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A Retrospective Comparison of a Medial Pivot and Posterior-Stabilized Total Knee Arthroplasty With Respect to Patient-Reported and Radiographic Outcomes

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ABSTRACT

Background: Medial pivot (MP) type total knee arthroplasty (TKA) implants are designed with a highly congruent medial tibiofemoral articulation. Compared with the cam-and-post design of the posterior-stabilized (PS) TKA, the MP-TKA design has been hypothesized to better replicate the natural kinematics of the knee. We compared the MP-TKA and PS-TKA designs, with our primary outcome measures being range of motion (ROM) and patient-reported satisfaction.

Methods: This study was a retrospective comparison between the 2 groups (76 MP-TKA vs 88 PS-TKA). ROM was collected preoperatively, 6 weeks, 6 months, and 1 year postoperatively. The Forgotten Joint Score-12 (FJS-12) scores were collected at a minimum of 1 year postoperatively.

Results: There was no statistically significant difference in age, gender, or body mass index between the groups. We found a statistical difference in preoperative ROM (MP = 120.3°, PS = 112.8°, $P = .002$). There was no difference in ΔROM at 6 weeks (MP = −12.36, PS = −3.79, $P = .066$), 6 months (MP = −4.23, PS = 2.73, $P = .182$), or 1 year (MP = .17, PS = 3.31, $P = .499$). Patients who underwent the MP-TKA scored significantly better than the PS-TKA on the FJS-12 score (MP = 59.72, PS = 44.77, $P = .007$).

Conclusion: We found that patients who underwent the MP-TKA scored better on the FJS than those who underwent the PS-TKA; particularly with regard to deep knee flexion and stability of the prosthesis. The MP-TKA design may offer improved patient outcomes because of its highly congruent medial tibiofemoral articulation.

Since the invention of the total knee arthroplasty (TKA) in the early 1950s, the design has undergone many revisions and modifications. Each new iteration aims to improve patient outcomes, knee function, and implant longevity. The posterior-stabilized TKA (PS-TKA) was developed in 1978 to address the issue of abnormal posterior-cruciate ligament morphology [1]. Advantages of the PS-TKA include simpler exposure, easier soft-tissue balancing, predictable restoration of knee kinematics, and improved range of motion (ROM) [2]. The PS-TKA relies on a femoral cam that articulates with a tibial post, improving femoral rollback and increasing anteroposterior and translational stability of the knee [3–5]. It has been claimed that cam-post mechanism improves stair-climbing ability through the prevention of posterior tibial subluxation [2].

The medial pivot (MP-TKA) design was developed in the early 1990s to better mimic the natural kinematics of the knee, specifically more natural femoral rollback [6]. Kinematic studies showed that the medial compartment of the knee functioned like a ball-and-socket joint, with the lateral femoral condyle translating in an anteroposterior direction and rotating around the medial compartment in flexion [7–9]. The MP-TKA design features a deeper, highly conforming medial compartment and a less congruent lateral component to allow relative freedom of anteroposterior movement of the lateral condyle [7].

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The PS-TKA has shown good results with respect to the American Knee Society Score and survivorship at 10 years [3,4,6,10]. Similarly, the MP-TKA has also demonstrated excellent results regarding the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Oxford Knee Score, and Short Form (SF)-12 scores [11–14]. In this study, we sought to compare the ROM and patient-reported outcomes (using the Forgotten Joint Score [FJS]) between the EVOLUTION Medial-Pivot (MicroPort, Arlington, TN) and the Zimmer Persona Posterior Stabilized (Zimmer, Warsaw, IN) Knee Systems.

