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Original Research

A Medial Congruent Polyethylene Offers Satisfactory Early Outcomes and Patient Satisfaction in Total Knee Arthroplasty

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ABSTRACT

Background: Although a successful operation, almost 20% of patients are dissatisfied with total knee arthroplasty (TKA). The purpose of this retrospective cohort study was to see if a medial congruent (MC) polyethylene would offer satisfactory early outcomes and patient satisfaction after TKA.
Methods: We reviewed prospectively collected data on 327 TKAs using multiple bearings within the same implant system. Ninety-six received an MC bearing, 70 received a cruciate-retaining (CR) bearing, and 161 received a posterior-stabilized (PS) bearing. We evaluated the visual analog scale pain scores and range of motion (ROM) at 2 weeks, 6 weeks, 3 months, and 1 year; Patient-Reported Outcomes Measurement Information System (PROMIS-10) score and Knee Injury and Osteoarthritis Outcome Score (KOOS) at 3 months and 1 year; and Forgotten Joint Score (FJS-12) at 1 year.
Results: All groups had similar KOOS and PROMIS-10 scores. MC knees had lower visual analog scale scores than PS knees at all time points ($P < .05$) and a higher ROM than PS at 2 weeks (98.6 vs 93.7, $P = .002$). MC knees had a significantly higher FJS-12 than CR knees (71.6 vs 58.7, $P = .02$). More MC knees were "very satisfied" than CR (92.6% vs 81.5%, $P = .04$). Fewer MC knees were "not at all satisfied" than CR (1.2% vs 9.2%, $P = .04$). There were similar satisfaction ratings with MC and PS.
Conclusions: An MC bearing provided similar or improved early pain, ROM, KOOS, PROMIS-10, FJS-12, and patient satisfaction as compared with standard bearings in TKA.

Introduction

Total knee arthroplasty (TKA) has been a successful operation for end-stage knee arthritis for decades [1-4]. Implant design and manufacturing, surgical techniques, and perioperative pain and rehabilitation protocols continue to improve. These changes, along with preoperative medical optimization, have helped to decrease hospital length of stay and associated early complications. There are many ways to measure the "success" of TKA, including implant survivorship, pain relief, and the range of motion (ROM). TKA is effective at improving patients' pain, function, mobility, and overall quality of life (QOL). Despite these measures of success, upward of 20% of patients who underwent modern TKA are not completely satisfied or are unhappy with their operation [1-4].

Changes in the implant design, alignment concepts, and the use of advanced imaging, navigation, and robotic assistance have been used with the hope of improving function, survivorship, and patient satisfaction. Implant-guided motion is one way of potentially recreating the natural movement and kinematics of the knee after TKA, thus improving patient satisfaction. Studies have shown the normal kinematics of the knee joint follow a medial pivot concept where the medial compartment of the knee is relatively constrained and moves in a pivoting motion, whereas the lateral compartment is less constrained and combines rolling and translational movements [5-7].

Medially conforming polyethylene designs were developed with the goal of recreating the medial pivot kinematics of the knee [8-10]. One recent design offers a polyethylene insert that is highly congruent on the medial side and can be used with a standard cruciate-retaining (CR) femoral component [11]. This medial

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congruent (MC) polyethylene is one of multiple inserts within the same knee implant system that offers a spectrum of stability options.

A common goal of joint replacement surgery is for patients to be unaware of their artificial joint with daily activities. This concept of the "forgotten joint" may be a way to measure the "success" of joint replacement surgery. Patient-reported outcome measures (PROMs) are an increasingly important evaluation for determining outcomes and success for joint replacement surgery. The Forgotten Joint Score (FJS-12) is a newer PROM that assesses the concept of the "forgotten joint" after total joint arthroplasty [12]. Recreating natural knee kinematics with implant-guided motion may help provide the sensation of a "forgotten" joint and improve patient satisfaction. The purpose of this study was to examine the impact an MC polyethylene insert had on early outcomes and patient satisfaction as compared with standard bearing options in TKA. Our hypothesis was that an MC polyethylene would provide similar outcomes to CR and posterior-stabilized (PS) inserts.

