Mobile-bearing versus fixed-bearing total knee arthroplasty: a meta-analysis of randomized controlled trials.

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Abstract
Objective The purpose of this study was to perform a meta-analysis comparing mobile-bearing with fixed-bearing total knee arthroplasty (TKA) in terms of all-cause revision rates, aspetic loosening, knee functional scores, range of motion and radiographic lucent lines and osteolysis.

Methods PubMed, Cochrane Library, Google Scholar and Web of Science were searched up to January 2020. Randomized controlled trials that compared primary mobile-bearing with fixed-bearing TKA, reporting at least one of the outcomes of interest, at a minimum follow-up of 12 months were included. All outcomes of interest were pooled at short-term (< 5 years), mid-term (5 to 9 years) and long-term (> = 10 years) follow-up intervals.

Results A total of 70 eligible articles were included in the qualitative and statistical analyses. There was no difference between mobile-bearing or fixed-bearing TKA at short-term, mid-term and long-term follow-ups in all outcome measures including all-cause revision rate, aseptic loosening, oxford knee score, knee society score, Hospital for Special Surgery score, maximum knee flexion, radiographic lucent lines and radiographic osteolysis.

Conclusion The current level of evidence demonstrated that both mobile-bearing and fixed-bearing designs achieved excellent outcomes, yet it does not prove the theoretical advantages of the mobile-bearing insert over its fixed-bearing counterpart. The use of either design could therefore be supported based on the outcomes assessed in this study.
Level of Evidence: Level II, Therapeutic

Keywords Mobile · Fixed · Bearing · Total knee · Arthroplasty · Meta-analysis · Systematic review

Introduction
The design of the polyethylene insert has been debated numerously in the literature [22]. Fixed-bearing designs, which provide rigid fixation of the polyethylene insert within the tibial implant, have demonstrated satisfactory outcomes and long-term survival rates [1, 38, 45, 64]. However, implant loosening in fixed-bearing designs was theoretically attributed to higher contact stresses and polyethylene wear rates [20, 75], which motivated the pursuit of improved TKA designs. Mobile-bearing polyethylene designs were developed to mitigate the drawbacks of fixed-bearing TKA through improving the conformity, lowering contact stresses with the aim of mimicking the kinematics of the native knee [16]. However, these advantages are theoretical and yet to be fully proven in vivo. Furthermore, mobile-bearing TKA can introduce unique complications such as bearing dislocation [5].

Earlier meta-analyses have reported superior results with the mobile-bearing TKA [13, 85]. Subsequent meta-analysis with mid-term follow-up had refuted such findings without any significant difference between mobile-bearing and fixed-bearing TKA [55, 81]. However, in June 2020 two recent meta-analyses with a limited number of studies presented further contradicting results, with one meta-analysis supporting long-term clinical outcomes in favor of mobile bearing, whereas the other meta-analysis refuted such findings [15, 84]. Therefore, controversy continues to exist regarding the superiority of mobile-bearing over fixed-bearing designs.
This study aimed to provide an updated meta-analysis comparing mobile-bearing versus fixed-bearing TKA using a multi-modal method of outcomes to include overall revision rates, aseptic loosening, clinical as well as radiological outcomes. Our hypothesis was that no significant differences exist in all outcomes between the mobile-bearing and the fixed-bearing designs.

Materials and methods

This meta-analysis was conducted with adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [54]. The focus was randomized controlled trials that compared mobile-bearing with fixed-bearing TKA. The primary outcome was the all-cause revision rate. The secondary outcomes were aseptic loosening rates, knee functional scores, maximum knee flexion, radiographic lucent lines and osteolysis.

Eligibility criteria

The inclusion criteria were randomized controlled trials that compared primary mobile-bearing with fixed-bearing TKA, reporting at least one of the outcomes of interest, a minimum follow-up of 12 months. Exclusion criteria were inaccessible full-text, abstracts and studies reporting outcomes of interest but with unextractable data for meta-analytic comparisons. Articles published in English were only sought. Studies that reported the same sample population were not excluded if the follow-up intervals were different. The exclusion criteria were non-randomized clinical trials and studies with a population reported in a previous study with an overlapping follow-up interval.

Information sources and search strategy

PubMed, Cochrane Library, Google Scholar and Web of Science were searched till January 2020.

The search strategy involved the use of the following keywords that involved synonyms of “total knee arthroplasty” AND “mobile bearing” AND “fixed bearing” AND “randomized controlled trials.”

Studies were screened by titles and abstracts. A full-text review was performed if a study matched the eligibility criteria. Furthermore, the references of each eligible article were manually searched to ensure eligible studies were not missed. The search strategy was performed by three authors independently. Any disagreement between the three authors in the search strategy was resolved by the senior author.

