

# Mobile bearing and fixed bearing total knee arthroplasty

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**Abstract:** The mobile bearing (MB) concept in total knee arthroplasty (TKA) was developed as an alternative to fixed bearing (FB) implants in order to reduce wear and improve range of motion (ROM), especially focused on younger patients. Unfortunately, its theoretical advantages are still controversial. In this paper we exhibit a review of the more recent literature available comparing FB and MB designs in biomechanical and clinical aspects, including observational studies, clinical trials, national and international registries analyses, randomized controlled trials, meta-analyses and Cochrane reviews. Except for some minor aspects, none of the studies published so far has reported a significant improvement related to MBs regarding patient satisfaction, clinical, functional and radiological outcome or medium and long-term survivorship. Thus the presumed superiority of MBs over FBs appears largely inconsistent. The routine use of MB is not currently supported by adequate evidences; implant choice should be therefore made on the basis of other factors, including cost and surgeon experience.

**Keywords:** Clinical results; fixed bearing (FB); knee joint; mobile bearing (MB); total knee arthroplasty (TKA)

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## Introduction

Conventional fixed bearing (FB) total knee arthroplasty (TKA) showed a proven clinical success over time; nevertheless, most of the patients involved in long term survival studies have been elderly individuals with low activity levels (*Figure 1*). Because of changing demographics in patients requiring TKA, with an increasing proportion of younger patients with higher functional demands, mobile bearing (MB) inserts have been proposed to achieve greater survivorship and clinical outcomes (1) (panel A in *Figures 2,3*).

MBs were designed to reduce the wear and the consequent loosening of the implant documented in FB devices. Decoupling the complex multidirectional motions which occur in FB designs in unidirectional motion at two bearing interfaces, the MB implants allow a more congruent articular surface increasing the contact area and reducing the contact stresses (2). MB should also address the problem

of wear between the Polyethylene (PE) insert and the tibial baseplate. FB implants, in order to grant a suitable locking junction in the tibial component, are necessarily made of titanium alloy and thus, however well finished, unable to provide an ideal smooth surface for PE; MB tibial baseplate are usually made of a highly polished chromium-cobalt alloy instead (3).

*In vivo* kinematic studies have shown that normal knee permits axial rotation during flexion: the lateral femoral condyle contacts the tibia anterior to the midline in the sagittal plane and with progressive knee flexion there is an average of 14.2 mm of posterior translation (4). Thus the introduction of MB portended an enhancement in range of motion (ROM) and deep knee flexion due to a more physiological sagittal gait kinematics.

At least, a MB offers the potential advantage of self-correcting the rotational mismatch between the tibia and the femur providing an optimization of patello-femoral mechanics and a potential reduction of related



**Figure 1** Fixed bearing primary total knee replacement.

complications including anterior knee pain and patellar clunk syndrome.

In contrast, the mobile junction between the tibial baseplate and the insert could be a relevant cause of failure due to PE dislocation, with a reported incidence ranging from 0 to 9.3% (5,6) (panel B in *Figures 2,3*). Component malposition, extensor mechanism dysfunction, hamstring contracture, extensive postero-lateral release, and increased flexion laxity were contributed to dislocation after TKA (7,8). At least, the cost of a MB TKA is higher, up to 35% more than the corresponding FB device.

The first widely used MB device was the Oxford Unicompartmental Knee (Biomet, Warsaw, IN, USA), introduced in 1976 and still used today, followed by the Low Contact Stress (LCS, formerly New Jersey Knee, DePuy, Warsaw, IN, USA) which was approved by FDA in 1984. While most orthopedic surgeons in USA at the time did not accept the MB concept, there was more enthusiasm for LCS system in Europe, where the first European congress on MB was held in 1988. In 1994, 10 years after the LCS concept introduction, the majority of LCS prostheses were sold in Europe and Asia, compared with only 25% in USA. MB knee designs implants then increased between 1994 and

1998 from 25% to 88% of all TKAs in USA, and from 37% to 72% in Europe and Asia (9). After an increasing trend maintained in the first part of the century, a recent analysis on a database representing approximately a 3% sample in USA, reported a decrease in MB implants from 19% to 7% of primary TKAs between 2005 and 2012 (10).