Material and methods

After obtaining approval from our institutional review board, consecutive patients undergoing elective TKA for osteoarthritis of the knee between January 2017 and March 2018 by 4 fellowship-trained adult reconstruction surgeons at a tertiary referral center were included in the study. The TKA design chosen for the study was the Persona TKA (Zimmer Biomet, Warsaw, IN). A single anatomic tibial component accepts all polyethylene options. This knee system has 2 femoral components, a PS and a CR version. The PS femoral component accepts standard and moderately constrained PS inserts. The CR femur accepts standard CR, ultra-congruent (UC), and MC inserts. This modularity allows for multiple design options within the same implant system and intraoperative flexibility and shift between various levels of constraint.

The 3 polyethylene options used in this study were the CR, PS, and MC. Given the limited use at our institution, UC inserts were excluded from the study. Patients receiving a constrained PS insert were excluded as it could be representative of ligament instability. The inserts chosen were primarily based on surgeon preference and occasionally on intraoperative findings. One surgeon uses exclusively MC inserts, 2 surgeons use exclusively PS inserts, and one surgeon uses mostly CR inserts but would convert intraoperatively to PS if posterior cruciate substitution was necessary. All surgeons performed the same surgical technique consisting of measured resection and ligament balancing with implant rotation set according to anatomic landmarks. Tranexamic acid and tourniquets were used in all cases.

All patients received the same preoperative education including an in-person "joint replacement class," perioperative pain regimen, and anesthesia and rehabilitation protocols. The same preoperative medications were administered including acetaminophen, celecoxib, and aprepitant; intraoperative medications included dexamethasone, ondansetron, and a multimodal periarticular injection consisting of ropivacaine, epinephrine, Toradol, and clonidine. Surgeries were performed under neuraxial anesthesia when possible. Each patient received scheduled acetaminophen postoperatively with breakthrough Toradol and oxycodone available as needed. Patients were mobilized with physical therapy and nursing staff on the day of surgery and given the same ambulatory-assistive devices and discharge physical therapy protocols. All patients were discharged with celecoxib, acetaminophen, and breakthrough oxycodone prescriptions.

In total, 327 TKAs including 96 MC, 70 CR, and 161 PS were analyzed using the visual analog scale (VAS) pain score and ROM at 2 weeks, 6 weeks, 3 months, and 1 year; Patient-Reported Outcomes Measurement Information System (PROMIS-10) and Knee Injury and Osteoarthritis Outcome Score (KOOS) at 3 months and 1 year; and FJS-12 at 1 year. All data were obtained prospectively and then retrospectively reviewed in our institutional database and electronic medical record system. The VAS pain scores and ROM were recorded during the patient encounter, and the KOOS and PROMIS-10 PROMs were collected at clinic visits via an electronic tablet. At 1 year, we collected the FJS-12 and solicited answers to an independent follow-up questionnaire (Appendix) via phone calls by research personnel. Analyses for numerical responses were performed using a mixed-effects analysis of variance model and Tukey's method of multiple comparisons. Categorical variables were analyzed using contingency tables and chi-square significance tests. A significance level of $P < .05$ was used to determine significance in all analyses. All analyses were carried out using JMP V13 Software (SAS, Inc., Cary, NC).

Results

Preoperative data

When comparing the preoperative VAS pain scores between the patients who received MC, PS, and CR, the VAS pain score was significant with MC > CR ($P = .0078$) and PS > CR ($P = .0026$), whereas there was no difference in the VAS pain score between MC and PS. Before treatment, there was no difference in the ROM in patients who received MC and CR TKA; however, they were both significantly greater than in the patients who received PS TKA ($P = .0048$, $P = .0227$). There was no significant difference in the age; gender; body mass index; PROMIS-10 mental or PROMIS-10 physical (P-10P) scores; or KOOS QOL, sport, activities of daily living (ADLs), symptom, or pain scores among the 3 groups preoperatively. Preoperative demographics are outlined in Table 1.