Data collection process and data items

The data items that were collected included: the first author’s surname, study year, study location, age, sex, number of patients, type of prosthetic bearing used (mobile-bearing or fixed-bearing), the specific type of mobile-bearing prosthesis (rotating platform, rotating platform and gliding, and meniscal bearing), patella resurfacing, follow-up timepoints, all-cause revision rates, Oxford Knee Scores (OKS), Knee Society Scores (KSS), the Hospital for Special Surgery (HSS) knee scores, reported maximum knee flexion, radiographic radiolucent lines, radiographic osteolysis and rates of aseptic loosening. The OKS was transformed into the 0–48 scale to facilitate data synthesis. The Western Ontario and McMaster Universities Arthritis Index was not collected as it was reported variably among studies with the 0–96 Likert scores or the 0–100 visual analog scales. Data collection forms were used independently by three authors, with any arising disagreement in the collected data being resolved by the senior author.

Risk of bias in individual studies

The qualitative analysis was performed with the revised Cochrane risk-of-bias tool for randomized trials (RoB 2) [74]. The tool contains five domains that assesses the randomization, adherence to intended treatments, missing outcomes, measurement bias and reporting bias. Each study was assessed with the RoB 2 by three authors independently, and the final rating of each study was reviewed by the three authors and the senior author to arrive at a consensus.

Statistical analysis

Analysis was performed with the use of Stata/IC (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.). The outcomes were estimated with the use of 95% confidence interval (CI). The risk ratio (RR) was utilized for dichotomous outcomes such as the revision rates and the aseptic loosening rates. The mean difference (MD) was used for expressing continuous outcomes such as the OKS, the KSS and the HSS knee score. The Hedge’s G mean difference was used for maximum knee flexion due to potential variability in the range of motion measurements. The outcome measures of interest were pooled at three different follow-up intervals at short term (<5 years), mid-term (5 to 9 years) and long term (>=10 years). The meta-analytic models were based on random effects (RE) with the use of the DerSimonian-Laird method as a heterogeneity variance estimator [17]. The formulas developed by Hozo et al.[31]
were used in studies that reported medians instead of means and ranges instead of standard deviations (SD).

**Results**

**Study selection**

The search strategy resulted in 581 (569 articles from database search and 12 articles from manual references search) articles, of which 409 articles were excluded due to duplications. Subsequently, a total of 172 articles were screened by titles and abstracts, of which 67 articles were excluded. This resulted in a total of 105 articles that were eligible for full-text reviews, of which 35 articles were excluded. Thus, a total of 70 articles were included in the qualitative and statistical analyses. The PRISMA flowchart is displayed in Fig. 1.