Over the years, the term “mobile bearing” has been referred to various designs, differing in their mobility: rotating-platform designs allow for free rotation of the PE insert around the central axis of the tibia, meniscal-bearing designs allow unconstrained movement of the insert, and rotating/translating designs allow for gliding in the AP plane and some rotation around the central axis of the tibia (11).

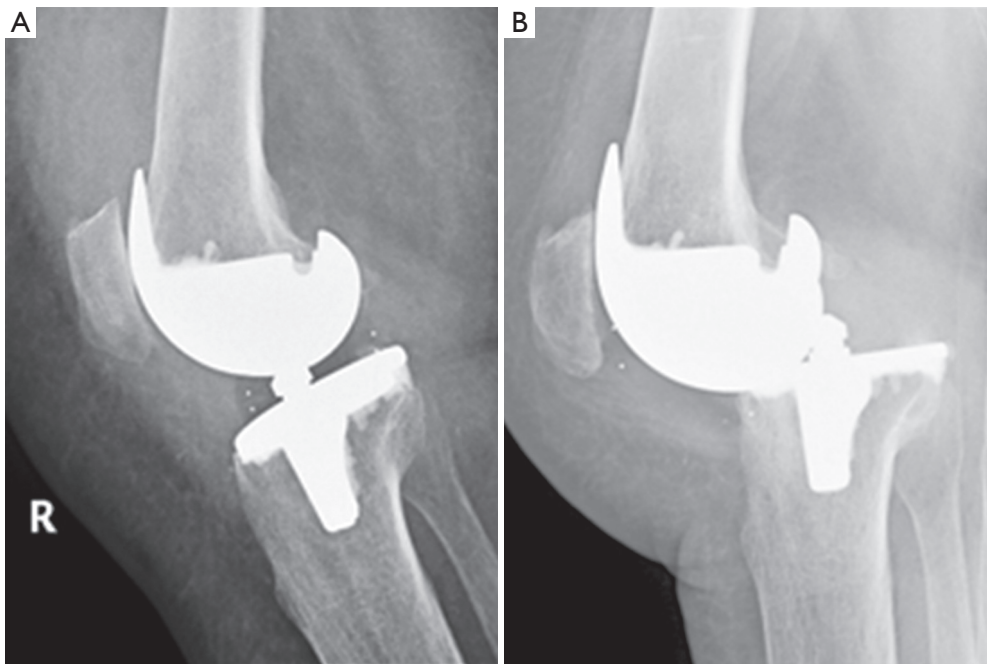
### Biomechanical and clinical review

Over the past years, few studies were able to prove some of the theoretical advantages of MB TKAs.