Postoperative data

VAS pain score

The VAS pain score was significantly lower in patients who received MC than those who received PS at 2 weeks (2.83 [SD: 1.92] vs 4.13 [SD: 2.39], $P < .00002$), 6 weeks (1.30 [SD: 1.32] vs 2.06 [SD: 2.26], $P = .0132$), 3 months (0.41 [SD: 0.80] vs 1.13 [SD: 2.07], $P < .00002$), and 1 year (0.14 [SD: 0.70] vs 0.51 [SD: 1.88], $P = .01360$). There was no difference in MC and CR at 2 weeks (2.83 [SD: 1.92] vs 3.17 [SD: 2.21], $P = .3432$), 6 weeks (1.30 [SD: 1.32] vs 1.90 [SD:

Table 1
Preoperative patient demographics.

Variable	MC	SD	CR	SD	PS	SD
	n = 96		n = 70		n = 161	
Age	64.3	10.3	63.4	7.4	66.3	9.4
Female %	54%		58%		57%	
Male %	46%		42%		43%	
BMI	34.3	5.96	34.4	7.16	33.5	6.00
VAS pain	8.34[a]	1.51	7.37	2.07	8.5[a]	1.79
ROM	110.6°	10.90°	110.2°	9.78°	105.7°[a]	13.31°
P-10M	48.6	8.96	47.8	9.02	46.5	8.80
P-10P	38	5.64	38.2	6.52	36.8	6.83
KOOS QOL	21.1	16.43	21.9	17.11	17	17.31
KOOS sport	22.3	22.21	25.2	20.94	19.4	22.30
KOOS ADL	46.5	16.58	48.8	15.25	45.3	19.78
KOOS symptom	46.3	17.88	46.6	18.29	46.7	19.78
KOOS pain	40.8	14.76	42.1	16.40	39.3	18.49

BMI, body mass index; P-10M, PROMIS-10 mental; P-10P, PROMIS-10 physical; SD, standard deviation.
[a] $P < .05$.

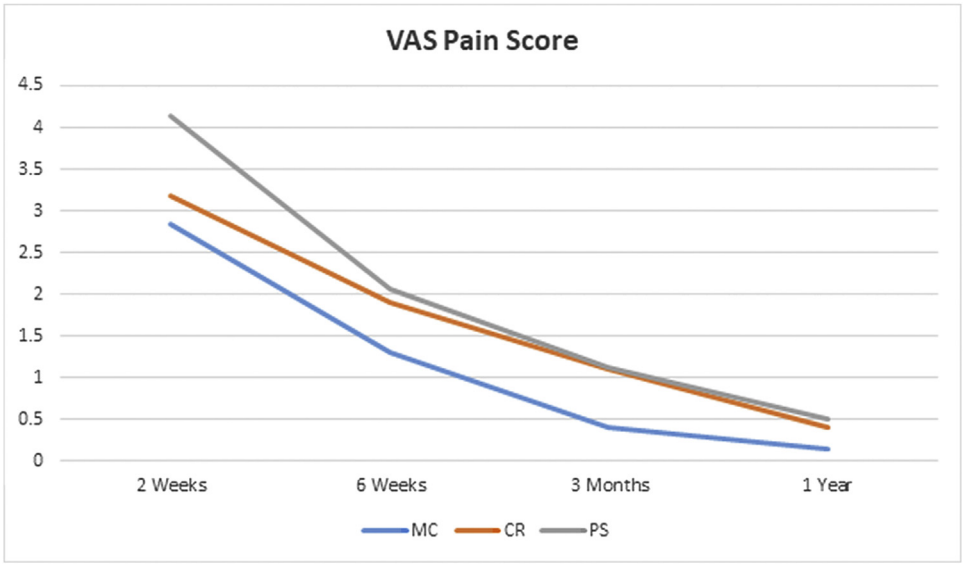

Figure 1. Postoperative VAS pain score values.

1.79], $P = .1686$), 3 months (0.41 [SD: 0.80] vs 1.10 [SD: 1.50], $P = .1983$), and 1 year (0.14 [SD: 0.70] vs 0.40 [SD: 0.76], $P = .7557$). The observed trend for less pain in the MC group at all time points was not significant (Fig. 1).