**Study characteristics**

Among the 70 included studies, 4968 patients underwent mobile-bearing TKA and 5034 patients underwent fixed-bearing TKA. The most utilized TKA implant was PFC Sigma® (DePuy) in 34.3% of all studies. A posterior-stabilized (PS) implant was routinely used in 60% of studies, whereas a cruciate-retaining (CR) design was routinely used in 25.7%. The rest of the studies used either CR or PS designs (4.3%) depending on the total knee system utilized, and 10% of studies did not specify whether the posterior cruciate ligament was sacrificed. The mobile-bearing designs used were a rotating platform in 81.4%, rotating and anterior–posterior gliding in 11.4% and meniscal bearing in 2.86%. Patella resurfacing was performed routinely in 48.57% of studies, unresurfaced in 22.86% and selectively resurfaced on a case-by-case basis in 17.14%. Study characteristics are summarized in Table 1.
| Study                  | Country      | LoE  | Group | Knees (N) | Age   | Females (%) | TKA design                  | MB type | Cruciate design | Patella resurfacing | Follow-up |
|-----------------------|--------------|------|-------|-----------|-------|-------------|------------------------------|---------|-----------------|---------------------|-----------|
| Killen, 2019[36]      | USA          | Level I | MB    | 30        | 76.57 | 66.6%       | PFC Sigma; DePuy             | RP      | CR or PS        | All resurfaced      | 13.95     |
| Tiwari 2019[78]       | South Korea  | Level I | MB    | 260       | 69.7  | 94.6%       | E. Motion PS-Pro; B.Braun-Aesculap | RP      | PS              | All resurfaced      | 2         |
| Sappey-Marinier 2019[70] | France     | Level I | MB    | 65        | 71    | 58.7%       | HLS Noetos knee prosthesis; Torner  | RP      | PS              | All resurfaced      | 7.4       |
| Park 2019[62]         | South Korea  | Level II | MB   | 70        | 69.5  | 94.2%       | ACS; Implantcast              | -       | PS              | All resurfaced      | 4         |
| Kim 2019[39]          | South Korea  | Level I  | MB    | 164       | 63    | 86.5%       | NexGen LPS-Flex; Zimmer        | RP      | PS              | All resurfaced      | 17        |
| Kim 2018[43]          | South Korea  | Level I  | MB    | 92        | 61.5  | 81.5%       | NexGen LPS-Flex; Zimmer        | RP      | PS              | All resurfaced      | 12        |
| Van Hamersveld 2018[82] | Netherlands | Level II | MB   | 23        | 67.5  | 76.1%       | Triathlon; Stryker             | RP      | PS              | None                | 6         |
| Powell 2018[64]       | New Zealand  | Level I  | MB    | 91        | 65.5  | 43.7%       | PFC Sigma; DePuy              | RP      | CR              | At surgeon’s discretion | 14        |
| Chaudhry 2018[14]     | India        | Level II | MB    | 50        | 58.7  | 54.5%       | PFC Sigma; DePuy              | RP      | PS              | At surgeon’s discretion | 6–8       |
| Abdel 2018[1]         | USA          | Level I  | MB    | 55        | 67.4  | 65.6%       | PFC Sigma; DePuy              | RP      | PS              | All resurfaced      | 10        |
| Amaro 2017[3]         | Brazil       | Level I  | MB    | 32        | 65.2  | 71.9%       | NR                            | RP      | PS              | None                | 2         |
| Feczko 2017[18]       | Netherlands  | Level II | MB    | 42        | 66.2  | NR          | Scorpio; Stryker              | RP      | PS              | All resurfaced      | 5         |
| Schotanus 2017[71]    | Netherlands  | Level I  | MB    | 20        | 61.9  | 41.4%       | Vanguard; Zimmer Biomet        | RP      | NR              | NR                  | 3         |
| Baktir 2016[7]        | Turkey       | Level I  | MB    | 47        | 64.9  | 88.2%       | TC-PLUS; Smith & Nephew        | RP      | CR              | None                | 8         |
| Artz 2015[4]          | UK           | Level II | MB    | 104       | 61.7  | 51%         | Rotaglide; Corin              | RP + AP gliding | NR              | NR                  | 2         |
| Minoda 2015[53]       | Japan        | Level I  | MB    | 46        | 74.3  | 88.3%       | Vanguard; Zimmer Biomet        | RP      | PS              | NR                  | 2         |
| Van De Groes 2015[80] | Netherlands  | Level II | MB    | 24        | 66.5  | 49%         | PFC Sigma; DePuy              | RP      | PS              | None                | 1.2       |
| Study          | Country       | LoE       | Group | Knees (N) | Age  | Females (%) | TKA design                      | MB type            | Cruciate design | Patella resurfacing | Follow-up |
|---------------|--------------|-----------|-------|-----------|------|-------------|---------------------------------|--------------------|-----------------|-------------------|-----------|
| Fransen 2015  | Netherlands  | Level I   | MB    | 114       | 65.7 | 69.6%       | Genesis II; Smith & Nephew      | RP or RT/AP gliding | CR              | At surgeons discretion | 5         |
|                |              |           | FB    | 123       | 65.8 |             |                                 |                    |                 |                   |           |
| Tjørnild 2015  | Denmark      | Level II  | MB    | 27        | 66   | 54%         | PFC Sigma; DePuy                | RP                 | CR              | All resurfaced    | 2         |
|                |              |           | FB    | 28        |      |             |                                 |                    |                 |                   |           |
