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Review Article

Mobile-Bearing Total Knee Arthroplasty

Better Than a Fixed-Bearing?

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Abstract: The purported advantages of mobile-bearing knee include increased survivorship and restoration of more natural knee kinematics compared to a standard fixed-bearing design. To evaluate these claims, an extensive review of the available literature was undertaken. We compared survivorship and clinical function, including patient preference. We found no difference in survivorship at 12 to 23 years. Kinematic profiles of both designs did not differ significantly: rotation, flexion, and extension were comparable. Studies evaluating both designs in the same patient showed no difference in range of motion, knee preference, knee scores, and survivorship at midterm follow-up. Both designs were capable of producing excellent long-term results and clinical outcomes if properly implanted. The available evidence does not point to the superiority of one design over another in survivorship and clinical function. **Keywords:** mobile bearing, fixed bearing, TKA, survivorship, functional score.

Total knee arthroplasty (TKA) is the most reliable procedure for pain relief and restoration of function for patients having degenerative joint disease. The long-term survivorship of TKA has been reported in multiple studies to be greater than 90% at 15 years [1-6]. Excellent survival and functional results have been reported for a variety of designs that differ in methods of fixation (cemented vs cementless), levels of conformity, geometry of the implants, and cruciate retention.

Background

Long-term survivorship of TKA is related to wear of the bearing surface and is well described in the orthopedic literature. The wear pattern in TKA differs from that in total hip arthroplasty in that delamination and pitting from the shear force results in larger particles [7,8]. However, substantial submicron polyethylene debris is still generated that can result in osteolysis [9-11]. This can lead to loosening and failure of the implant [11,12]. In spite of good long-term survival, engineers and orthopedic surgeons have long sought a "better" knee design with longer survivorship.

The traditional fixed-bearing knee replacement uses essentially 2 designs: ones that retain the posterior cruciate ligament and those that substitute for it. In both designs, the polyethylene insert is relatively flat and is not truly conforming to the femoral prosthesis. This is based on kinematic data that demonstrates that the knee, in addition to flexion and extension, also has components of sliding and rotation during normal motion [13]. Polyethylene that is less conforming has a smaller contact area between the femoral condyle and the polyethylene and thus increased contact stress [13]. A more conforming polyethylene component adds constraint to the knee preventing it from sliding and rotating. With a more conforming polyethylene, there is a greater area of contact for distribution of the force and, therefore, less stress. However, the increased conformity leads to greater stress on the implant. The design of the mobile-bearing knee was intended to take advantage of the decreased stress seen in conforming designs reducing therefore polyethylene wear while reducing stress on the implant and lowering the risk of tibial component loosening [14]. In addition, the mobile design was felt to more closely recreate native knee kinematics [13,15].

To overcome the limitation of constraint associated with increased conformity of the poly in a mobile-bearing

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Fig. 1. Example of conventional fixed-bearing (left) and mobile-bearing (right) PCL-TKA designs. With the fixed-bearing design, the polyethylene insert is locked into the modular tibial tray, whereas with the mobile-bearing design, the polyethylene can rotate around the central peg on the highly polished tibial surface.

knee, the base of the polyethylene is mobile. Instead of a modular polyethylene that locks into a tibial component, the tibial base plate is made of polished cobalt chrome and allows motion of the polyethylene on the base (Fig. 1). The mobility of the insert is intended to replicate the rotation of the native knee throughout the flexion-extension arc. With a more "natural" motion, some surgeons feel that the kinematics of the mobile-bearing knee more closely resemble those of a native knee [14,16].

Trying to distinguish which total knee design is superior can be a difficult task. When evaluating knee replacement designs the 2 most important criteria should be survivorship and clinical function. The purpose of this article is to present an evidence-based review comparing fixed-bearing and mobile-bearing TKA by comparing their long-term survivorship and clinical outcomes.