Range of motion

When comparing the ROM (degrees) between the 3 groups at all time points, MC had a significantly greater ROM than PS at 2 weeks (98.6 [SD: 12.6] vs 93.7 [SD: 13.2], $P = .0018$) but no difference at 6 weeks (111.5 [SD: 11.0] vs 111.2 [SD: 13.9], $P = .7051$), 3 months (115.7 [SD: 8.9] vs 116.2 [SD: 10.6], $P = .7568$), or 1 year (118.4 [SD: 5.5] vs 119.8 [SD: 9.9], $P = .9853$). There was no significant difference between MC and CR at 2 weeks (98.6 [SD: 12.6] vs 95.1 [SD: 15.8], $P = .1811$), 6 weeks (111.5 [SD: 11.0] vs 109.6 [SD: 14.5], $P = .5813$), 3 months (115.7 [SD: 8.9] vs 113.8 [SD: 11.3], $P = .4082$), or 1 year (118.4 [SD: 5.5] vs 115.3 [SD: 9.3], $P = .0913$). The observed trend of a higher ROM in MC than in CR was not significant (Fig. 2). PS knees showed a higher average ROM improvement from baseline (preoperative: 105.7, postoperative: 119.8, change of 14.1) than MC knees (preoperative: 110.6, postoperative: 118.4, change of 7.8) and CR knees (preoperative: 110.2, postoperative: 115.3, change of 5.1), but this did not reach statistical significance ($P = .053$).

Patient-reported outcomes

The PROMIS-10 scores and KOOS were collected from all patients who underwent TKA at 3 months and 1 year (Table 2). All groups (MC, PS, and CR) improved from preoperative scores. There was no difference in the PROMIS-10 mental scores between the 3 groups at 3 months ($P = .75$) or 1 year ($P = .76$). In addition, all groups improved in the PROMIS-10 physical scores from preoperative values, but there was no difference between the groups at 3 months ($P = .69$) or 1 year ($P = .53$). The KOOS QOL score between the groups was significantly improved when compared with the baseline score at 3 months and 1 year ($P = .0016$), but there was no

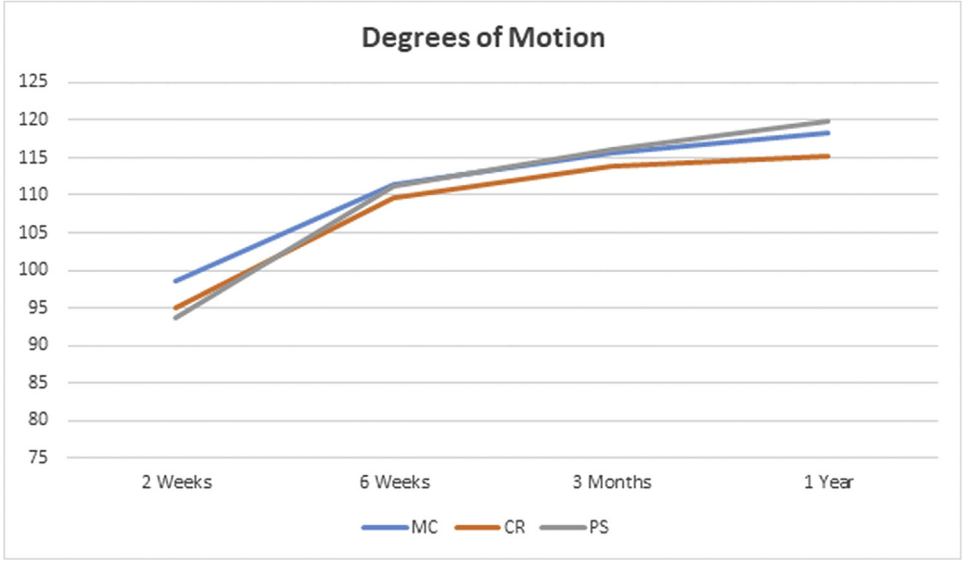

Figure 2. Postoperative range of motion (degrees).

Table 2
Postoperative PROMIS-10 scores and KOOS.