| Marques 2015   | Germany      | Level I   | MB    | 48        | 69.4 | 73%         | Columbus, BBraun Aesculap       | RP                 | CR              | None              | 4         |
|                |              |           | FB    | 52        | 68.9 |             |                                 |                    |                 |                   |           |
| Bailey 2015    | UK           | Level I   | MB    | 161       | 69.2 | 57.1%       | PFC Sigma; DePuy                | RP                 | CR              | At surgeons discretion | 2         |
|                |              |           | FB    | 170       | 70.1 |             |                                 |                    |                 |                   |           |
| Okamoto 2014   | Japan        | Level I   | MB    | 20        | 76   | 85%         | NexGen LPS-Flex; Zimmer         | RP                 | PS              | None              | 1         |
|                |              |           | FB    | 20        | 78   |             |                                 |                    |                 |                   |           |
| Breugem 2014   | Netherlands  | Level II  | MB    | 29        | 78   | 65.2%       | NexGen Legacy; Zimmer           | RP                 | PS              | All resurfaced    | 7.9       |
|                |              |           | FB    | 40        | 80   |             |                                 |                    |                 |                   |           |
| Ferguson 2014  | UK           | Level II  | MB    | 176       | 70.2 | 53.1%       | PFC Sigma; DePuy                | RP                 | PS              | At surgeons discretion | 2         |
|                |              |           | FB    | 176       | 69.8 |             |                                 |                    |                 |                   |           |
| Breeman 2013   | UK           | Level II  | MB    | 276       | 69   | 60.1%       | Non-specific                    | Non-specific        | CR              | At surgeons discretion | 5         |
|                |              |           | FB    | 263       |      |             |                                 |                    |                 |                   |           |
| Nieuwenhuijse  | Netherlands  | Level I   | MB    | 37        | 66.8–68.7 | 80.8% | NexGen LPS-Flex/ LPS; Zimmer | RP                 | PS              | At Surgeons discretion | 5         |
| 2013[58]       |              |           | FB    | 41        | 68.5–72.2 |             |                                 |                    |                 |                   |           |
| Prasad 2013    | India        | Level II  | MB    | 16        | 63.75 | 62.5%       | Exactech; Optettek              | RP                 | PS              | None              | 1         |
|                |              |           | FB    | 16        | 63.68 |             |                                 |                    |                 |                   |           |
| Radetzki 2013  | Germany      | Level II  | MB    | 17        | 66.5 | 53.8%       | NexGen LPS-Flex; Zimmer         | RP                 | PS              | All resurfaced    | 10.8      |
|                |              |           | FB    | 22        | 65.6 |             |                                 |                    |                 |                   |           |
| Kim 2012       | South Korea  | Level I   | MB    | 108       | 45   | 76.9%       | LCS; DePuy                      | RP                 | PS              | All resurfaced    | 16.8      |
|                |              |           | FB    | 108       |      |             |                                 |                    |                 |                   |           |
| Scuderi 2012   | USA & Canada | Level I   | MB    | 152       | 63.7 | 58.4%       | NexGen LPS-Flex; Zimmer         | RP                 | PS              | All resurfaced    | 4         |
|                |              |           | FB    | 141       | 63.4 |             |                                 |                    |                 |                   |           |
| Pijls 2012     | Netherlands  | Level II  | MB    | 21        | 64   | 81%         | Interax; Stryker                | RP + AP gliding    | PS              | NR                | 10–12      |
|                |              |           | FB    | 21        | 66   |             |                                 |                    |                 |                   |           |
| Nutton 2012    | UK           | Level I   | MB    | 36        | 68.3 | 51.3%       | PFC Sigma; DePuy                | RP                 | PS              | None              | 1         |
|                |              |           | FB    | 40        | 69.8 |             |                                 |                    |                 |                   |           |
| Mahoney 2012   | USA          | Level II  | MB    | 252       | 66   | 63.9%       | Scorpio – Stryker               | RP                 | PS              | All resurfaced    | 2         |
|                |              |           | FB    | 255       |      |             |                                 |                    |                 |                   |           |
| Jolles 2012    | Switzerland  | Level I   | MB    | 26        | 67.1 | 58%         | NexGen LPS-Flex; Zimmer         | RP                 | PS              | All resurfaced    | 2         |