Materials and Methods

Our search was designed to find articles that tracked long-term survivorship of fixed-bearing or mobile-bearing total knees, addressed functional outcome, or involved direct comparison of mobile-bearing and fixed-bearing prostheses. The search strategy included searches on Ovid/Medline, Cumulative Index Nursing and Allied Health Literature, Cochrane Central Register of Controlled Trials, Scopus, reference of retrieved articles, table of contents from current *Journal of Bone and Joint Surgery* (British and American volumes), *Journal of Arthroplasty*, and *Clinical Orthopedic and Related Research*, as well as the bibliographies of major arthroplasty textbooks. Our search criteria were limited to primary TKA. All included studies must have used at least one clinical outcome measure and have a minimum 10 years of follow-up.

Results

Survivorship

The primary search identified 378 articles. Seven articles met the search criteria after review by 2 independent reviewers. Table 1 summarizes these studies.

The follow-up for fixed-bearing designs was 12 to 23 years, and survivorship ranged from 91.5% to 98.8% [1,4-6]. Two studies on the Press-Fit Condylar (PFC) (Depuy, Warsaw, Ind) TKA involving 310 knees with 12 to 15.8 years of follow-up yielded survivorship of 91.5% to 94.6% [4,5]. Ritter et al [1] published the results of the Anatomical Graduated Condylar (Biomet, Warsaw, Ind) TKA in 4583 knees at 15 years with a survivorship of 98.8%. Pavone et al [6] published 23-year follow-up on 120 Total Condylar Knee (Depuy, Warsaw, Ind) with survivorship of 91%.

In the mobile-bearing group, the follow-up ranged from 15 to 20 years with survivorship from 83% to 100% [17-19]. Callaghan et al [17] published the results of 119 Low Contact Stress (LCS) (Depuy, Warsaw, Ind) TKA with 100% survivorship at 15 years. Huang et al [18]

Table 1. Long-Term Survivorship in Both Fixed-Bearing and Mobile-Bearing Knee Arthroplasties

Authors	Prosthesis Used	n	Follow-Up (y)	Survivorship (%)	Functional Score
Fixed Bearing					
Rodricks et al [5]	PFC	160	15.8	91.5	KS functional, 65; KS clinical, 89
Rasquinha et al [4]	PFC	150	12	94.6	KS functional, 73; KS clinical, 88
Ritter et al [1]	AGC	4583	15	98.8	Knee functional, 81
Pavone et al [6]	Total condylar	120	23	91	Knee functional, 88
Mobile Bearing					
Callaghan et al [17]	LCS	119	15	100	KS functional, 58 KS clinical, 85
Huang et al [18]	LCS (RP)	267	15	92.1	KS functional, 89 KS clinical, 79
	LCS (MB)	228	15	83	KS functional, 85 KS clinical, 72
Buechel et al [19]	NJ LCS (RP)	233	20	97.7	See text

AGC indicates anatomical graduated component; NJ, New Jersey; RP, rotating platform; MB, meniscal bearing; n, number of patients; KS, Knee Society.

published on 2 versions of the LCS knee (rotating platform and meniscal bearing) with more than 200 patients in each group at 15-year follow-up. The rotating platform and meniscal bearing versions had survivorship of 92.1% and 83%, respectively. Buechel et al [19], in a designer series, published a survivorship of 97.7% for the New Jersey LCS knee at 20-year follow-up.

In summary, a review of the evidence-based data demonstrates that at a follow-up of 12 to 23 years there is no difference in survivorship between mobile-bearing and fixed-bearing designs. Although the current literature does not support longer survivorship for the mobile-bearing knee, examination of fixation and osteolysis is worthwhile.