Variable	MC	SD	CR	SD	PS	SD
P-10M 3 months	51.77	7.51	52.37	8.65	51.36	7.67
P-10M 1 year	52.12	7.35	51.28	6.37	51.08	9.72
P-10P 3 months	47.71	7.39	46.62	6.40	46.94	7.28
P-10P 1 year	52.12	8.75	51.28	7.45	51.08	8.84
KOOS QOL 3 months	55.84	22.84	53.96	17.57	56.66	22.11
KOOS QOL 1 year	60.66	26.49	58.62	22.79	67.99	28.29
KOOS sport 3 months	54.35	28.28	51.16	28.18	56.11	33.03
KOOS sport 1 year	58.53	33.46	57.52	28.95	65.57	32.96
KOOS ADL 3 months	76.18	18.31	75.69	16.73	75.52	18.85
KOOS ADL 1 year	82.01	17.68	76.56	20.02	86.69	21.03
KOOS symptom 3 months	76.54	18.33	77.04	16.58	79.60	16.04
KOOS symptom 1 year	80.55	18.47	76.05	18.96	82.58	19.87
KOOS pain 3 months	73.57	18.99	71.65	17.56	74.92	19.54
KOOS pain 1 year	80.67	18.29	76.56	22.56	84.94	22.40

P-10M, PROMIS-10 mental; P-10P, PROMIS-10 physical; SD, standard deviation.

difference between the groups at both time points ($P = .2656$). The KOOS sport score followed the same trend with significant improvements from baseline ($P = .0174$); however, there was no difference between the 3 groups at follow-up at 3 months and 1 year ($P = .6629$). Similarly, the KOOS ADL scores improved from baseline to 3 months and 1 year ($P = .0009$). There was no difference in KOOS ADL between the groups at 3 months and 1 year ($P = .0595$); however, there was a trend of PS > MC > CR at 1 year. The KOOS symptom score improved significantly in all groups from baseline to 3 months and 1 year, but there was no significant difference between groups ($P = .495$). The KOOS pain scores improved from baseline at 3 months and 1 year ($P < .0001$), but there was no difference between groups ($P = .4484$).

In addition, patients were questioned on "satisfaction" and how "natural" their knees felt 1 year postoperatively. When asking patients how "normal" their knees felt, there was no difference between the 3 groups ($P = .1456$); when asked how "mechanical" their knees felt, there was no difference across the 3 groups ($P = .7928$). There was no difference across the 3 groups ($P = .41$) when asked how "naturally" their knees moved, but there was a nonsignificant trend for MC > PS > CR (92.6%, 86.5%, 83%) (Table 3). When asking patients if their "expectations for TKA were met," there was no difference across groups answering "yes" or "no" ($P = .2825$); however, there was a nonsignificant trend in answering "yes" for MC (93.8%) and PS (93.6%), both greater than CR (87.7%). Similarly, patients answering "no" followed a nonsignificant trend with MC (6.2%) and PS (6.4%), both less than CR (12.3%) (Table 3). When asked about "satisfaction of knee replacement," there was a significant increase in patients answering "very satisfied" with MC and PS compared with CR (92.6%, 92.9%, and 81.5%, respectively, $P = .04$). There was also a significant difference in patients who answered "not at all satisfied" with MC and PS being equal and both being less than CR (1.2%, 2.1%, and 9.2%, respectively, $P = .04$) (Fig. 3).

Forgotten Joint Score

FJS-12 was collected from all 3 groups at a 1-year postoperative follow-up. The mean FJS-12 for MC was 71.62 (95% confidence interval [CI]: 65.44-77.81), PS was 68.71 (95% CI: 64.07- 73.34), and CR was 58.68 (95% CI: 51.9-65.46). There was no difference between the FJS-12 for MC and PS at 1 year ($P = .7381$). Both MC and PS had a significantly higher FJS-12 score at 1 year over CR (MC, $P = .0161$; PS, $P = .0445$) (Fig. 4).

Discussion

In an effort to improve on an already successful surgical procedure, we continue to examine the kinematics and bearing surfaces used in TKA. In our study, patients receiving the MC bearing obtained pain relief and exhibited improved PROMs and high levels of satisfaction. These patients also reported high levels of natural movement and a high FJS-12. The CR and PS groups demonstrated similar improved results from baseline. There were trends toward improvement when comparing MC with the other 2 bearing surfaces for the FJS-12 and perceived feelings within the knee. The purported benefits of this knee design may be due to more accurately recreating the normal kinematics of the knee.

