■ KNEE ARTHROPLASTY: MANAGEMENT FACTORIALS

A functional comparison of medial pivot and condylar knee designs based on patient outcomes and parameters of gait

B. Benjamin,
J. R. T. Pietrzak,
J. Tahmassebi,
F. S. Haddad

From University College London Hospitals, London, United Kingdom

Aims

The outcome of total knee arthroplasty (TKA) is not always satisfactory. The purpose of this study was to identify satisfaction and biomechanical features characterising the gait of patients who had undergone TKA with either an anatomical single radius design or a medial pivot design. We hypothesised that the latter would provide superior function.

Patients and Methods

This is a study of a subset of patients recruited into a prospective randomised study of a single radius design *versus* a medial pivot design, with a minimum follow-up of one year. Outcome measurements included clinical scores (Knee Society Score (KSS) and Oxford Knee Score (OKS)) and gait analysis using an instrumented treadmill.

Results

There was no statistically significant difference between the two groups for both the KSS and OKS. There was also no statistical significance in cadence, walking speed, stride length and stance time, peak stride, mid support and push-off forces.

Conclusion

This study corroborates a previous study by the same authors that showed equally good results in clinical outcome and gait between the conventional single radius and medial pivot designs under stringent testing conditions.

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Total Knee Arthroplasty (TKA) has transformed the treatment of end-stage osteoarthritis of the knee.[1,2] It is a highly successful, effective procedure that provides pain relief and restores function.[3] The National Joint Registry (NJR) for England, Wales and Northern Ireland reports that approximately 90 000 TKAs are performed annually.[4] More than 700 000 are performed each year in the United States.[5] There is an increasing demand for TKA worldwide. It is estimated that the need for primary TKA will increase by 600% by 2030.[6] The outcomes of TKA can be evaluated in a number of ways including implant survivorship, the assessment of different radiographic parameters, clinical examination, subjective patient-reported outcome measures (PROMs) and reports of satisfaction.

The rates of survival of TKA are satisfactory and equivalent to those of total hip arthroplasty (THA).[7-9] Subjectively, an improvement in pain and function of between 50% and 168% has been reported six months post-operatively,[10,11] and between 52% and 194% at one year.[12] Most improvement has been reported to be in functional gains in sport and recreation.[12] The perpetuation or amelioration of pain has a major influence on the manner in which patients subjectively report functional outcomes.[13]

A rate of satisfaction after TKA of between 82% and 89% has been reported.[2,14,15] This is less than the 93% that has been reported for satisfaction after THA.[16] Continued disability, a reduced ability to work, a limited quality of life and poor function are still described by up to 30% of patients after TKA.[17,18]

Pain relief and return to walking alone as endpoints after TKA are insufficient for today's patients.[19] The achievement of a satisfactory range of movement (ROM) and a reasonable radiographic appearance does not ensure satisfaction.[20] Satisfaction may be improved by providing patients with a more kinematic, natural-feeling knee that is completely stable throughout a full ROM.[21]

The total condylar knee prosthesis was first introduced in 1974 with encouraging results and subsequent reports of high functional scores.[21-23] The posterior-stabilised (PS) prosthesis signalled an evolution in the design of

■ B. Benjamin, MBBS, MS (Ortho), Ch.M Ortho & Trauma) (Edin), MFSEM (Ireland), Department of Trauma and Orthopaedics
■ J. R. T. Pietrzak, MBBCh, FC Orth (SA), Department of Trauma and Orthopaedics
■ J. Tahmassebi, BSc, Research Physiotherapist
University College London Hospitals, 235 Euston Road, NW1 2BU, London, UK.

■ F. S. Haddad, BSc MD (Res), FRCS (Tr&Orth), Professor of Orthopaedic Surgery
University College London Hospitals, 235 Euston Road, London, NW1 2BU, UK and NIHR University College London Hospitals Biomedical Research Centre, UK.

Correspondence should be sent to B. Benjamin; email: bijuben@yahoo.com

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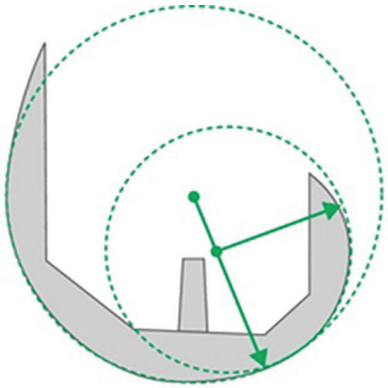

Fig. 1

Anatomical single radius design.

