Introduction

Unicompartmental knee arthroplasty (UKA) has currently evolved into the treatment of choice for localized arthritis of the knee in the middle-aged and elderly patients. However, the bearing modularity continues to incite debates since both bearings yield similar outcomes in spite of fundamentally different design concepts. Non-conforming articulating surfaces and restricted bearing motion inherent to fixed bearings predispose them to repetitive edge loading and peripheral wear\(^1\). Highly conforming mobile bearings were designed to overcome these limitations; thus, it offers better restoration of natural kinematics of the knee and reduction of contact stress and wear\(^2-4\). However, the superiority of mobile bearings to their predecessors is questionable, as concurrent advances in polyethylene processing, implant design and surgical technique enabled fixed bearings to offer competent results with a relatively forgiving technique\(^5-8\).

The first meta-analysis that attempted to resolve this debate was constrained by paucity of studies that could support a robust statistical analysis\(^9\). A recently reported meta-analysis employed thorough statistical analysis and reached a conclusion that shows no essential differences in revision rates between mobile and fixed bearings\(^10\). Both studies\(^9,10\) faced the same limitations—paucity of randomized control trials (RCT) and variations in study objectives. For comparative analysis of data based on various sample sizes and follow-up periods, we calculated reoperation rates per hundred component years in this study. Data pertaining to measures of survivorship and frequency and timing of failures was extracted and analyzed. We thought that the crux of the debate between fixed and mobile bearing UKA lies in propensity and timing of complications. Therefore, we focused on comparative analysis and discussion of complications.

Keywords: Knee, Unicompartmental arthroplasty, Postoperative complications, Prosthesis failure
Materials and Methods

This review followed the guidelines of Preferred Reporting Items for Systematic reviews and Meta Analyses (PRISMA)\(^\text{11}\). A search for articles was conducted on PubMed, Cochrane library and EMBASE for records available till June 2014. We used keywords such as “knee arthroplasty”, “fixed”, “mobile” and “bearing” and Boolean operators (AND, OR) for various combinations. All 723 studies comparing fixed and mobile medial UKAs were included, regardless of implant manufacturer, study period, study design, indication for surgery or language of reporting. A total of 169 unique titles were identified after elimination of duplicate results and screening for relevance. References in review papers and eligible studies were assessed manually. After stepwise exclusion of studies comparing in vivo behavior, retrieval analysis and cadaveric studies as shown in Fig. 1, only 10 comparative studies were found to be eligible. Since only three RCTs/ quasi-RCTs were found in our search, we included non-randomized comparative studies. After screening full text of the eligible studies, we formulated an analysis protocol that would ensure collection of all comparative data, including research methodology and level of evidence. One of the authors extracted data from each study regarding the number of patients, number of knees, study period, demographic data, implant, inclusion and exclusion criteria, indication for surgery, surgical technique, pre-operative scores, type of prosthesis, surgical approach, experience of surgeon and duration of follow-up.

There were no differences in the indications for the mobile type and fixed type UKAs. The outcome measures included reason and incidence of reoperation, timing of reoperation and survivorship. All data was verified by another author and discrepancies and disagreements were resolved through discussion.

The structure of study, sample size, follow-up period and outcome measures were not consistent in the literature. To compare the diverse data, we calculated the number of reoperations per 100 observed component years, as described by the Australian arthroplasty registry\(^\text{12}\). In this study, we combined different follow-up periods and number of knees reported in every study to calculate the observed component years at risk for each bearing design. Cumulative reoperations and cause-specific reoperations were then compared to the denominator using a simple formula: reoperations per hundred component years = 

\[
\frac{\text{number of reoperations for any reason} \times 100}{\text{total number of observed component years}}
\]

where the total number of observed component year = \(\sum_{i=1}^{n} \text{individual years from implantation}\).