|                |              |           | FB    | 29        | 70.2 |             |                                 |                    |                 |                   |           |
| Study          | Country      | LoE  | Group | Knees (N) | Age  | Females (%) | TKA design                  | MB type | Cruciate design | Patella resurfacing | Follow-up |
|---------------|--------------|------|-------|-----------|------|-------------|------------------------------|---------|----------------|---------------------|-----------|
| Lizaur-Utrilla 2012 [49] | Spain        | Level I | MB    | 61       | 74.6 | 79%         | Trekking; Samo               | RP      | CR             | At surgeons discretion | 2         |
|                |              |       | FB    | 58       | 73.9 |             | Multigen Plus; Lima          |         |                |                      |           |
| Tienboon 2012 [77] | Thailand     | Level II | MB   | 100      | 69.9 | 85.5%       | PFC Sigma; DePuy             | RP      | NR             | All resurfaced       | 2         |
|                |              |       | FB    | 100      | 68.4 |             |                              |         |                |                      |           |
| Wolterbeek 2012 [87] | Netherlands  | Level I | MB    | 9        | 63   | 65%         | Triathlon; Stryker           | RP      | PS             | None                | 1         |
|                |              |       | FB    | 11       | 66   |             |                              |         |                |                      |           |
| Kalisvaart 2012 [35] | USA          | Level I | MB    | 76       | 67.4 | 70%         | PFC Sigma; DePuy             | RP      | PS             | All resurfaced       | 5         |
|                |              |       | FB    | 76       | 67.1 |             |                              |         |                |                      |           |
| Kim 2012 [37] | South Korea | Level II | MB   | 40       | 68   | 96.3%       | PFC Sigma; DePuy             | RP      | PS             | NR                  | 2.5       |
|                |              |       | FB    | 40       | 66   |             | NexGen LPS; Zimmer           |         |                |                      |           |
| Shemshaki 2012 [73] | Iran         | Level I | MB    | 150      | 68   | 64%         | PFC Sigma; DePuy             | RP      | PS             | All resurfaced       | 5         |
|                |              |       | FB    | 150      | 70   |             |                              |         |                |                      |           |
| Jacobs 2011 [33] | Netherlands  | Level I | MB    | 46       | 67.6 | 70.7%       | BalanSys; Mathys Medical      | RP      | CR             | None                | 1         |
|                |              |       | FB    | 46       | 66.7 |             |                              |         |                |                      |           |
| Tibesku 2011 [76] | Germany      | Level II | MB   | 16       | 65   | 63.6%       | Genesis II; Smith & Nephew   | RP      | CR             | None                | 2         |
|                |              |       | FB    | 17       | 66   |             |                              |         |                |                      |           |
| Lampe 2011 [47] | Germany      | Level I | MB    | 48       | 70   | 73%         | Columbus; B.Braun-Aesculap   | RP      | CR             | None                | 1         |
|                |              |       | FB    | 52       | 69   |             |                              |         |                |                      |           |
| Woolson 2011 [88] | USA          | Level I | MB    | 33       | 78   | NR          | LCS; DePuy                   | RP      | PS             | All resurfaced       | 11.5      |
|                |              |       | FB    | 30       | 77.9 |             | NexGen; Zimmer               |         |                |                      |           |
| Ball 2011 [8]  | USA          | Level I | MB    | 51       | 64.9 | 56.0%       | Scorpio; Stryker             | RP      | PS             | NR                  | 4         |
|                |              |       | FB    | 42       | 64   |             |                              |         |                |                      |           |
| Rahman 2010 [68] | Canada       | Level I | MB    | 24       | 62.6 | 62.7%       | PFC Sigma; DePuy             | RP      | PS             | At surgeons discretion | 3.5       |
|                |              |       | FB    | 27       | 62   |             |                              |         |                |                      |           |
| Munro 2010 [56] | New Zealand  | Level I | MB    | 25       | 67.2 | 43.75%      | PFC Sigma; DePuy             | RP      | NR             | At surgeons discretion | 2         |
|                |              |       | FB    | 23       | 67.7 |             |                              |         |                |                      |           |
| Hanusch 2010 [25] | UK           | Level I | MB    | 50       | 70   | 49.5%       | PFC Sigma; DePuy             | RP      | CR             | None                | 1.1       |
|                |              |       | FB    | 55       | 69.4 |             |                              |         |                |                      |           |
| Matsuda 2010 [52] | Japan        | Level I | MB    | 30       | 73   | 77.0%       | NexGen LPS; Zimmer           | RP      | PS             | All resurfaced       | 5.7       |