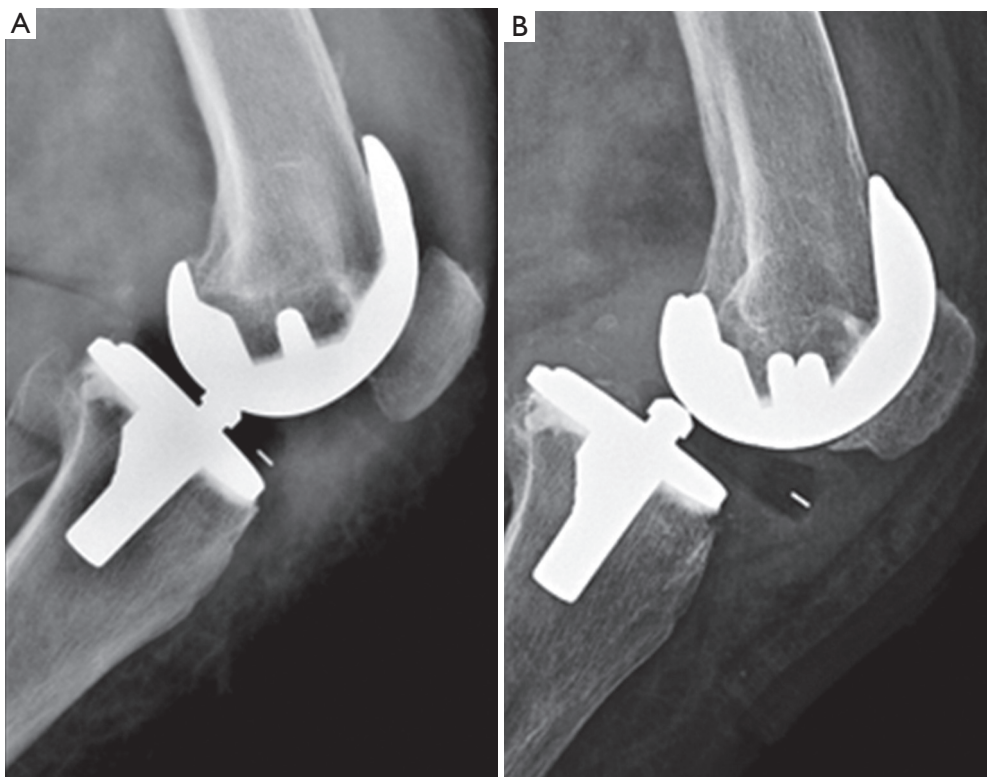
Among these, Tibesku *et al.* (12) reported a better clinical result (Knee Society Score, KSS) in cruciate-retaining rotating/translating MB TKAs; nevertheless, the results of gait analysis, electromyography and other functional and clinical measures did not show any differences compared to FB TKAs.

In 2015 Tjørnild *et al.* (13) randomised 46 patients to a mobile or a FB PFC Sigma (DePuy Warsaw, IN, USA) TKA and accomplished a radiostereometric and bone mineral density (BMD) study; they found higher migration for the FB than for the MB tibial plateau, but with equal loss of periprosthetic BMD at the 2-year follow-up time. Overall, the implant migration measured was low and similar to that reported for other well-performing cemented TKAs; functional outcomes (Oxford Knee Score, OKS) were similar in both groups.

The results of a randomized trial comparing FB and MB TKAs in 61 patients at 9-year follow-up was recently published by Poirier *et al.* (14); they implanted the same prosthesis, Natural-Knee II (Zimmer, Warsaw, IN, USA), that was cementless in all but four cases. There was no significant difference between the two bearing types in terms of ROM, being the ROM at final follow-up identical to the preoperative value. The functional evaluation (KSS and OKS) did not reveal any significant differences between the FB and MB groups. They found a significantly greater risk of osteolysis after 9 years in the FB group, but all the cases of osteolysis occurred in patients with cementless tibial baseplates that had screw holes, which likely caused back-side wear of the PE insert and diffusion of debris along



**Figure 2** Mobile bearing, rotating platform, primary total knee replacement (A); atraumatic dislocation of the insert at 2 years post-surgery in the same patient (B).



**Figure 3** Mobile bearing, rotating platform, primary total knee replacement (A); insert failure due to breakage of the retaining socket at 4 years post-surgery in the same patient (B).

the screws; this difference between the two groups was not clinically meaningful in terms of survival rates.

In 2015 Pais-Brito *et al.* (15) evaluated 157 consecutive knees which underwent NexGen (Zimmer Warsaw, IN, USA) TKA implantation with patellar resurfacing (82 FB LPS and 75 MB MBK). They found a statistically significant advantage for the MB group at 5-year follow-up in terms of pain on walking, pain on ascending/descending stairs, patello-femoral pain, patients' ability to walk and to ascend/descend stairs; no difference was detected in patient satisfaction or muscular strength at 5 years. Nevertheless this non randomized study is affected by some relevant patient related bias, as preoperative data reported in the FB group showed statistically significant higher age, higher proportions of female gender, higher degrees of extension lag and lower muscular strength. Furthermore, the study compared a FB posterior stabilized (PS) design with a meniscal bearing posterior cruciate retaining (PCR) design, being PS implants related to patello-femoral complications in several previous studies (16).