Interpretation of results is fairly straightforward, such that the value of 1 implies reoperation rate of 1% per year, or 10% at ten years. To evaluate whether heterogeneity of data confounded our results, we created subgroups within eligible studies and calculated the same values for the subgroups for comparison with the

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**Fig. 1. Flowchart for the identification of eligible studies. TKA: total knee arthroplasty, UKA: unicompartmental knee arthroplasty.**
cumulative results. The number of knees reported may imply results of a high volume center, while follow-up of more than three years may identify complications dependent on time since surgery. Subgroups were created within eligible studies based on these criteria and results compared with the cumulative mean.

Results

1. Baseline Characteristics

As indicated in Table 1, the review of 10 studies generated data on 1,019 knees in 887 patients. Fixed bearing UKAs were implanted in 595 knees of 515 patients and mobile bearing UKAs were implanted in 424 knees of 372 patients. All studies except one reported detailed demographic information and compared study populations for patient specific factors that may influence the outcome. The mean age of patients receiving fixed bearing UKA was 66.57 years (range, 33 to 88 years; standard deviation [SD], 2.28), while that in mobile bearing group was 65.08 years (range, 38 to 84 years; SD, 3.50). Women comprised 54% of the patients in the fixed bearing group and 56% of the patients in the mobile bearing group. Body mass index (BMI) was reported in four studies for a total of 324 fixed bearing knees and 221 mobile bearing knees. The average BMI in the fixed bearing group was 27.70 kg/m² (range, 16.8 to 44 kg/m²; SD, 1.15), while that in the mobile bearing group was 29.24 kg/m² (range, 19.3 to 43.1 kg/m²; SD, 2.04). The mean duration of follow-up in the fixed bearing group was 6.96±4.66 years (range, 1.03 to 17.2 years), while that of mobile bearing group was 7.15±5.08 years (range, 2 to 17.2 years).

Considerable variety existed in the implant used in the fixed bearing group–Miller-Galante (Zimmer Inc., Warsaw, IN, USA) was used in four studies, Robert Brigham (Johnson & Johnson, Somerville, NJ, USA) in two studies, and St Georg Sled (Waldemar Link, Hamburg, Germany), Preservation All Poly (DePuy, Warsaw, IN, USA), Optetrak (Exactech, Gainesville, FL, USA), Allegro (Centerpulse, Baar, Switzerland) were

Table 1. Baseline Characteristics of Studies and Participants

| Author            | Type of study (level of evidence) | No. of knees (patients) | Mean/median age (yr) | Gender (M:F) | Body mass index (kg/m²) | Body weight (kg) | Follow-up duration (yr) |
|-------------------|----------------------------------|-------------------------|----------------------|--------------|--------------------------|------------------|------------------------|
| Gleeson et al. 5) | Cohort study (II)                | FB 57 (49)              | 66.7                 | 29:20        | 83                       | 4 (2.7–5.3)      |                        |
|                   |                                  | MB 47 (43)              | 64.7                 | 17:26        | 77.7                     | 4 (2.7–5.3)      |                        |
| Parratte et al. 13) | Retrospective (III)            | FB 79 (75)              | 62.8±9.2             | 29:50        | 17.2±4.8                 | 17.2±4.8 (15–21.2) |                        |
|                   |                                  | MB 77 (72)              | 63.4±11              | 25:52        | 27.3                     | 27.3±4.8 (15–21.2) |                        |
| Biau et al. 14),b) | Retrospective (III)            | FB 67 (57)              | 66 (59–71)           | 33:34        | 28 (27–32)               | 3.25 (2.25–5)    |                        |
|                   |                                  | MB 37 (33)              | 60 (55–65)           | 15:22        | 32 (29–34)               | 5.25 (4.9–6.33)  |                        |
| Li et al. 15)     | RCT (I)                          | FB 28 (24)              | 70                   | 20:8         | 26.5                     | 2                |                        |
|                   |                                  | MB 28 (24)              | 74                   | 20:8         | 27.6                     | 2                |                        |
| Emerson et al. 8) | Retrospective (III)             | FB 51 (45)              | 63 (33–84)           | 18:33        | 84.4 (47.2–124.7)        | 6.1 (0.5–13.2)   |                        |
|                   |                                  | MB 50 (43)              | 63 (38–65)           | 22:28        | 79.4 (50.8–108.9)        | 6.8 (2–10.9)     |                        |
| Whittaker et al. 16) | Retrospective (III)        | FB 150 (117)            | 68 (45–79)           | 71:79        | 28.7 (16.8–44)           | 8.1 (1–17.8)     |                        |
|                   |                                  | MB 79 (62)              | 63 (49–87)           | 41:38        | 30.7 (19.3–43.1)         | 3.9 (1–11.3)     |                        |
| Confalonieri et al. 17) | RCT (I)              | FB 20 (20)              | 69.5 (58–81)         | 8:12         | NA                       | 5.7 (5.5–6.3)    |                        |
|                   |                                  | MB 20 (20)              | 71 (58–84)           | 11:19        | NA                       | 5.7 (5.5–6.3)    |                        |
| Bhattacharya et al. 18) | Retrospective (III)     | FB 91 (79)              | 67.7 (48–88)         | 33:46        | NA                       | 3.7 (2–6.1)      |                        |
|                   |                                  | MB 49 (44)              | 68.8 (50–83)         | 22:22        | NA                       | 5.6 (2–9.9)      |                        |
| Catani et al. 19) | Retrospective (III)             | FB 10 (10)              | 70.3±7.6             | 4±3±4        | 76.3±14.4                | 1.03±0.6         |                        |
|                   |                                  | MB 10 (10)              | 70.3±5.8             | 2.8          | 75.4±11.9                | 3.84±2.09        |                        |
| Emerson et al. 20) | Retrospective (III)             | FB 42 (39)              | NA                   | NA           | NA                       | NA               |                        |
|                   |                                  | MB 27 (21)              | NA                   | NA           | NA                       | NA               |                        |