|                |              |       | FB    | 31       | 76   |             |                              |         |                |                      |           |
| Gioe 2009 [24] | USA          | Level I | MB    | 176      | 71.8 | 2.8%        | PFC Sigma; DePuy             | RP      | PS             | All resurfaced       | 3.5       |
|                |              |       | FB    | 136      | 72.62|             |                              |         |                |                      |           |
| Study          | Country     | LoE | Group | Knees (N) | Age  | Females (%) | TKA design          | MB type | Cruciate design | Patella resurfacing | Follow-up |
|---------------|-------------|-----|-------|-----------|------|-------------|---------------------|---------|-----------------|---------------------|-----------|
| Kim 2009[44]  | South Korea | Level I | MB   | 92       | 69.5 | 92.4%       | PFC Sigma; DePuy DeMed Artic | RP      | CR              | All resurfaced       | 2.6       |
|               |             |       | FB    | 92       |      |             | Advance medial pivot; Wright Medical |         |                 |                      |           |
| Kim 2009[41]  | South Korea | Level I | MB   | 61       | 48.3 | 73.8%       | LCS; DePuy MeBe | MeBe    | CR              | All resurfaced       | 10.8      |
| Vasdev 2009[83] | India     | Level I | MB   | 60       | 63   | 58.3%       | LCS; DePuy RP | RP      | NR              | None                | 3.5       |
|               |             |       | FB    | 60       |      |             | NexGen LPS; Zimmer |         |                 |                      |           |
| Wohlrab 2009[86] | Germany   | Level I | MB   | 30       | 65.5 | 56.7%       | NexGen; Zimmer RP | PS      | CR              | All resurfaced       | 5         |
|               |             |       | FB    | 30       |      |             |                    |         |                 |                      |           |
| Harrington 2009[26] | USA    | Level II | MB  | 68      | 63.7 | 64.3%       | PFC Sigma; DePuy RP | CR or PS | All resurfaced       | 2         |
|               |             |       | FB    | 72      | 63.3 |             |                    |         |                 |                      |           |
| Hasegawa 2009[27] | Japan    | Level I | MB   | 25      | 73   | 88%         | PFC Sigma; DePuy RP | PS      | All resurfaced       | 3.3       |
|               |             |       | FB    | 25      |      |             |                    |         |                 |                      |           |
| Higuchi 2009[30] | Japan     | Level II | MB  | 31      | 68.4 | 72.1%       | PFC Sigma; DePuy RP | CR      | NR              | 4         |
|               |             |       | FB    | 45      |      |             |                    |         |                 |           |
| Lädermann 2008[46] | Switzerland | Level I | MB  | 52      | 72   | 67.3%       | PFC Sigma; DePuy RP | PS      | All resurfaced       | 7.1       |
|               |             |       | FB    | 52      | 69.8 |             |                    |         |                 |           |
| Wylde 2008[89] | UK          | Level I | MB   | 118     | 68.9 | 54.5%       | Kinemax Plus; Stryker | -       | CR              | At surgeons discretion | 2         |
|               |             |       | FB    | 132     | 67.6 |             |                    |         |                 |                      |           |
| Breugem 2008[11] | Netherlands | Level I | MB  | 48      | 71.2 | 64.1%       | NexGen LPS; Zimmer RP | PS      | All resurfaced       | 1         |
|               |             |       | FB    | 55      | 68.9 |             |                    |         |                 |           |
| Kim 2007[45]  | South Korea | Level I | MB   | 146     | 69.8 | 94.5%       | LCS; DePuy AMK; DePuy CR | CR      | All resurfaced       | 13.2      |
|               |             |       | FB    | 146     |      |             |                    |         |                 |           |
| Kim 2007[40]  | South Korea | Level I | MB   | 174     | 67   | 64.4%       | PFC Sigma; DePuy PFC Sigma; DePuy | RP      | CR              | All resurfaced       | 5.6       |
|               |             |       | FB    | 174     |      |             |                    |         |                 |           |
| Henrikson 2006[29] | Sweden  | Level I | MB   | 26      | 72   | 62.5%       | MBK; Zimmer NexGen LPS; Zimmer | RP + AP gliding | CR | At surgeons discretion | 2         |
|               |             |       | FB    | 26      |      |             |                    |         |                 |           |
| Garling 2005[23] | Netherlands | Level II | MB  | 21      | 66   | 63.6%       | Interax; Stryker RP + AP gliding | PS      | All resurfaced       | 2         |
|               |             |       | FB    | 21      |      |             |                    |         |                 |           |
| Aglietti 2005[2] | Italy      | Level II | MB  | 103     | 71   | 83.8%       | MBK; Zimmer NexGen LPS; Zimmer | RP + AP gliding | CR | All resurfaced       | 3         |
|               |             |       | FB    | 107     | 69.5 |             |                    |         |                 |           |
| Bhan 2005[9]  | India       | Level I | MB   | 16      | 63   | 68.8%       | LCS; DePuy Columbus; Zimmer | RP      | PS              | None        | 6         |
|               |             |       | FB    | 16      |      |             |                    |         |                 |           |
Quality assessment