Materials and Methods

This study was approved by our institutional research ethics board. We used our prospectively collected institutional total joint registry and examined the electronic medical records of all patients who underwent a primary TKA from March 2014 to April 2017. Inclusion criteria included any patient undergoing a primary TKA with a diagnosis of osteoarthritis, rheumatoid arthritis, or posttraumatic arthritis. There were no specific criteria for implant selection, as the surgeon did not selectively use the MP-TKA design for specific preoperative conditions. The 2 groups represent 2 consecutive cohorts of patients as the primary surgeon gradually changed his practice and preference. All surgeries were performed by the senior author (DB). Standard surgical technique included a midline incision, medial parapatellar arthrotomy, subluxation (but not eversion) of the patella, intramedullary distal femur resection, extramedullary proximal tibia resection, and resurfacing of the patella depending on the intraoperative wear pattern. The patella was resurfaced in 90% of the patients. Patients received standard, weight-based doses of preoperative antibiotics and intravenous tranexamic acid, followed by 24 hours of postoperative antibiotics and 3 weeks of venous thromboembolism prophylaxis with low-molecular-weight heparin.

Demographics

The mean age of all the patients in this study was 65.63 years (standard deviation [SD] 9.56). The mean age for the MP group was 64.4 years (10.5) and the mean age of the PS group was 66.7 years (8.61) (Table 1). There was no statistically significant difference in mean age between the 2 groups ($P = .131$). Of the 164 patients, 101 were female and 63 were male. The male:female ratio of the MP group was 29:47 and 34:54, respectively ($P = .85$).

Range of Motion

The ROM was measured with the patient supine. It was recorded as the difference between the maximum active extension and flexion. ROM was measured at the preoperative consultation, and again at the 6-week, 6-month, and 1-year postoperative follow-up consultations. All ROM angles were measured by a trained Advanced Practice Physiotherapist using a standard 30-cm goniometer. The Advanced Practice Physiotherapist was blinded to the type of knee design used. The ROM was measured at each time point for both MP-TKA and PS-TKA groups and a mean flexion angle was obtained.

Table 1
Patient Demographics.

Variable	MP	PS	*P* Value
Gender (M:F)	29:47	34:54	.85
Age, y	64.4 (±10.5); range 26-87	66.7 (±8.61); range 47-86	.131
BMI, kg/m^2	29.7 (±5.24)	31.3 (±8.20)	.137

BMI, body mass index; MP, medial pivot; PS, posterior-stabilized.

Forgotten Joint Score

The FJS [15] is a validated measure of patient satisfaction after TKA. The score consists of 12 questions, each pertaining to the patient's ability to carry out daily activities. For each question, the patient is asked to answer as one of “Never,” “Almost never,” “Rarely/Seldom,” “Sometimes,” or “Mostly.” Each response corresponds to a value (ie, “Never” = 1, “Mostly” = 5). The raw scores range from 12 to 60, with a higher raw score indicating a worse outcome. The raw score is then converted to a linearly scaled score of 100 using the following formula: Final score = 100 − ([sum {item 1 to item 12} − 12]/48*100). A high final score indicates a good outcome and a low final score indicates a poor outcome.

Radiographic Analysis

Postoperative radiographs, taken at least 1 year after surgery, were available for 112 of 165 patients (68%). The radiographs were reviewed by 2 fellowship-trained orthopedic surgeons (JW and IV) using the Modern Knee Society Radiographic Evaluation System [16]. Any disagreements were reviewed with the senior surgeon (DB). The radiographic criteria for loosening included a wide (>2 mm) or progressive cement-bone or metal-cement lucent line, component migration, collapse of underlying trabecular bone with subsidence of the component, and cement mantle fractures. Nonprogressive lucent zones measuring 0-2 mm between cement and bone are considered normal and likely secondary to cement contraction. The standard radiographs included standing anteroposterior, lateral, and skyline views.

Statistical Analysis

We performed a power calculation to detect a difference in mean ROM of 5° with a common SD of 10° [6]. A total of 62 patients were required to have a statistical power of 90%, with a 2-sided alpha set at 0.05. The independent *t* test was used to determine statistical significance in mean ROM between the 2 groups. The mean scores for ROM and FJS were calculated for both groups and analyzed for statistical significance using the independent *t* test. All statistical analysis was performed using SPSS, version 24 (IBM SPSS Statistics, Armonk, NY).

Results

A total of 164 patients were included in this study; 76 patients in the MP-TKA group and 88 patients in the PS-TKA group. One hundred seventeen patients completed the FJS at their 1-year follow-up (57 MP vs 60 PS).