As stated in the introduction, one of the rationale for the mobile-bearing knee suggests that by uncoupling flexion and rotational forces there is less force transmission to the bone-cement interface [20]. This decrease in force transmission should reduce the torque on the interface of fixation and therefore reduce the risk of tibial loosening. Two different randomized controlled studies comparing the 2 designs used radiostereometric analysis (RSA) to quantify the magnitude of migration as a surrogate measure for future loosening [21,22]. Henricson et al [21] randomized 52 patients to receive either mobile-bearing or a fixed-bearing cemented knee design, each with RSA markers on the undersurface of the tibial base plate and in the tibia. The patients were observed for 2 years using RSA to monitor motion of the tibial tray. Their results showed no difference between the 2 designs in the amount of rotation in both the sagittal and coronal planes. Furthermore, they found no difference in subsidence. Within the 2 years follow-up, they concluded that there was no benefit, about fixation, with use of the mobile-bearing design as compared to fixed-bearing. These results were similar to the results reported by Hansson et al [22] at 2 years of follow-up comparing an uncemented knee designs.

The mobile-bearing design purports to uncouple knee motion, thereby, turning multidirectional movement into 2 unidirectional motions [20]. The wear rate of polyethylene is theoretically reduced with unidirectional wear compared with multidirectional wear [23]. Several studies have shown a relationship between wear and osteolysis that is a potential etiology of total knee arthroplasty failure [11,12,23,24].

Using knee simulators, Fisher et al [25] studied the in vitro wear characteristics of both PFC cruciate-retaining fixed-bearing knees and LCS rotating platform mobile-bearing knees using different polyethylene implants. They found that the LCS rotating platform resulted in lower wear rates compared to the fixed-bearing PFC knee design. These findings were duplicated in a subsequent report comparing the wear and wear debris from rotating-platform mobile-bearing and fixed-bearing knees [26]. In this second report, they found that the wear rate of the fixed-bearing design increased with increasing kinematics due to a higher degree of in internal/external rotation and anteroposterior translation. On the other hand, the mobile-bearing knee was shown to decouple the knee kinematics: at the inferior tibial articulating surface a pure rotation was found, whereas at the superior femoral articulating surface, a linear flexion/extension and anteroposterior sliding was found. Furthermore, the authors did not find a difference between the wear debris from the 2 designs. The work by Fisher et al was contradicted in a recent study by Haider and Garvin [27], who showed no difference in the in vitro wear characteristics comparing mobile-bearing and fixed-bearing designs using ultra-high-molecular-weight polyethylene.

With regard to osteolysis, the number of in vivo looking at the mobile-bearing design is limited. A study published by Huang et al [28] looked at osteolysis seen around mobile-bearing and fixed-bearing knees at the time of revision. There was a significant difference in the amount of osteolysis (47%-13%) around the mobile-bearing as compared to the fixed-bearing implants. This study clearly demonstrates that the mobile-bearing design is not immune to osteolysis, as has been suggested.

Clinical Outcomes

The determination of whether a TKA design is successful, in addition to survivorship, is reflected in clinical outcomes. In the fixed-bearing group, Rasquinha et al [4] reported mean Knee Society functional score at the time of the latest follow-up for the 84 patients (105 knees) was 73 points (range, 50-100 points), and a mean clinical score was 88 points (range, 50-100 points). The overall clinical result was excellent for 79 knees (75%), good for 15 knees (14%), fair for 6 knees (6%), and poor for 5 knees (5%). At 14 to 17 years of follow-up, Rodricks et al [5] reported on 160 consecutive PFC TKA using the Knee Society function and clinical scores and x-rays. The mean Knee Society function score was 65, and the mean clinical score was 89. None of the implants were loose according to the Knee Society criteria and their long-term analysis indicated that the PFC total knee was a successful implant system. Ritter et al [1] at 15 years of follow-up using the anatomical graduated condylar TKA reported the overall knee score to be 81 points (range, 26-96 points). Lastly, Pavone et al [6] reported on 120 Total Condylar Knee TKA using a modified Knee Society rating system. Their overall knee functional score was 88 points.

