLICTS OF INTEREST

490

AUTHOR CONTRIBUTIONS

HRM, AJ and DWM designed the study. HRM analysed the data with statistical support from

AJ. HRM, AJ, and DWM helped with data interpretation. HRM wrote the initial manuscript

draft which was then revised appropriately by all authors. All authors approved the final

submitted manuscript.

496

497

498

REFERENCES

500   1.   Liddle AD, Judge A, Pandit H, Murray DW. Adverse outcomes after total and
501   unicompartmental knee replacement in 101 330 matched patients: a study of data from the
502   National Joint Registry for England and Wales. The Lancet. 2014;384(9952):1437-45.
503   2.   Liddle A, Pandit H, Judge A, Murray D. Patient-reported outcomes after total and
504   unicompartmental knee arthroplasty: a study of 14 076 matched patients from the National
505   Joint Registry for England and Wales. Bone Joint J. 2015;97(6):793-801.
506   3.   Burn E, Liddle AD, Hamilton TW, Judge A, Pandit HG, Murray DW, et al. Cost-
507   effectiveness of unicompartmental compared with total knee replacement: a population-
508   based study using data from the National Joint Registry for England and Wales. BMJ Open.
509   2018;8(4):e020977.
510   4.   UK National Joint Registry. UK National Joint Registry 15th Annual Report. National
511   joint registry for England and Wales. [Accessed on 12/1/2019]. 2018.
512   5.   Australian Orthopaedic Association. Australian Orthopaedic Association National
513   Joint Replacement Registry (AOANJRR). Hip, Knee & Shoulder Arthroplasty. 2018.
514   6.   The New Zealand Joint Registry. Seventeen Year Report January 1999 to December
515   2015. New Zealand Joint Registry 2016.
516   7.   Pandit H, Jenkins C, Barker K, Dodd CA, Murray DW. The Oxford medial
517   unicompartmental knee replacement using a minimally-invasive approach. The Journal of
518   bone and joint surgery British volume. 2006 Jan;88(1):54-60. Epub 2005/12/21.
519   8.   Gulati A, Chau R, Pandit H, Gray H, Price A, Dodd C, et al. The incidence of
520   physiological radiolucency following Oxford unicompartmental knee replacement and its
521   relationship to outcome. Bone & Joint Journal. 2009;91(7):896-902.
522   9.   Pandit H, Liddle A, Kendrick B, Jenkins C, Price A, Gill H, et al. Improved fixation in
523   cementless unicompartmental knee replacement: five-year results of a randomized
524   controlled trial. JBJS. 2013;95(15):1365-72.
525   10.   Mohammad HR, Matharu GS, Judge A, Murray DW. Comparison of the 10-year
526   outcomes of cemented and cementless unicompartmental knee replacements: data from
527   the National Joint Registry for England, Wales, Northern Ireland and the Isle of Man. Acta
528   Orthop. 2020;91(1):76-81.
529   11.   Mohammad HR, Matharu GS, Judge A, Murray DW. The Effect of Surgeon Caseload
530   on the Relative Revision Rate of Cemented and Cementless Unicompartmental Knee
531   Replacements: An Analysis from the National Joint Registry for England, Wales, Northern
532   Ireland and the Isle of Man. J Bone Joint Surg Am. 2020 Jan 31. Epub 2020/02/01.
533   12.   Mohammad HR, Strickland L, Hamilton TW, Murray DW. Long-term outcomes of
534   over 8,000 medial Oxford Phase 3 Unicompartmental Knees—a systematic review. Acta
535   Orthopaedica. 2017:1-7.
536   13.   National Joint Registry. National Joint Registry 15th Annual Report. National joint
537   registry for England, Wales, Northern Ireland and Isle of Man. . 2018.
538   14.   Murray D, Fitzpatrick R, Rogers K, Pandit H, Beard D, Carr A, et al. The use of the
539   Oxford hip and knee scores. The Journal of bone and joint surgery British volume.
540   2007;89(8):1010-4.
541   15.   Group TE. EuroQol-a new facility for the measurement of health-related quality of
542   life. Health policy. 1990;16(3):199-208.