Range of Motion (ROM)

There was a statistically significant difference in the mean preoperative flexion angle between the MP-TKA and the PS-TKA groups (MP-TKA 120.3° [SD 16.5] vs PS-TKA 112.8° [SD 15.6], $P = .002$). There was no statistically significant difference in the mean flexion angle between the 2 groups at the 6-week (MP-TKA 105.9° vs PS-TKA 107.2°, $P = .572$) or 6-month (MP-TKA 115.6° vs PS-TKA 114.8°; $P = .726$) follow-up. At the 6-week, 6-month, and 1-year follow-up visits, there was no statistically significant difference in the change in ROM between the 2 groups (Table 2). We

Table 2
Summary of Results of the Range of Motion Comparison Between the MP and the PS Groups.

Measure Outcome	Preoperative, °			6 wk, °			6 mo, °			1 y, °		
	MP Group	PS Group	*P* Value	MP Group	PS Group	*P* Value	MP Group	PS Group	*P* Value	MP Group	PS Group	*P* Value
Range of motion	121.00 (17.75)	112.63 (16.20)	.002**	108.62 (17.4)	108.84 (21.75)	.946	116.77 (12.67)	115.36 (16.30)	.616	121.70 (10.51)	115.94 (19.27)	.149
Δ Range in motion (from preoperative)	n/a			−12.36 (22.52)	−3.79 (23.10)	.066	−4.23 (22.58)	2.73 (17.19)	.182	0.7 (15.67)	3.31 (32.70)	.499

MP, medial pivot; PS, posterior-stabilized.
** $P < .05$ was statistically significant.

Table 3
Change in Range of Motion Angles From Preoperative to 1-y Postoperative.

Preoperative Flexion Angle Range, °	Follow-Up Time	MP	PS	*P* Value
90-99	6 wk	12.29 (±15.008)	11.46 (±15.49)	.910
	6 mo	20.50 (±14.34)	18.67 (±15.16)	.818
	1 y	n/a	n/a	n/a
100-109	6 wk	1.75 (±12.95)	−5.45 (±21.5)	.413
	6 mo	18.75 (±7.67)	2.44 (±15.77)	.079
	1 y	13.5 (±9.19)	10.75 (±24.61)	.891
110-119	6 wk	−4.93 (±16.28)	4.05 (±29.99)	.194
	6 mo	2.17 (±16.58)	8.15 (±12.91)	.287
	1 y	11.25 (±5.82)	5.50 (±11.47)	.241
120-129	6 wk	−15.93 (±12.04)	−11.35 (±12.86)	.157
	6 mo	−3.42 (±11.12)	−3.21 (±12.6)	.953
	1 y	3.38 (±12.29)	1.71 (±17.57)	.816
>130	6 wk	−23.8 (±25.4)	−22.76 (±18.4)	.884
	6 mo	−22.76 (±21.44)	−11.29 (±18.8)	.113
	1 y	−9.8 (±12.13)	−8.00 (±53.63)	.919

MP, medial pivot; PS, posterior-stabilized.

evaluated the change in ROM between the groups according to preoperative flexion ranges. There was no statistically significant difference between the MP-TKA and PS-TKA cohorts in any of the preoperative flexion groups (Table 3).

Forgotten Knee Score

We found a statistically significant difference in the overall mean FJS scores between the 2 groups in favor of the MP-TKA system (MP-TKA 60.56 ± 31.38 vs PS-TKA 48.47 ± 28.81, *P* value = .037; Table 4). There was also a statistically significant difference between the 2 groups for the question "[Are you aware of your artificial joint when you are] *standing up from a low-sitting position*" (MP-TKA 2.69 ± 1.68; PS-TKA 3.50 ± 1.41, *P* value = .006). The MP-TKA cohort scored better on all other questions on the FJS, although they did not achieve statistical significance.

Radiographic Analysis

Follow-up radiographs were available for 106 patients at 6 months and 112 patients at 1 year. The mean length of follow-up for all patients was 1.05 years (±0.83). There were 18 cases with nonprogressive radiolucent lines measuring <1 mm. This was not associated with any clinical findings and likely represents cement contraction. There were no cases of progressive osteolysis or aseptic loosening in any of the patients included in this study.