Low risk of bias was found in 27 studies, some concern for bias in 28 studies and high risk of bias in the remaining 15 studies. Most studies had a low risk of bias for deviation from intended interventions, missing outcome data, measurement of outcomes and in the selection of reported results. In terms of randomization, 55.7% of included studies had a low risk of bias, 38.5% had some concern for bias, and 5.7% had a high risk for bias. A graphic summary of the qualitative assessment is displayed in Supplementary Fig. 1.

Revision Rates

Revisions were reported in 58 studies, with 2.4% (96 out of 3978) revision rates in mobile-bearing TKA and 2.2% (88 out of 3947) revision rate in fixed-bearing TKA. The all-cause revision rates were not statistically significant when comparing mobile-bearing versus fixed-bearing TKA at short-term (RR 1.06; 95% CI 0.7, 1.58; P = 0.793; I² = 0%), mid-term (RR 1.39; 95% CI 0.84, 2.29; P = 0.197; I² = 0%) and long-term (RR 0.78; 95% CI 0.45, 1.34; P = 0.361; I² = 0%) follow-up intervals. Likewise, among 5 studies there was no significant difference in aseptic loosening at the three follow-up intervals (Fig. 2).

Functional Scores

Eleven and 3 studies reported the OKS at short and mid-term, respectively. There was no significant difference between mobile-bearing and fixed-bearing TKA at both short term (MD 0.04; 95% CI −0.78, 0.86; P = 0.926; I² = 0%) and mid-term (MD 0.94; 95% CI −2.14, 4.02; P = 0.551; I² = 88.9%) follow-up intervals. Likewise, among 5 studies there was no significant difference in the KSS knee sub-score. The long-term follow-up demonstrated statistically significant better KSS knee sub-score in favor of fixed-bearing TKA (MD −1.21; 95% CI −2.06, −0.37; P = 0.005; I² = 0.39%).

The KSS knee and function sub-scores were reported in 24 studies at short-term, 14 studies at mid-term and 8 studies at long-term follow-up. There was no statistically significant difference between mobile-bearing and fixed-bearing TKA at short-term (MD 0.36; 95% CI −1.06, 1.78; P = 0.619; I² = 87.89%) and mid-term (MD 0.94; 95% CI −2.14, 4.02; P = 0.551; I² = 88.9%) follow-up intervals (Fig. 3).

The HSS knee score was reported in 8 studies at short term, 3 studies at mid-term and 3 studies at long term. The
short-term follow-up comparison demonstrated slightly better HSS scores in favor of mobile-bearing TKA (MD 2.92; 95% CI 0.06, 5.78; P = 0.045; \( I^2 = 77.88\% \)). The mid-term (MD -0.84; 95% CI -2.18, 0.51; P = 0.223; \( I^2 = 0\% \)) and long-term (MD -0.48; 95% CI -2.9, 1.95; P = 0.7; \( I^2 = 79.88\% \)) follow-up intervals did not demonstrate any statistically significant difference for the HSS knee scores (Fig. 3).

The range of motion was reported in 27 studies at short term, 12 studies at mid-term and 6 studies at long term. No differences were significant between mobile-bearing and fixed-bearing TKA at any of the three follow-up intervals (Fig. 4).

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**Fig. 2** Random-effect meta-analytic comparison for all-cause revision and aseptic loosening between mobile-bearing versus fixed-bearing total knee arthroplasty. CI: confidence interval

**Fig. 3** Random-effect meta-analytic comparison for functional knee scores between mobile-bearing versus fixed-bearing total knee arthroplasty. CI: confidence interval
Radiographic outcomes

Radiolucent lines were pooled in 14 studies at short-term, 11 studies at mid-term and 9 studies at long-term follow-up intervals. There was no statistically significant difference at short-term (RR 1.17; 95% CI 0.99, 1.4; P = 0.072; I² = 0%), mid-term (RR 0.95; 95% CI 0.76, 1.17; P = 0.615; I² = 0%) or long-term (RR 0.9; 95% CI 0.62, 1.31; P = 0.588; I² = 27.87%) intervals between mobile-bearing and fixed-bearing TKA (Fig. 5).

Osteolysis was pooled in 14 studies at short-term, 10 studies at mid-term and 8 studies at long-term follow-up intervals. Meta-analytic comparison of mobile-bearing TKA with fixed-bearing TKA failed to demonstrate any statistically significant difference at short-term (RR 0.76; 95% CI 0.28, 2.08; P = 0.592; I² = 0%), mid-term (RR 0.76; 95% CI 0.23, 2.49; P = 0.647; I² = 0%) and long-term intervals (RR 0.83; 95% CI 0.35, 1.97; P = 0.675; I² = 0%) (Fig. 5).

Discussion

This meta-analysis on randomized controlled trials demonstrated no significant difference between mobile-bearing and fixed-bearing TKA with regard to all outcome measures compared. The revision rates among studies throughout all follow-up intervals were 2.4% in mobile-bearing TKA and 2.2% in fixed-bearing TKA. Furthermore, this meta-analysis did not result in statistically significant differences in revision rates or aseptic loosening between both designs at short-term, mid-term and long-term follow-up intervals. The long-term follow-up interval ranged from 10 to 17 years postoperatively in 12 studies for revision rates and 11 studies for aseptic loosening. Likewise, previous meta-analyses and the vast majority of included randomized trials found similar survivorship when comparing mobile-bearing and fixed-bearing TKA [55, 81]. In contrast, few non-randomized studies have found contradicting evidence. A registry-based prospective study by Namba et al. [57] on 47,339 knees found that mobile-bearing TKA had a twofold increase in...
aesthetic revision at 6.7 years when compared to fixed-bearing TKA following a multi-variate adjusted regression analysis (P < 0.001). Likewise, Heesterbeek et al. [28] found in a recent multicenter retrospective study that fixed-bearing had superior survivorship at 12 years as opposed to mobile-bearing designs. In a randomized trial by Fransen et al. [21], mobile-bearing TKA was found to have a 6-times higher risk for all-cause revision compared to fixed-bearing TKA at 5-year follow-up. This study had major limitations such as a 38% drop-out rate and lack of blinding of those who assessed outcomes.