Values are presented as mean±standard deviation or median (range).
FB: fixed bearing, MB: mobile bearing, RCT: randomized controlled trial, NA: not available
aFollow-up of fixed or mobile bearing is not mentioned separately. b)Values are expressed as median (first quartile to third quartile). c)Follow-up reported in months converted into years. d)Values are expressed as median.
used in one study each. In contrast, there was considerable uniformity in use of implant in the mobile bearing group. All studies utilized Oxford (Biomet, Warsaw, IN, USA) mobile bearing knee except Confalonieri et al.\textsuperscript{17}, who used AMC (Alphanorm, Quer- shed, Germany) mobile bearing knee.

We found that most studies adjudged inclusion of participants based on criteria similar to Kozinn and Scott\textsuperscript{21} criteria or Goodfellow's criteria\textsuperscript{22}. Variations were observed in acceptable magnitude, and many studies added supplementary criteria depending on the objective of the study. However, these variations did not affect the internal validity of meta-analyses\textsuperscript{9,23}.

2. Complications

Reoperation rates were calculated in terms of hundred component years from eight studies\textsuperscript{5,8,13-18} (Table 2). The overall reoperation rate of mobile bearing designs was almost the same as that of fixed bearing designs. There was no wear in the mobile bearing group; however, progression of arthritis and aseptic loosening were more frequent in the mobile bearing group. In contrast, wear was the main complication requiring reoperation in the fixed bearing group, and there was no bearing dislocation in the fixed bearing group. The overall average time to reoperation unrelated to infection was shorter for mobile bearings, while the time to reoperation due to aseptic loosening or tibial component subsidence was longer in the mobile bearing group than in the fixed bearing group (7.15 years and 5.95 years, respectively). The time to reoperation for progression of arthritis and persistent unexplained pain was similar between mobile and fixed bearing groups (7.44 years vs. 7.05 years and 3.25 years vs. 3.61 years, respectively). The timing of bearing dislocations in the mobile bearing group was 0.49 years after surgery and the time to reoperation for wear in the fixed bearing group was 8.59 years.