Reoperation

Four patients underwent a reoperation during the follow-up period. There were 2 polyethylene liner exchanges in the MP-TKA group, both for subjective instability. One of these patients has an underlying diagnosis of Ehlers-Danlos syndrome. This patient was treated with an upsizing of the polyethylene liner from 10 to 12 mm. The second patient had their liner changed from 10 to 14 mm thickness to address varus and/or valgus laxity. In the Persona group, there were 2 reoperations, one for instability requiring a polyethylene exchange and lateral release and one due to a postoperative infection. The infection was treated with a 2-stage revision.

Discussion

The aims of this study were to compare the mean ROM and patient satisfaction after a TKA using an MP-design or a PS-design.

Table 4
Mean FJS Scores. This Score is a Scaled Score That is Derived From the Raw Score Obtained From the Questionnaire, With Lower Scores Correlating With a Better Outcome.

Question: Are You Aware of Your Artificial Joint When?	Mean MP Score	Mean PS Score	*P* Value
1. In bed at night	2.49	2.83	.238
2. Sitting in chair >1 h	2.51	3.05	.064
3. Walking for >15 min	2.49	3.08	.061
4. Taking a bath/shower	1.85	2.02	.490
5. Travelling in a car	2.45	2.81	.205
6. Climbing stairs	2.92	3.46	.067
7. Walking on uneven ground	2.76	3.27	.077
8. Standing from low sitting position**	2.71	3.52	.005**
9. Standing for long period of time	3.00	3.48	.079
10. Doing housework/gardening	2.97	3.25	.297
11. Taking a walk/hike	2.78	3.18	.171
12. Doing your favorite sport	2.92	3.15	.294
Total score**	59.72 ± 31.68	44.77 ± 28.53	.007**

FJS, Forgotten Joint Score; MP, medial pivot; PS, posterior-stabilized.
** $P < .05$ was statistically significant.

Multiple studies have reported favorable outcomes for the MP-TKA, with satisfactory results at medium to long-term follow-up [14,17–20]. Fan et al [21] reported significant improvements in the ROM and pain scores at 5-year follow-up. Bordini et al [22] also reported good outcomes of the ADVANCE MP-TKA, having a 10-year survivorship estimate of 96.6% for the MP-TKA, higher than all other cemented TKA types. The highly conforming design of the MP-TKA may contribute to reduced polyethylene wear and osteolysis, resulting in improved survivorship compared with other TKA designs. However, the Australian Orthopaedic Association National Joint Replacement Registry found higher rates of revision for MP-TKAs because of patellofemoral pain and loosening and/or osteolysis [17].

It is the authors' impression that the MP-TKA design offers improved anteroposterior stability because of the elevated medial anterior and posterior lips of the polyethylene liner, yet more normal kinematics is permitted because of the lack of lateral constraint combined with a single radius of curvature femoral component and more normal tensioning of the collateral ligaments.

The present study found similar results to the literature with respect to ROM, showing no difference between the MP-TKA and PS-TKA designs [23,24]. Shakespeare et al [23] reported a mean flexion angle of 111° in the MP group vs 109° in the PS group at one-year follow-up ($P = .110$). These mean angles were lower than our findings at the same follow-up period; however, the patients in their study had lower preoperative flexion angles. One randomized controlled trial (RCT) showed a greater ROM with a medially conforming ball-and-socket prosthesis compared with the PS-TKA at both 1-year and 2-year follow-up [12]. Conversely, another study [25] reported a worse outcome for an MP-TKA compared with a mobile-bearing prosthesis.