Assessment of knee functional outcomes demonstrated no clinically significant differences between mobile-bearing and fixed-bearing TKAs. The OKS was only pooled at the short- and the mid-term follow-up intervals without any statistical significance. The KSS knee sub-score was not statistically significant at the short- and the mid-term follow-up intervals; however, at the long-term there was a statistically significant effect in favor of fixed-bearing TKA. It is paramount to acknowledge that this finding was not clinically significant as the minimal clinically important difference (MCID) of the KSS knee sub-score is between 5.3 and 5.9 points [48]. The KSS functional sub-score was statistically insignificant at short-, mid- and long-term follow-ups. The HSS knee score was in favor of mobile-bearing TKA at the short-term follow-up which was statistically significant, however, yet clinically irrelevant as the HSS MCID is 8.29 points [32]. The mid- and the long-term follow-up for the HSS knee score had no statistically significant difference between mobile-bearing and fixed-bearing TKA. Furthermore, there was no statistically significant difference between mobile-bearing and fixed-bearing TKA for the post-operative maximum knee flexion. Most prior meta-analyses and randomized trials have shown similar results without any statistical difference in clinical outcomes. Nonetheless, several studies have had better outcomes with mobile-bearing TKA. At 6–10-year follow-up, the randomized trial Baktir et al. [7] resulted in significantly improved pain and KSS knee sub-scores in mobile-bearing TKA. However, the authors found no difference in the functional sub-score of the KSS. In a recent randomized trial by Powell et al. [64], mobile-bearing TKA had superior results with the OKS and the Knee Injury and Osteoarthritis Outcome Score sports and quality of life subscales. This difference was observed at 10-year follow-up which exceeded the MCID threshold. In contrast, a similarly well-designed trial by Abdel et al. [1] refuted such findings without any advantages provided by the mobile-bearing design over fixed-bearing TKA in terms of maximum knee flexion or function at 10-year follow-up.

In terms of radiological outcomes, no significant differences were detected between both mobile-bearing and fixed-bearing TKA at the short-, mid- and long-term follow-up intervals for either radiolucent lines or osteolysis. In all randomized trials included except for the study by Bailey et al. [6], there was no statistical difference between mobile-bearing and fixed-bearing designs in radiological outcomes. Bailey et al. [6] have reported that radiolucency was higher in the mobile-bearing designs around the tibial component; however, this was clinically insignificant. Furthermore, in a radiostereometric analysis (RSA) by Schotanus et al. [71] both mobile-bearing and fixed-bearing designs had similar implant migration detected by the maximum total joint motion at 2 years.

The strengths of this study were the inclusion of the largest number of randomized trials thus far, and the analyzing outcomes measure at the short-, mid- and long-term follow-up intervals. To the best of our knowledge, this is the most comprehensive recent meta-analysis on the topic. The last systematic review was performed in 2017 by Fransen et al. [22]. In addition, the last two meta-analyses were performed in June 2020 on this topic by Chen et al. [15] and Wang et al. [84]; however, both meta-analyses combined had 16 randomized trials versus 70 randomized trials in our meta-analysis. Furthermore, both meta-analyses had conflicting results as one supported long-term outcomes of mobile-bearing TKA, yet the other found no difference between fixed-bearing and mobile-bearing designs. In contrast, our study found no differences between mobile- and fixed-bearing designs at anytime point; this is mainly due to pooling data from 70 RCTs, thereby demonstrating more valid results. Several limitations to this meta-analysis should be acknowledged. Although we included RCTs, several trials had high risk of bias as evident in our qualitative review. Another limitation was that outcome measures varied among included studies, which prevented measuring the long-term outcome using the OKS and pooling a higher number of patients in other outcome measures. Implant migration using RSA was not analyzed due to the variability in its reporting across RSA-based studies. Another important limitation was that different types of mobile-bearing TKA were used by different trials, in turn this could be a potential source of bias given the mobile-bearing type was not adjusted for.

Conclusion

This meta-analysis on 70 randomized controlled trials demonstrated no clinically significant differences between mobile-bearing and fixed-bearing TKA at short-, mid- and long-term follow-up for revision rates, aseptic loosening rates, knee functional scores, maximum knee flexion and radiographic lucent lines and osteolysis. The current level of evidence demonstrated that both mobile-bearing and fixed-bearing designs achieved excellent outcomes, yet it does not prove the theoretical advantages of the mobile-bearing insert over its fixed-bearing counterpart. Given that the use
of either design can be supported by this meta-analysis, we recommend that surgeons can use mobile- or fixed-bearing inserts in TKA at their own discretion.

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Declarations

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