| Parameter                          | Bearing  | Overall\textsuperscript{a) | Progression of arthritis | Aseptic loosening or tibial component subsidence | Bearing dislocation | Persistent unexplained pain | Infection | Wear |
|------------------------------------|----------|-----------------------------|--------------------------|-------------------------------------------------|--------------------|----------------------------|-----------|------|
| Reoperation rates per 100 component years | Fixed    | 1.377                       | 0.357                    | 0.255                                           | 0                  | 0.179                      | 0.076     | 0.383|
|                                    | Mobile   | 1.392                       | 0.428                    | 0.393                                           | 0.285              | 0.071                      | 0.071     | 0    |
| Time to reoperation in years       | Fixed    | 6.79                        | 7.05                     | 5.95                                            | NA                 | 3.61                       | 0.23      | 8.59 |
|                                    | Mobile   | 5.34                        | 7.44                     | 7.15                                            | 0.49               | 3.25                       | 6.51      | NA   |

NA: not available.

\textsuperscript{a)Infection was excluded in calculation of overall time to revision since two cases of infection were reported in the mobile bearing group at 0.125 and 12.9 years after surgery.

| Parameter                          | Bearing  | No. of knees | Component years | R/100CY | Progression of arthritis | Aseptic loosening or tibial component subsidence | Bearing dislocation | Persistent unexplained pain | Infection | Wear |
|------------------------------------|----------|--------------|-----------------|---------|--------------------------|-------------------------------------------------|--------------------|----------------------------|-----------|------|
| >100 knees\textsuperscript{5,8,13,14,16,18} | Fixed    | 495          | 3,750.97        | 1.38    | 0.37                     | 0.27                                              | 0                  | 0.16                       | 0.08      | 0.40 |
|                                    | Mobile   | 339          | 2,630.77        | 1.33    | 0.46                     | 0.38                                              | 0.30               | 0.08                       | 0.04      | 0    |
| Follow-up>3 years\textsuperscript{5,8,13,14,16-18} | Fixed    | 515          | 3,864.97        | 1.37    | 0.36                     | 0.26                                              | 0                  | 0.18                       | 0.08      | 0.18 |
|                                    | Mobile   | 359          | 2,744.77        | 1.28    | 0.44                     | 0.36                                              | 0.29               | 0.07                       | 0.04      | 0    |
| Metal backed fixed bearings\textsuperscript{5,8,13,14,16} | Fixed    | 395          | 3,354.00        | 1.28    | 0.358                    | 0.209                                             | 0                  | 0.089                      | 0.089     | 0.047|
|                                    | Mobile   | 291          | 2,336.75        | 1.327   | 0.471                    | 0.385                                             | 0.214              | 0                          | 0.086     | 0    |

R/100CY: reoperations per 100 component years.
Progression of arthritis leading to reoperation was noted at a unique stage of arthritis. Therefore, a comparative evaluation of complications of different bearing designs and their timings in UKA is at the heart of this discussion.

Aseptic loosening, progression of arthritis and wear of polyethylene insert are the main complications requiring reoperation following UKA. Our results suggest that first two complications are more common in the knees with mobile bearings than fixed bearings. While no knees with mobile bearings were re-operated for wear, the most common complication requiring reoperation for mobile bearing UKA was progression of arthritis. Mobile bearings were found to generate wear with a smaller particulate size (0.58 μm) but greater granular debris (mean, 93% granular debris) as compared to Miller-Galante (5.23 μm, 15%) and anatomic porous coated designs (1.17 μm, 77%)31. Smaller wear particles of mobile bearing designs are biologically more active and have high propensity for osteolysis32. Bloom et al.33 compared the complexity of revision surgery after fixed and mobile bearing UKA. They reported that 46.7% of knees required tibial augments when the primary implant used was a mobile bearing design, compared to only 11.1% of knees that required augments when an implant with a fixed bearing design was revised. In the current review, aseptic loosening was the second highest complication requiring reoperation in mobile bearing UKAs. This was probably caused by osteolysis resulting from the wear of submicron particles32. Therefore, it is worthwhile to ponder whether aseptic loosening caused by wear of submicron particles that necessitates reoperation before the wear is grossly evident.