Fig. 2

MCBS design.

TKAs in 1978. These posterior-stabilised TKA implants afford stability to the knee by blocking posterior translation of the tibia on the femur through a post (on the polyethylene insert) and a cam (on the posterior femoral condyles). They were introduced with the aim of improving stair-climbing, allowing an increased ROM and stopping posterior tibial subluxation.[24] The advancement to the posterior cruciate ligament (PCL) retaining knee component in the 1990s sought to allow an even greater ROM and further limit femoral roll-back. Comparisons between the PS- and PCL-retaining components showed equivalent ROM and functional outcomes as assessed by various PROM scores.[25,26] Both these designs show paradoxical anterior femoral translation during flexion of the knee in fluoroscopic studies.[27]

The conceptualisation, in 1994, of a medially conforming 'ball-and-socket' (MCBS) articulation of the medial tibiofemoral compartment aimed to provide more appreciable stability in a full ROM. The MCBS design was intended to replicate the kinematics of normal knees by ensuring minimal or no femoral rollback of the medial condyle.[28-30] Kinematic studies had shown that the normal knee is essentially a medial ball and socket, in which a more mobile lateral side moves around the medial side.[28,31] Thereafter, the constraint of the TKA was enhanced by increasing the curvature of the medial femoral condyle. Subsequently, contact stresses were better with reduced polyethylene wear.[32] The increased restraint that the medial rotation knee provided as a result of the augmented congruence did not compromise fixation.[32] Both PS and MCBS designs have components which minimise paradoxical movements during mobilisation.[33]

Little has been reported about the objective measurements of the patterns of gait after TKA.[10] Previously, gait analysis was used simply as a research tool,[34-36] and the conventional laboratory-based assessment of gait was expensive, time-consuming and required a specialist laboratory. However, newer methods of gait analysis have evolved.

Gait analysis after TKA has revealed a constant decrease in the total ROM in the knee, especially reduced flexion during the stance phase.[7,37,38] The kinematics of the knee are changed after TKA, with only a third of patients showing a biphasic pattern of sagittal plane moments.[39] The patterns of gait are different in TKA when compared with THA. The speed of gait is lower after TKA than after either THA or unicompartmental arthroplasty of the knee (UKA).[39,40]

This study uses new technology in gait analysis to compare the functional outcomes of single radius PS and medial pivot designs of TKAs. The purpose was to identify satisfaction and biomechanical features characterising the gait of patients who had undergone TKA using either the anatomical single radius or medial pivot design. We hypothesised that the latter would provide superior function.

Patients and Methods

This was a subset of a prospective, single-centre, randomised controlled trial (RCT) comparing the anatomical single radius (Press Fit Triathlon knee system, Stryker, Kalamazoo, Michigan) (Fig. 1) and the MCBS (SAIPH Knee system, MatOrtho, Leatherhead, United Kingdom) (Fig. 2) TKAs.

The indications for surgery in both groups included osteoarthritis, traumatic and rheumatoid arthritis. Those who had previously undergone UKA or a high tibial osteotomy with progression of disease were also included. The contraindications included active, local and systemic infection, poor muscle function, severe osteoporosis, and vascular impairment in the affected limb. We also excluded patients with cognitive impairment, a neurological deficit affecting mobility and a pre-existing contralateral TKA. The patients were blinded to the design of the implant. Randomisation was performed using a computer random number generator by a specialist physiotherapist who was not involved in the surgery. A total of 45 patients were randomised into each group.

All operations were performed either by the senior author (FSH) or under his supervision using a standard midline incision and medial parapatellar arthrotomy. Cruciate sacrificing implants were used and tibial cuts were