In the mobile-bearing group, Callaghan et al [17] sited 15-year follow-up for cemented mobile-bearing TKA and demonstrated improvement at the time of final follow-up in Knee Society clinical and functional scores respectively over preoperative assessment. Average preoperative Knee Society clinical and functional scores for living patients were 43 points (range, 17-70 points) and 49 points (range, 30-70 points), respectively. At the time of final follow-up for living patients, Knee Society clinical and functional scores were 85 points (range, 41-99 points) and 58 points (range, 0-100 points), respectively. The Hospital for Special Surgery knee rating system also demonstrated significant improvement at time of final follow-up relative to preoperative levels. Preoperative scores averaged 61 points (range, 41-77 points) and final follow-up scores averaged 79 points (range, 56-95 points), respectively. Huang et al [18] compared Rotating Platform TKA to Meniscal Bearing TKA and their respective functional and Knee Society scores. Both systems overall averaged a functional score of 87 and Knee Society score of 75. It is worth noting that the mobile-bearing TKA scored higher in both functional score (89 and 85, respectively) and Knee Society score (79 and 72, respectively) relative to the rotating platform TKA at the time of final follow-up. Buechel et al [19] evaluated the New Jersey LCS Rotating Platform TKA and its' functional score at more than 10 years survival in 4 separate cohorts involving cemented vs cementless TKA and whether the patient had a history of knee surgery. Results of the cemented rotating platform TKA group that had not undergone prior knee surgery demonstrated a preoperative New Jersey Orthopedic Hospital Scoring Scale (NJOHSS) average score of 39 points (range, 22-59 points) and a postoperative average score of 84 points (range, 70-95 points). Results of the cemented rotating platform TKA group that had underwent previous knee surgery demonstrated a preoperative NJOHSS average score of 42 points (range, 35-57 points) and a postoperative average score of 86 points (range, 72-92 points). Results of the cementless rotating platform TKA group that had not underwent prior knee surgery demonstrated a preoperative NJOHSS average score of 49 points (range, 33-68 points) and a postoperative average score of 87 points (range, 64-100 points). Results of the cementless rotating platform TKA group who underwent previous knee surgery demonstrated a preoperative NJOHSS average score of 51 points (range, 42-61 points) and a postoperative average score of 87 points (range, 72-97 points).

Several other authors have evaluated mobile-bearing knees and compared them with fixed-bearing replacements [29,30]. One prospective randomized study by Aglietti et al [29] found no difference in outcome, specifically Knee Society scores, at 4 years of follow-up. The fixed-bearing knees did have increased average flexion when compared to the mobile-bearing group. Another prospective study comparing mobile-bearing and fixed-bearing knees found no difference in knee scores, pain scores, or postoperative flexion at an average of 41 months of follow-up [30]. This study did note an increased early revision rate in the mobile-bearing group secondary to polyethylene complications.

Another analysis of the 2 designs involves direct comparison in the same patient [31-33]. The patients in these prospective studies underwent TKA with a mobile bearing on one side and a fixed bearing on the other. Ranawat et al [31], albeit with short-term results, showed no difference in knee preference, knee pain, range of motion, overall satisfaction, and knee scores. There was no evidence of osteolysis or loosening on either side in this short-term follow-up. One weakness was the differential in follow-up, with 46 months for the fixed-bearing side and 16 months for the mobile-bearing. Their conclusion was that both designs produced excellent results and high satisfaction rates. Another midterm study compared knee designs in the same patient in 32 patients [32]. This study was conducted in patients undergoing simultaneous bilateral TKA, one side with mobile bearing and the other with fixed. At a minimum follow-up of 4.5 years and average of 6 years, they found no difference in range of motion, knee preference, knee scores, survivorship, and patellofemoral complications. These authors did caution against possible early revision due to bearing subluxation in the mobile-bearing group but felt that this was technique related. Another similar study also involved a single-surgeon randomized prospective study of simultaneous bilateral knee arthroplasties [33]. At a mean follow-up of 13.2 years, they found no significant difference in the postoperative clinical function, radiologic results, polyethylene wear rates, and osteolysis between the 2 designs. In general, they found a higher prevalence of instability in the mobile-bearing group and more radiolucent lines in the fixed-bearing group, but this did not reach statistical significance. The conclusions of the clinical and radiologic results of both designs were encouraging at long-term follow-up.