Considering that bearing dislocation is a complication unique to mobile bearings, understanding that observed rate of zero reoperations in fixed bearings is straightforward. However, observed rate of zero reoperations of mobile bearings for wear even in studies with follow-up exceeding 17 years is intriguing30. Further research in understanding wear behavior of bearings is warranted to establish the actual effectiveness of mobile bearings in reducing wear rates.

Progression of arthritis leading to reoperation was noted at a higher frequency in mobile bearing knees as compared to fixed bearing knees. Bearing dislocations are clearly a complication unique to mobile bearings. It is likely that the two causes are in-
terrelated, such that prevention of one predisposes occurrence of the other. Smith et al. theorized that a surgeon may tend to choose a tight knee and risk slight valgus overcorrection to avoid bearing dislocation. This can result in greater contact stresses and overt loading of the lateral compartment, accelerating the progression of arthritis. Conversely, any undercorrection of deformity may have more play in the medial compartment and predispose to bearing dislocation. Perfect ligament balancing and limb alignment is, therefore, mandatory to avoid both complications, making mobile bearing UKA an unforgiving and a technically challenging procedure. The low tolerance of mobile bearings to gap mismatch even in hands of high-volume surgeons reiterates the difficulty in widespread reproduction of their results. Fixed bearing designs permit undercorrection and may offload the lateral compartment to decelerate the progression of arthritis in the aging knee.

Wear of polyethylene insert is the principal complication requiring reoperation of fixed bearings, occurring around 8.59 years after primary surgery. Wear is a complication inherent to the design of fixed bearings, secondary to higher surface deformation and delamination in comparison to mobile bearings. The mechanism of the polyethylene wear is different according to the type of bearing. In fixed bearings, wear of the polyethylene is caused by the fatigue and shear stress-related mechanism. However, in mobile bearings, wear of the polyethylene is due to the abrasive and adhesive mechanism. Even though some in vitro studies based on knee stimulators report lower wear rates of fixed bearings in comparison to mobile bearings, our results suggest that higher wear rates are constantly seen in association with fixed bearing UKA, in spite of advancements in polyethylene processing and implant design.

Reoperations for persistent pain are higher for fixed bearings than mobile bearings. However, 50% of knees re-operated for persistent pain were all polyethylene UKAs of a single manufacturer reported in a single study that contributed less than 15% of the total study population. The overall reoperation rates for persistent pain excluding the studies reporting all polyethylene UKAs are 0 for mobile bearings and 0.089 for fixed bearings. Authors of the study theorized that the all-polyethylene tibial components increased load transfer to the proximal tibia, resulting in persistent bone remodeling and unexplained medial knee pain.

We recognize several limitations in this review. Due to limited availability of published RCTs, nonrandomized comparative studies were included in the analysis.

Data used for review was observational data that relied primarily on reporting standards, which may vary with geography, surgeon’s experience and study design. Although a subgroup of studies with level I evidence would be desirable, the cumulative sample size of these studies was found to be too small to be able to reflect findings that can be extrapolated to the study population.

Use of reoperation as a measure of failure restricts inclusion of patients who elected to forgo additional surgery. Sporadic causes for reoperation, such as arthroscopy for removal of cement segments or anterior cruciate ligament tear, could not be comparatively assessed.

Constant evolution of implant design may have affected the comparability of studies separated by decades. The confounding effect of these variables on results of our analysis cannot be controlled or ruled out. In spite of these factors, most studies reported equivalent outcomes of both bearing designs, and collection of their individual data on complications has allowed this review to draw cumulative results and inferences that may have overcome effect of an individual study. The method of calculation was simplistic and differences between values compared were small, but the pattern of these differences was fairly constant within subgroups. It reiterates the effect of heterogeneity of the data and overall equivalence of outcomes, similar to the meta-analyses previously published. Nevertheless, the results should be interpreted with caution.

In conclusion, the overall incidence of complications is similar for fixed and mobile bearing UKAs. The discussion of complications presented above may assist surgeons in their choice of bearing design. Further research on progression of arthritis with undercorrection in UKA, biologic activity of wear debris and mechanisms of persistent pain after UKA is desirable for improvement of outcomes and survivorship of UKA.

**Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

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