Examining the 11-year report of the New Zealand Joint Registry, in 2013 Wyatt *et al.* (17) found a significantly higher rate of revision for secondary resurfacing of the patella in the FB PS TKA designs compared with either FB PCR or MB designs. They included only TKAs implanted in more than 500 knees, but unfortunately they did not differentiate between PS and PCR implants within the MB group and were not able to know the indication for secondary resurfacing of the patella (pain or instability).

In contrast, several papers in literature rejected the theoretical kinetic and kinematic advantages of the MB design. A summary of the results of previous *in vivo* kinematic studies about antero-posterior femorotibial contact pattern was reported by Callaghan *et al.* in 2001 (3). Patient treated with a FB PS TKA exhibited a paradoxical anterior femoral translation during gait. Patients with a meniscal bearing TKA demonstrated a posterior contact position at full extension, a small amount of posterior femoral rollback during the first 60° of flexion, then a paradoxical anterior femoral translation from 60° to 90° of flexion; thus contact pathways in meniscal bearing TKAs proved to be quite similar to FB TKAs. In further analyses, LCS PS rotating-platform TKA showed a continual posterior rollback of the lateral femoral condyle from 0° to 90° of flexion during a deep knee bend, while a paradoxical anterior femoral translation was observed at some point in the range of flexion in 40% of posterior cruciate substituting (PCS) rotating-platform TKA. Both PCR and

PS rotating-platform TKA demonstrated axial femorotibial internal rotation with progressive flexion, although less in magnitude than normal knees. However, both PCR and PS rotating-platform TKAs demonstrated minimal variance in contact patterns of medial and lateral femoral condyles during gait; PS rotating-platform TKA showed a normal axial rotational pattern, whereas PCS rotating-platform TKA demonstrated an abnormal reverse rotational pattern. The overall ROM was reduced in weight bearing condition compared to passive non weight bearing condition and the average ROM of rotating-platform and meniscal-bearing TKAs were not superior to FB TKAs.

In 2014 Urwin *et al.* (18) published the results on gait analysis of fixed and mobile-bearing TKA during walking; sixteen patients were randomized to receive a FB or MB PS Sigma (DePuy Warsaw, IN, USA) TKA. No significant differences were observed between FB and MB in spatiotemporal, kinematic and kinetic results (stride length, gait velocity, stride time, minimum knee flexion angle during walking, sagittal knee ROM and maximum knee adduction moment) at 9 months post-surgery. Comparing FB and MB groups to the controls, important differences were reported following surgery: both TKA groups walked with greater minimum knee flexion and reduced knee adduction moment than the control group.

The femorotibial contact points at 90° of flexion and their relation with anterior knee pain were recently analyzed by van Stralen *et al.* (19) using the study population of the randomized multi-centre trial of Jacobs *et al.* (20). They found that the contact point was significantly more anterior in MB than in FB TKAs (59.5% SD 7.8 vs. 66.1% SD 5.3 of the tibial plateau), with the FB group comparable to the healthy non-prosthetic knees. However, this difference in contact points was not correlated with visual analogue scale (VAS) pain, knee function and ROM in KSS.

In 2014 Okamoto *et al.* (21) studied the weight bearing TKA kinematics in step-up activity; 37 patients (40 knees) were randomized to a MB or a FB Nexgen LPS Flex (Zimmer, Warsaw, IN, USA) TKA, being all the interventions performed by the same surgeon with a measured resection technique and without patellar resurfacing. They found no statistically significant difference between the two groups in post-operative ROM, Hospital for Special Surgery (HSS) score, tibiofemoral angle and component alignment. FB and MB groups demonstrated no major kinematic differences in terms of antero-posterior translation and axial rotation during step-up activity, although a wider range of axial rotation was

registered in MB group.