Kinematics

A proposed advantage for the mobile-bearing knee is a more natural kinematic profile, compared with a traditional fixed-bearing [13,15,34]. In a comprehensive fluoroscopic study, Dennis et al [34] showed that mobile-bearing knees demonstrated less variability with gait than did fixed-bearing knees. In addition, mobile-bearing knees had less femoral AP translation during gait. Otherwise, kinematic patterns were similar for fixed bearings and mobile bearings. In another fluoroscopic study, Ranawat et al [13] found that mobile-bearing knees demonstrated significantly greater axial rotation and less condylar liftoff than fixed-bearing designs. However, they concluded that both fixed-bearing and mobile-bearing knees have kinematic patterns similar to those of a native knee. They also emphasized that proper surgical technique is paramount to restore proper kinematics. Pagnano et al [35] examined the potential advantage of mobile-bearing knees about patellofemoral kinematics. They showed that mobile-bearing knees did not decrease the incidence of lateral retinacular release, patellar tilt, or subluxation. Furthermore, they found that a mobile bearing did not improve knee flexion or stair climbing ability at 3 months and 1 year as compared to a posterior-stabilized fixed-bearing knee.

Discussion

The mobile-bearing knee is a design based on theoretical kinematic and wear advantages. Most of available in vitro data such as the study by Fisher et al [25,26] shows decreased wear with the mobile-bearing design. However, the decreased wear did not result in a decreased level of osteolysis and subsequent 2 RSA randomized controlled studies failed to show a difference between the 2 designs in subsidence [21,22]. The long-term survivorship and clinical results of mobile-bearing TKA are excellent. However, a thorough review of the literature shows no difference in long-term survivorship or clinical function when compared to conventional fixed-bearing TKA. However, most of the available literature has a scientific evidence level of III or IV. Furthermore, most of the studies in the mobile-bearing groups discussed the use of one specific type of prosthesis, called the LCS. This prosthesis has one of the longest track records and was the second mobile-bearing prosthesis introduced on the market behind the Oxford unicompartmental replacement (Biomet, Warsaw, Ind). With the development of newer mobile-bearing designs by the different manufacturers, further follow-up is needed to assure that the long-term results achieved with the LCS can be reproduced by other mobile-bearing TKA designs. We also need to design level I randomized controlled trials with long follow-up to better compare these 2 designs and determine the superiority of one design.

With regard to the purported kinematic advantages of the mobile-bearing TKA, they are not as clearly demonstrated in clinical studies. Studies comparing the 2 designs in the same patient do not demonstrate a difference in range of motion, knee preference, knee scores, survivorship, and patellofemoral complications [31-33].

In conclusion, the available current literature does not justify one design over the other. The most important factor in clinical success and long-term survivorship appears to be the accuracy with which the components are implanted. Therefore, from this evidence-based review, we conclude that the best design is the one with which the surgeon is most comfortable and most able to reproducibly implant. All claims to the superiority of a particular design await longer and more definitive follow-up. There is a strong need to develop level I randomized controlled studies comparing the 2 designs to determine the superiority of one over the other; until then, the available literature, being level III or IV, does not completely answer the question at hand.

Conclusion

The mobile-bearing and fixed-bearing TKA designs are both capable of producing excellent long-term results with excellent clinical outcomes if properly implanted. The available evidence does not point to the superiority of one design over another in survivorship and clinical function. There is a strong need for a well-designed randomized controlled study comparing the 2 designs.

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