Komistek et al., using fluoroscopic analysis [5], and Freeman and Pinskerova, using magnetic resonance imaging [6], showed the normal kinematics of the healthy knee to be a rotating and pivoting action with little translation in the medial compartment and a rolling and translating action in the lateral compartment. In 2002, Blaha showed that the Medial-Pivot knee prosthesis (MicroPort Orthopedics, Arlington, TN) reproduced rotation and pivoting on the medial side with rolling and translation on the lateral side [7]. In an in vitro analysis, Steinbruck et al showed that a medially stabilized TKA design more reliably restored the physiologic medial pivot with lateral translation than a PS design [13].

Previous medially stabilized knee designs have shown good patient satisfaction and survivorship at early, midterm, and long-term follow-up. Van Overschelde and Fitch showed high patient satisfaction using the Western Ontario and McMaster Universities Arthritis Index (WOMAC) and Knee Society Score (KSS) at 2 months immediately after TKA with the Evolution Medial-Pivot knee (MicroPort Orthopedics) [14]. After the first 50 cases, 99.4% of

Table 3
Independent survey on knee movement and patient expectations.

Question	MC	CR	PS
Does your knee feel "normal"?	(80/96 responded)	(65/70 responded)	(141/161 responded)
Very	52.7%	67.7%	71.6%
Somewhat	32.5%	23.1%	25.5%
Not at all	2.5%	9.2%	2.8%
Does your knee feel "mechanical"?	(80/96 responded)	(65/70 responded)	(141/161 responded)
Very	10%	7.7%	7.1%
Somewhat	25%	18.5%	23.4%
Not at all	65%	73.8%	69.5%
Does your knee move "naturally"?	(80/96 responded)	(65/70 responded)	(141/161 responded)
Very	92.6%	83.1%	86.5%
Somewhat	6.2%	12.3%	11.3%
Not at all	1.2%	4.6%	2.1%
Were your expectations met with TKA?	(80/96 responded)	(65/70 responded)	(141/161 responded)
Yes	93.8%	87.7%	93.6%
No	6.2%	12.3%	6.4%

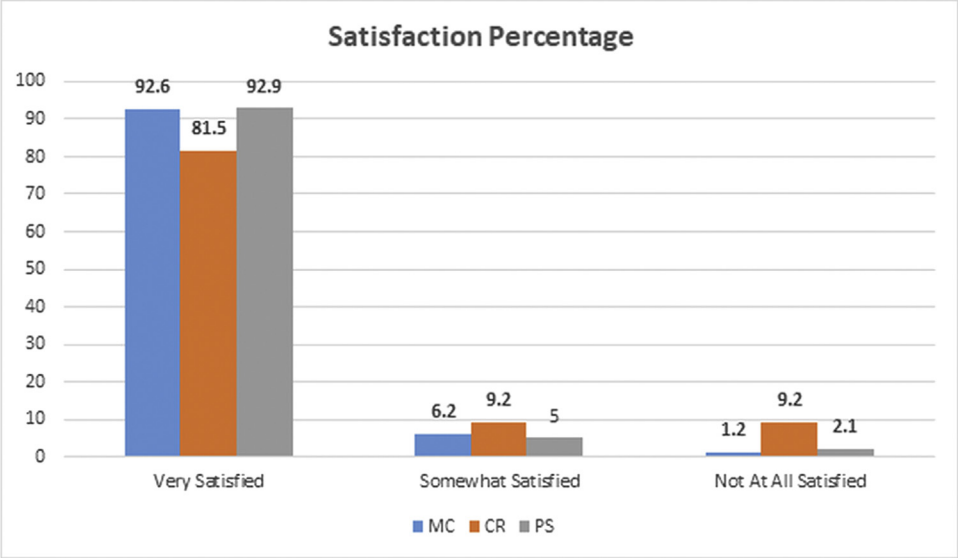

Figure 3. Patient-reported satisfaction (percentage).

patients were reported to be satisfied or very satisfied. Karachalios et al. showed significant improvements in the KSS, WOMAC, Short Form Health Survey, and Oxford Knee Scores (OKSs) with 99.1% survivorship at 5 years with the Advance Medial-Pivot knee (MicroPort Orthopedics) [15]. The same authors went on to publish 11- to 15-year outcomes with the same implant showing improvement in the same PROMs and overall survivorship of 97.3% and survivorship free of aseptic loosening of 98.8% [16]. Chinzei et al. also showed significant improvement in the KSS, with 98.3% survivorship at 8 years in the Advance Medial-Pivot knee [17]. Macheras et al. published long-term follow-up of the Advance Medial-Pivot knee with significant improvements in the KSS, WOMAC, Short Form Health Survey, and OKS with 98.8% survivorship at 17 years [18].