Recently, Artz *et al.* (22) surveyed FB and MB TKAs regarding kneeling ability, which is considered an important outcome by approximately 50% of patients. Including 206 TKAs, self-reported kneeling ability from OKS at 1 and 2 years after surgery was significantly higher in FB (from 4% preoperative to 28% at 2 years after surgery) versus MB group (from 3% preoperative to 11% at 2 years after surgery), with a significant correlation for Western Ontario and McMaster Universities Arthritis Index (WOMAC) pain and function scores; interestingly, in spite of the difference in reported ability to kneel, ROM and WOMAC score were similar in both groups after surgery.

In a cadaveric study, Heinert *et al.* (23) compared patellar tracking and patellar kinematics in the natural knee and in mobile and FB PS Sigma (DePuy, Warsaw, IN, USA) TKAs without patellar resurfacing using optical computer navigation. The study reproduced the intraoperative situation where the surgeon assess patellar tracking without muscle tone, with the proximal femur, pelvis, quadriceps attachment and soft tissue envelope intact; furthermore, *in vivo* quadriceps contraction doesn't seem to affect patellar congruence angles (24). No significant differences between FB and MB TKAs were found in patellar tilt, patellar rotation, mediolateral position at 0° of flexion and medio-lateral translation relative to the contact point on the patellar groove. Compared to the natural knee, both TKA groups showed a significantly more medial tilt from 50° of flexion, a lack of external rotation with flexion, a tendency of the patella to be slightly more medial relative to its groove in extension and to move laterally with flexion and an early loss of contact with the patellar groove on the femoral component.

In 2014 Snir *et al.* (16) published a retrospective study on patellar clunk syndrome incidence in fixed (Scorpio NRG, Stryker, Mahwah, NJ, USA) *vs.* MB (PFC Sigma, DePuy, Warsaw, IN, USA) PS TKAs. They found a significantly higher incidence of clunk syndrome in the MB group compared to the FB group (11.7% *vs.* 1.8%); there was a significantly higher incidence in males compared to females (8.8% *vs.* 5.5%), comparably to other recent studies (25), probably due to the higher femoral component average size in males.

Lateral release rates in FB *vs.* MB TKAs were recently compared by Ferguson *et al.* (1). A total of 352 patients were randomized to receive a FB or a MB PFC Sigma PS (DePuy, Warsaw, IN, USA) TKA, with a subrandomisation to

determine whether the patella would be resurfaced or not; lateral release was performed when tilting or subluxation of the patella was observed through the ROM using a “no thumb” technique. The lateral release rate was equal for the two groups (10%), with a significantly higher incidence in patellar resurfaced group (14% *vs.* 6%). In the MB group, a statistically significant lower rate of lateral release was found in patients who had patellar resurfacing compared to those who did not; based on this findings, they suggested that the advantages offered by the MB are only realized once the patello-femoral geometry has been optimized by patellar resurfacing.

Even the incidence and the functional effect of partial posterior cruciate ligament (PCL) release in FB and MB PCR TKAs has been analyzed by Schwarzkopf *et al.* (26); a tight PCL is thought to produce excessive posterior femoral rollback in FB inserts, while is thought to be a potential cause of spin-out or dislocation of a MB insert. They reviewed 1,388 PFC Sigma (DePuy, Warsaw, IN, USA) TKAs (1,014 FB and 374 MB) performed by the same surgeon; percentage of PCL release was decided intra-operatively in order to best balance the flexion gap, beginning with the antero-lateral PCL band and progressing as needed from lateral to medial and from anterior to posterior, then subjectively estimated in percentage. They found a significantly greater proportion of TKAs requiring some degree of PCL release and a significantly greater percentage of the PCL released overall in the MB group, presumably due to the increased sagittal conformity of the insert; however, partial PCL release did not show a clinically significant impact on intra-operative flexion amount or post-operative knee stability at 1 year.