543   16.   Devlin NJ, Parkin D, Browne J. Patient-reported outcome measures in the NHS: new
544   methods for analysing and reporting EQ-5D data. Health economics. 2010;19(8):886-905.
545   17.   Pandit H, Jenkins C, Gill H, Barker K, Dodd C, Murray D. Minimally invasive Oxford
546   phase 3 unicompartmental knee replacement: results of 1000 cases. The Journal of bone
547   and joint surgery British volume. 2011;93(2):198-204.
548   18.   Williams D, Blakey C, Hadfield S, Murray D, Price A, Field R. Long-term trends in the
549   Oxford knee score following total knee replacement. The bone & joint journal.
550   2013;95(1):45-51.
551   19.   Breeman S, Campbell M, Dakin H, Fiddian N, Fitzpatrick R, Grant A, et al. Five-year
552   results of a randomised controlled trial comparing mobile and fixed bearings in total knee
553   replacement. The Bone & Joint Journal. 2013;95(4):486-92.
554   20.   Browne JP, Bastaki H, Dawson J. What is the optimal time point to assess patient-
555   reported recovery after hip and knee replacement? A systematic review and analysis of
556   routinely reported outcome data from the English patient-reported outcome measures
557   programme. Health and quality of life outcomes. 2013;11(1):128.
558   21.   Mohammad HR, Matharu GS, Judge A, Murray DW. A matched comparison of
559   revision rates of cemented Oxford Unicompartmental Knee Replacements with Single and
560   Twin Peg femoral components, based on data from the National Joint Registry for England,
561   Wales, Northern Ireland and the Isle of Man. Acta Orthop. 2020;(in press).
562   22.   Mohammad HR, Matharu GS, Judge A, Murray DW. New surgical instrumentation
563   reduces the revision rate of unicompartmental knee replacement: A propensity score
564   matched comparison of 15,906 knees from the National Joint Registry. Knee. 2020.
565   23.   Matharu GS, Judge A, Murray DW, Pandit HG. Trabecular metal acetabular
566   components reduce the risk of revision following primary total hip arthroplasty: A
567   propensity score matched study from the National Joint Registry for England and Wales. J
568   Arthroplasty. 2017.
569   24.   Matharu GS, Judge A, Murray DW, Pandit HG. Outcomes after metal-on-metal hip
570   revision surgery depend on the reason for failure: a propensity score-matched study. Clin
571   Orthop Relat Res. 2018;476(2):245-58.
572   25.   Liddle AD, Pandit H, Judge A, Murray DW. Effect of surgical caseload on revision rate
573   following total and unicompartmental knee replacement. J Bone Surg Am. 2016;98(1):1-8.
574   26.   Austin PC. Some methods of propensity-score matching had superior performance
575   to others: results of an empirical investigation and Monte Carlo simulations. Biometrical
576   Journal: Journal of Mathematical Methods in Biosciences. 2009;51(1):171-84.
577   27.   Austin PC. Balance diagnostics for comparing the distribution of baseline covariates
578   between treatment groups in propensity-score matched samples. Stat Med.
579   2009;28(25):3083-107.
580   28.   Abram SG, Marsh AG, Brydone AS, Nicol F, Mohammed A, Spencer SJ. The effect of
581   tibial component sizing on patient reported outcome measures following uncemented total
582   knee replacement. The knee. 2014;21(5):955-9.
583   29.   NHS Digital. Hospital Admitted Patient Care Activity 2019-20. NHS Digital Accessed
584   [4/10/2020]; 2020; Available from:
585   https://digital.nhs.uk/data-and-information/publications/statistical/hospital-admitted-
586   patient-care-activity/2019-20.
587   30.   Bernasek T, Rand J, Bryan R. Unicompartmental porous coated anatomic total knee
588   arthroplasty. Clinical orthopaedics related research. 1988 (236):52-9.

589 31.   Lindstrand A, Stenström A, Egund N. The PCA unicompartmental knee: a 1–4-year
590 comparison of fixation with or without cement. Acta Orthopaedica Scandinavica.
591 1988;59(6):695-700.
592 32.   Harilainen A, Sandelin J, Ylinen P, Vahvanen V. Revision of the PCA
593 unicompartmental knee: 52 arthrosis knees followed for 2–5 years. Acta orthopaedica
594 Scandinavica. 1993;64(4):428-30.
595 33.   Bergenudd H. Porous-coated anatomic unicompartmental knee arthroplasty in
596 osteoarthritis: a 3-to 9-year follow-up study. The Journal of arthroplasty. 1995;10:S8-S13.
597 34.   Epinette J-A, Manley M. Hydroxyapatite-coated total knee replacement: clinical
598 experience at 10 to 15 years. Bone Joint J. 2007;89(1):34-8.
599 35.   Fernandez-Fairen M, Hernández-Vaquero D, Murcia A, Torres A, Llopis R. Trabecular
600 metal in total knee arthroplasty associated with higher knee scores: a randomized
601 controlled trial. Clin Orthop Relat Res. 2013;471(11):3543-53.
602 36.   Mohammad HR, Kennedy JA, Mellon SJ, Judge A, Dodd CA, Murray DW. Ten-year
603 clinical and radiographic results of 1000 cementless Oxford unicompartmental knee
604 replacements. Knee Surgery, Sports Traumatology, Arthroscopy. 2020;28:1479-87.
605 37.   The New Zealand Joint Registry. Twenty Year Report January 1999 to December
606 2018. New Zealand Joint Registry 2019.
607 38.   Campi S, Kendrick B, Kaptein B, Valstar E, Jackson W, Dodd C, et al. Five-year results
608 of a randomised controlled trial comparing cemented and cementless Oxford
609 unicompartmental knee replacement using radiostereometric analysis. The Knee.
610 2021;28:383-90.
611 39.   Murray D, Fitzpatrick R, Rogers K, Pandit H, Beard D, Carr A, et al. The use of the
612 Oxford hip and knee scores. The Journal of Bone & Joint Surgery British Volume.
613 2007;89(8):1010-4.
614 40.   Coretti S, Ruggeri M, McNamee P. The minimum clinically important difference for
615 EQ-5D index: a critical review. Expert review of pharmacoeconomics & outcomes research.
616 2014;14(2):221-33.
617 41.   Mohammad HR, Judge A, Murray DW. A matched comparison of the patient-
618 reported outcome measures of cemented and cementless total knee replacements, based
619 on the National Joint Registry of England, Wales, Northern Ireland, and Isle of Man and
620 England's National PROM collection programme. Acta Orthopaedica. 2022;93:164.
621 42.   Mohammad HR, Judge A, Murray DW. A matched comparison of the patient-
622 reported outcome measures of 38,716 total and unicompartmental knee replacements: an
623 analysis of linked data from the National Joint Registry of England, Northern Ireland and Isle
624 of Man and England's National PROM collection programme. Acta Orthopaedica.
625 2021;92(6):701-8.
626 43.   Mohammad HR, Judge A, Murray DW. A matched comparison of the long-term
627 outcomes of cemented and cementless total knee replacements: an analysis from the
628 national joint registry of England, Wales, Northern Ireland and the Isle of Man. JBJS.
629 2021;103(24):2270-80.
630 44.   Wade DT. Ethics, audit, and research: all shades of grey. BMJ. 2005;330(7489):468-
631 71.
632