Multiple articles document the validity and reliability of the FJS-12 at determining outcomes after total joint arthroplasty [12,19-21]. These studies also show a much lower ceiling effect than other PROMs, making it a good tool for detecting small differences in performance in groups of patients with good clinical results. This characteristic may make the FJS-12 a better outcome tool for determining clinical success and patient satisfaction. Rosinsky et al. published an FJS-12 of 73.96 at 1 year, representing a successful outcome in total hip arthroplasty (THA) [21]. THA is thought to have higher levels of patient satisfaction than TKA. The FJS-12 results for the MC bearing in this study were 71.62, close to that of a successful THA. These results also fell between the mean (66.8) and median (75.0) normative FJS-12 data for the knee determined by Giesinger et al., representing similar awareness to that of a healthy knee joint [22].

Other authors have published comparison studies of medially stabilized implants with other forms of TKA [23–25]. Choi et al. published a study showing similar PROMs between the Advance Medial-Pivot prosthesis and a rotating-platform cruciate-sacrificing TKA (Advance-Coated System; implantcast GmbH,

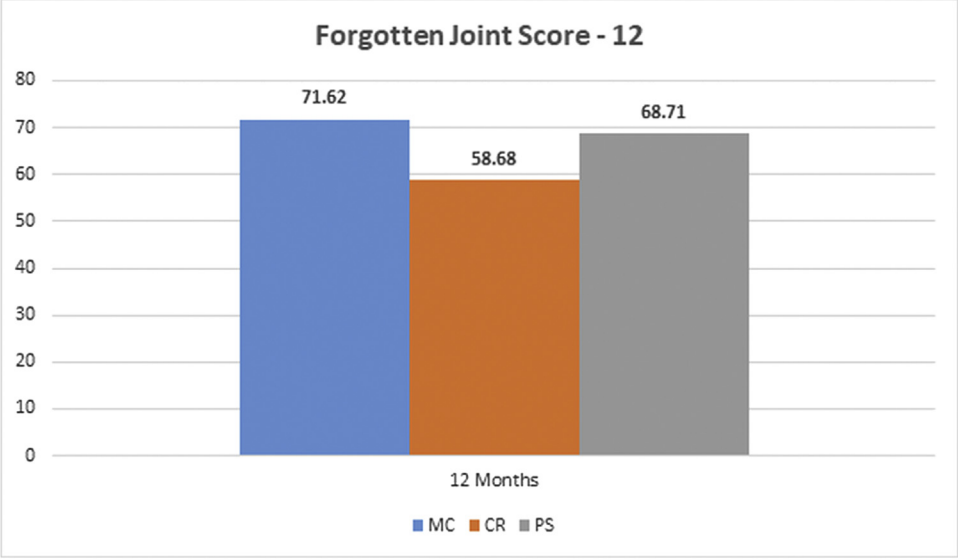

Figure 4. Forgotten Joint Score at 1 year.

Buxtehude, Germany) [23]. The rotating-platform implant, however, showed more functional satisfaction with higher demand activities. Bae et al. showed similar ROM and PROMs (KSS and WOMAC) between the Advance Medial-Pivot and the PS PFC Sigma TKA (Johnson & Johnson, Raynham, MA) [24]. A more recent study by Samy et al. compared outcomes between the Evolution Medial-Pivot (MicroPort Orthopedics) and the PS Zimmer Biomet Persona TKA [25]. There were no differences in change of the ROM after surgery, but the Medial-Pivot knees had a higher FJS-12 (MP = 59.72, PS = 44.77, $P = .007$). Pritchett published data on 440 patients undergoing staged bilateral TKA with different implants on each side [26]. The patients received a CR, PS, medial-pivot, or bicruciate-retaining implant. More patients in this study preferred bicruciate-retaining or medial-pivot implants than CR or PS. In comparison with other studies, ours is unique in that the comparison groups were all within the same implant platform.