Two international comparative evaluations on aggregated registry data collected by the International Consortium of Orthopaedic Registries, including six national and regional total joint arthroplasty registries were published in 2014. Namba *et al.* (27), including 319,616 patients who underwent FB (81%) or MB (19%) non PS TKAs between 2001 and 2010, found a significantly higher risk of revision for MB designs with a hazard ratio of 1.43 ( $P < 0.001$ ); similarly, Graves *et al.* (28), including 137,616 patients who underwent FB (82.4%) or MB (17.6%) PS TKAs between 2001 and 2010, found a significantly higher risk of revision for MB designs with a hazard ratio of 1.86 ( $P = 0.001$ ) in the first year post-surgery.

In recent years, many randomized trials were designed to compare the functional and radiological outcomes of FB and MB TKAs. In 2011 Mahoney *et al.* (29) published

their John Insall Award winning randomized study on short-term functional outcome of MB *vs.* FB bearing PS TKAs. No statistically significant differences in WOMAC, SF-12 or KSS scores were found up to 2 years post-surgery, although the MB group showed slightly greater average knee flexion at 6 months and 1 year post-surgery. Survival was similar between the two groups using revision of any component both for any reason and for radiolucency or tibial component subsidence as the end point; incidence of complications and non-revision reoperations was similar between the groups.

A randomized controlled trial comparing functional performance in 92 TKAs was published by Jacobs *et al.* (20), using the PCR Balansys (Mathys, Bettlach, Switzerland) fixed or rotating/translating bearing design without patellar resurfacing. They found no statistically significant difference in active knee flexion and overall functional KSS, with a significant advantage for FB group in stair climbing subscore at 3- and 12-month follow-up.

In a randomized controlled radiostereometric trial, Pijls *et al.* (30) found no significant differences in overall mean migration or clinical and radiological scores comparing mobile and FB TKAs at 10 to 12 years.

A long-term prospective comparison of FB and MB in patients younger than 51 years of age was published by Kim *et al.* (31); they evaluated 108 patients in which the FB and MB version of PFC Sigma (DePuy, Warsaw, IN, USA), manufactured by the same company at the same time, were implanted simultaneously by the same surgeon in the same patient. At a mean follow-up of 16.8 years (range, 15-18 years), they found no significant difference in ROM, clinical and functional KSS, survivorship, revision and complication rates.

In 2014 Ferguson *et al.* (32) published the results of a prospective study including 352 patients which were randomized to undergo a mobile or a FB PS PFC Sigma (DePuy, Warsaw, IN, USA), then subrandomised to have a resurfaced or a retained patella. At 2-year follow-up, they found no statistically significant differences in ROM, SF-12, OKS and KSS between the four subgroups; patients with resurfaced patella in MB TKAs showed marginally greater outcome in KSS and SF-12 scores.

The results of the Knee Arthroplasty Trial commissioned by the Health Technology Assessment programme of the UK NHS were published by Murray *et al.* (33) in 2014; the study consisted of a multicentre randomized controlled trial with 2,352 participants formally in the trial and 539 in the comparison assessing the MBs. They found no conclusive

evidence of any risks or benefits associated with MB in terms of post-operative functional status, quality of life, reoperation and revision rates or cost-effectiveness. There was a 2% incidence of instability or bearing dislocation in the MB group and none in the FB group. Although MB were more expensive for the hospital than FB, these initial costs were partly offset by decreases in the cost of subsequent follow-up; overall, MB increased costs by £85 (95% CI, -£911 to £1081; P=0.87).

In 2015 Fransen *et al.* (34) performed a prospective randomized controlled clinical trial to evaluate two types of MB inserts and two types of FB inserts of the Genesis II (Smith & Nephew, London, UK) TKA in 146 patients with 5-year follow-up, in order to test the effect of the advancement in insert design (deep dish FB and rotating/translating MB). Knee function (KSS), quality of life (SF-12) and temporal gait parameters did not show any clinically significant differences for both types of bearing and types of insert used. Compared to the MB, the survival of the FB TKAs with respect to revisions for any reasons was better and the number of manipulations was lower, especially when a rotating/translating insert was used.