To date, this study is the first to compare an MP-TKA and a PS-TKA using the FJS as a primary outcome measure. It was decided to use the FJS over other available scoring systems as an outcome measure as we felt that the FJS provides a better measure of high-end functionality postarthroplasty. Patients' expectations of outcomes after surgery have dramatically changed over the last 20 years, as patients are now expecting higher levels of functionality with their joint replacement. The FJS has been validated in several studies [26–30]. One study has used the FJS to compare a fixed-bearing TKA with a mobile-bearing TKA [30]. Several studies have been carried out comparing the MP-TKA with the PS-TKA using other patient-reported outcome measures. These include the WOMAC, SF-36, Knee Society Score (KSS), and Oxford Knee Score. Similar to our study, Hossain et al [12] found a statistically significant difference in the physical elements of the SF-36 and Total Knee Function Questionnaire scoring systems, favoring the medially conforming ball-and-socket prosthesis over the PS-TKA. Other studies have reported nonsignificant differences when comparing the MP-TKA with the PS-TKA [23,24]. Bae et al [24] compared ROM as well as the WOMAC, Kujala, and KSS scores, and found no significant difference in any of these outcomes between the MP-TKA and PS-TKA. One RCT reported worse outcomes in the MP-TKA when comparing the KSS and Hospital for Special Surgery knee scores to the press-fit condylar mobile-bearing TKA [25].

An interesting finding is that there was a statistically significant difference between the groups when patients were asked "[Are you aware of your artificial joint] when you are standing from a low sitting position?" We found that the patients who underwent the MP-TKA scored better than those with the PS-TKA (2.69 vs 3.50, respectively; $P = .006$). In most daily activities, the full weight of the patient acts through the knee joint not only in full extension, but also throughout flexion [31]. Standing from a low sitting position is an example of such an action, and requires a high degree of midflexion stability. Our results suggest that in PS-TKA patients, a noticeable element of this midflexion stability is compromised compared with the MP-TKA patients, as evidenced by the significantly lower score for this question. Flexion instability is defined as excessive laxity when the knee is in flexion [32], which was shown to be greater in the PS-TKA than with cruciate-retaining procedures by Hino et al [33]. In support of this finding, Schwab et al also reported a high degree of flexion instability of 10 patients, requiring a revision TKA [34]. A proposed consequence of this flexion instability would be dislocation of the PS-TKA implant, as was reported by Gebhard and Kilgus [35] and Lombardi et al [36]. From a mechanical point of view, Nakayama et al [37] reported there to be inevitably very high contact stress in the post-cam mechanism of the PS-TKA, which leads to greater instability and impedes on the patients' ability to extend from deep flexion of the knee.

Limitations

There were several limitations to this study. First, the number of patients lost to follow-up was high. Of our initial cohort of 164 patients, data were only available for 150 patients at 6-weeks, 109 patients at 6-months, and 70 patients at the 1-year follow-up. Although our sample size was adequately powered (a total of 69 patients were needed for a power of 90%, with a 2-sided alpha of 0.05), more complete follow-up may have enabled us to detect a significant difference between ROM scores or individual questions on the FJS. The low rate of follow-up reflects the extremely large geographical catchment area for our university-based tertiary care center and the desire of many well-functioning patients to follow-up with their primary care providers locally and closer to home. It may also suggest that unhappy patients are choosing to follow-up with a different surgeon, although this unlikely at such an early phase postoperatively.

Second, the retrospective nature of our study may result in recall bias when collecting the data. We recognize that the ideal study design for this comparison would be a prospective, RCT that compared the 2 knee systems and with regular patient follow-up. However, we addressed this potential recall bias by using our institution's joint registry, which collects patient follow-up data prospectively.

Lastly, there was an element of selection bias as the 2 groups had a statistically significant difference in preoperative ROM, which could potentially confound our results. There were no criteria used to select implant design. The patients who received the MP-TKA reflect a change in philosophy and implant choice by the senior

author (DB) in 2014, with a gradual transition from a PS to a MP TKA design. Both groups had improvements in their ROM after TKA regardless of implant design.

Conclusion

In summary, we found that patients who underwent the MP-TKA scored significantly better on the FJS than those who underwent the PS-TKA; particularly with regard to deep knee flexion and stability of the prosthesis. This is of importance as the goal of TKA surgery is to provide a joint replacement that functions as closely as possible to a normal knee without an artificial sensation. We found no significant difference in the ROM between these 2 groups and no difference in survivorship at 1-year follow-up. Future studies will include larger cohorts and a randomized, controlled design.

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