Despite these comparison studies, there is no definitive evidence to support the use of one bearing over another; the CR vs PS debate has been ongoing for decades. Many authors have shown excellent and equivalent function and survivorship with both bearings across multiple implant companies [27,28]. Our study shows excellent outcomes and improvements in function and pain relief with all 3 bearing types. In our patient population, MC and PS bearings have significant advantages over CR with regard to patient satisfaction and the feeling of a "forgotten joint" according to the FJS-12. A limitation of our study is that we did not have a pre hoc power analysis or an established minimal clinically important difference. This limitation questions if any statistically significant results are truly clinically significant. More study is required before any definitive recommendations of bearing choice can be made.

This study has several other limitations. The patients in this study were not randomized to receive a certain polyethylene. However, all the patient groups were quite similar in their preoperative evaluation. The bearing choice was largely based on surgeon preference. For this reason, there was not a uniform distribution of bearing choices across all surgeons. The combination of CR and PS implants in the study also present a potential for confounding, so without a randomized controlled trial, it is difficult to know if the results of this study are truly due to the bearing geometry. Subtle surgeon-specific differences in technique or desired "feel" of a TKA, along with skill and outcomes, could affect the results of the study. A surgeon-to-surgeon analysis was not performed as certain surgeons were responsible for the majority, if not all, of each different group. The results of this type of analysis would likely mirror the current results. The lack of randomization also led to an unequal number of knees in each group (MC: 96, CR: 70, PS: 161). We did not compare surgical times or discharge disposition between groups, which could affect outcomes at the various time points. Our results only represent 12-month follow-up, which was the goal of this study; however, further long-term data are needed on this relatively new MC bearing. At this point, the FJS-12 has shown its ability to distinguish highly satisfied patients at both 1-year and 2-year time points, which suggests our findings should translate out to at least the 2-year mark [21]. Finally, our independent questionnaire of patient expectations and how the knee "feels" is not validated.

Despite the retrospective nature of the design, this study has multiple strengths. All data, except for the phone collection of the FJS-12 and independent survey, were collected prospectively as part of the electronic medical record and institutional database. The phone data collection was also prospective, as the answers were given for that particular point in time. We selected PROMs that rely solely on patient input without potential surgeon bias (FJS-12, KOOS, PROMIS-10). The different bearing options studied were all part of the same total knee replacement system. In addition to the cam portion of the PS femoral component, the radius of curvature differs from that of the CR component. The CR femur has asymmetric condyles with a tighter sagittal radius medially in early to mid flexion allowing for medial rotation and faster lateral condyle rollback. This design is meant to facilitate the natural kinematics of the knee and work with an intact posterior cruciate ligament (PCL). This tighter radius also allows for the use of highly congruent inserts such as the MC and UC. The PS femur has a slightly larger distal sagittal radius and symmetric condyles, as well as 1-mm thicker posterior condyles. These differences were designed to accommodate PCL resection. A highly conforming insert used with a PS femur would result in two-point loading and higher contact stresses. Despite these subtle differences, using the same implant system prevented larger differences in geometry between different knee systems from potentially confounding results. In addition, all patients received the same perioperative education, pain control, and rehabilitation protocols as part of our center's care pathways.

Conclusions

In conclusion, an MC bearing provided similar or improved early pain scores, ROM, KOOS, PROMIS-10, FJS-12, and patient satisfaction as compared with standard bearings in TKA. This type of knee design may help surgeons achieve higher levels of patient satisfaction and close the gap on the elusive 20% dissatisfaction that has been previously reported. Further clinical studies are warranted to investigate the benefits of this established bearing surface that has received renewed clinical interest.

Conflict of interests

B.M. Frye is a paid speaker for Zimmer Biomet and is a paid consultant for Zimmer Biomet and NovoSource; M.J. Dietz is a paid consultant for Heraeus Medical, holds stock ownership in Synotrac/Graftworx, and is a research committee member for the AAHKS and a BME committee member for the AAOS; all other authors declare no potential conflicts of interest.

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