In a systematic review and meta-regression including 41 studies and over 6,000 TKAs, van der Voort *et al.* (35) found no significant differences in terms of revision rates, clinical or patient reported outcome (ROM, KSS, OKS, SF-12) and radiological scores between mobile and FB TKAs.

In 2009 Smith *et al.* (36) published a meta-analysis on clinical and radiological outcomes of FB and MB TKAs including 33 studies and 3,532 knees overall, with a mean follow-up period of 42.2 months. They found no statistically significant differences between MB and FB regarding ROM, quality of life (SF-12, SF-36) and all clinical outcome measures (KSS, HSS, OKS, WOMAC) with the exception of functional KSS, where better results were registered among patients with FB TKAs; moreover, there was no significant difference between the two groups regarding radiological outcome, revision and complication rates.

A meta-analysis comparing FB and MB TKAs, with the latter restricted to rotating platform designs, was carried out by Moskal *et al.* (11). Including 17 studies with over 1900 knees at a mean 6-year follow-up, they found no differences in clinical scores (KSS, HSS, or SF-12 scores), ROM measures, radiographic evaluations, complication and revision rates. Even if the evaluation of the frontal tibial alignment favored the FB groups, the effect size was small and was not considered clinically important.

In 2014 Bo *et al.* (7) published a meta-analysis considering

only bilateral TKAs using a MB design in one knee and a FB design in the other knee, in order to reduce observer and patient-related bias to the greatest degree; in total, 807 patients and 1,614 knees from 12 studies were included. Results showed that there was no statistical difference between MB and FB in terms of KSS, pain score, ROM, patient satisfaction, complication and reoperation rates and radiolucent lines at different follow-up times (1, 2 to 5, 5 to 8, and more than 8 years).

The first Cochrane review about post-operative functional status in MB versus FB designs for TKA was published by Jacobs *et al.* (37) in 2004. They found no evidence of superiority for 1 of the 2 prosthesis types with regard to ROM or functional performance of the patients, but the methodological quality of the considered studies was low; in fact only two articles were involved in this review. A newer Cochrane review was published by Hofstede *et al.* (38) in 2015, regarding only cruciate retaining design, including 19 studies, 1,641 participants (98.5% with osteoarthritis) and 2,247 knees; moderate quality evidence suggests that MB prostheses may have similar effects on knee pain compared with FB prostheses in PCR TKA, considering KSS and VAS. Both Cochrane reviews registered also the same results in clinical and functional scores, health-related quality of life, revision surgery rate, mortality, reoperation rate and other serious adverse events in the two groups, but with low quality evidence.

## Conclusions

When MB concept was introduced, the theoretical advantages were represented by the more conforming articular surfaces with lower contact stress and backside wear, the dissipation of the stress wear in two different surfaces and an enhancement of flexion allowing posterior translation, portending knee kinematics closer to physiological gait; moreover, a self-correcting rotational alignment was supposed to enhance the patello-femoral mechanics.

However, clinical studies did not confirm these advantages, as improvement in respect to FB designs in kinematics during step-up activity, kneeling ability, gait function and patello-femoral kinematic were not detected. Moreover, in PCR designs, MB inserts proved a higher need of partial PCL release. The more anterior contact point of MB inserts was proved but with no impact on functional and pain scores, and a lower incidence of lateral release in MB knees was detected just in resurfaced patellas.

No significant advantages in term of functional and radiological outcome, ROM, pain and patient satisfaction were detected by large cohort studies, randomized clinical trials and meta-analyses.

On the other hand, MB inserts showed a relevant complication not reported in FB designs regarding PE dislocation, a higher risk of revision in the first year after surgery, a higher incidence of patellar clunk syndrome in high-flex MB implants and higher costs of the implants.

In conclusion, the theoretical advantages of MB inserts in TKA have not been proven by clinical studies and scientific literature, while a higher rate of complications and higher revision rates were detected. On the basis of the literature review, the routine choice of a MB insert is not currently supported by evidence, as the choice of the implant should be made on the basis of other factors.

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## Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

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