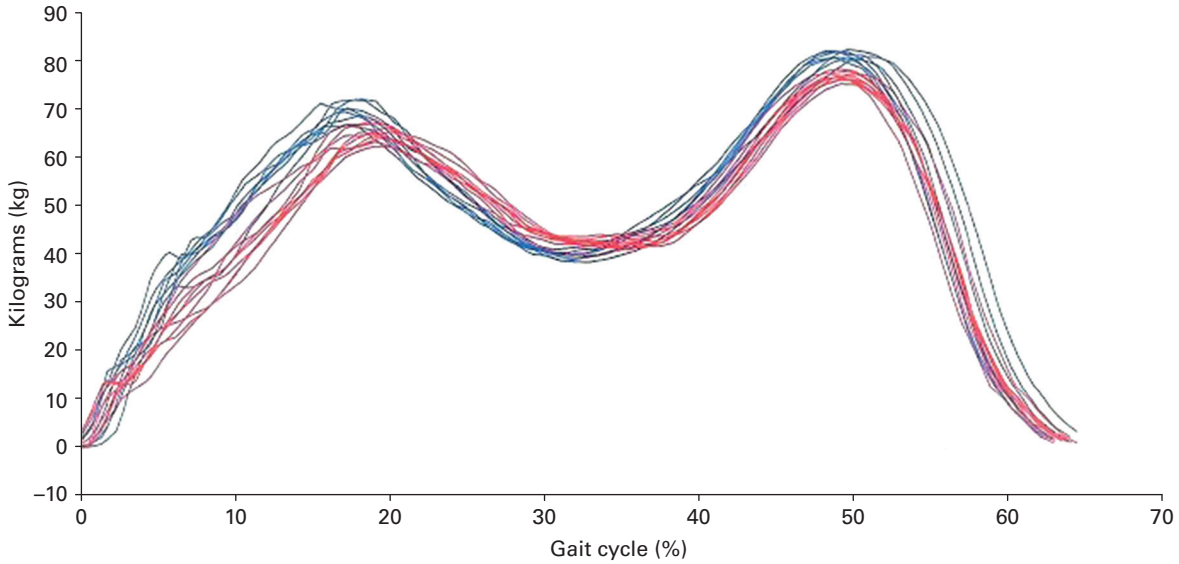

Fig. 3

Graph showing analysis of the pattern of gait using force plates built into treadmill. Red is for left and blue is for right lower limbs.

done first using extramedullary alignment jigs. These were made perpendicular to the long axis of the tibia with a posterior slope of between 0° and 3°. The femur was prepared using intramedullary alignment with a valgus angle of between 5° and 7° and external rotation of 3°.

Femoral bone cuts were made in the sequence as recommended by the surgical protocol of the Triathlon knee system and SAIPH Knee system. After removal of posterior and peripheral osteophytes, soft-tissue balance was assessed using the Tibial insert trial. Flexion and extension gaps were balanced using a sequential approach.[41] The patella was resurfaced in all patients. All components were implanted using cement. No drains were used.

The post-operative protocol included chemical and mechanical thromboprophylaxis unless specifically contraindicated. All patients received one dose of parenteral antibiotics at the induction of anaesthesia and two further doses post-operatively. Flexion and extension exercises of the ankle and isometric quadriceps contraction exercises were started on the first post-operative day, with full weight-bearing as tolerated. The aim of mobilisation with a physiotherapist was to obtain flexion of the knee of 90° mobilising with a walker and walking with crutches by the fifth post-operative day.

The patients were reviewed at six weeks, six months, one year, and two years post-operatively with routine clinical assessment. Radiographs were undertaken immediately post-operatively and at one year.

After the review at one year post-operatively, ten patients were randomly selected from each group. The mean age of the patients in the anatomical single radius group was 64.8 (58 to 73) years and in the MCBS group was 62.4 years (54 to 71). There were seven men and three women in the former group and six men and four women in the latter group. Clinical outcome was assessed using the Knee Society Score (KSS)[42] and Oxford Knee Score (OKS),[43] which were recorded pre- and post-operatively. Post-operative assessment was undertaken by a specialist physiotherapist who was blinded to the choice of implant.

All patients underwent gait analysis using an instrumented treadmill with force plates (Kistler Gaitway, Kistler Instrument Corporation, Amherst, New York) at the patient's self-selected comfortable speed on a level platform by a research fellow who was also blinded to the choice of implant. Vertical ground reaction forces and spatiotemporal data were obtained from force plates built into the treadmill (Fig. 3).

The study had ethical approval.

Statistical analysis. The gait data were captured for ten seconds at each speed and included cadence, walking speed, step length, stance time, peak force in stride, mid support force in stride and push-off force. We calculated descriptive statistics (mean, SD, range) for the continuous study variables. Statistical significance was also calculated for all the parameters by using independent-samples *t*-test calculation and GraphPad software (GraphPad Software, Inc., La Jolla, California). Statistical significance was set as < 0.05.

Results

In the anatomical single radius group, the mean pre-operative KSS and OKS were 51.8 (34 to 63) and 27.2 (21 to 38), respectively. In the MCBS group, the mean pre-operative KSS and OKS were 54.2 (38 to 65) and 29.7 (25 to 38), respectively.

One year post-operatively, the outcome scores were better for the anatomical single radius group than for the MCBS

Table I. Clinical outcome scores

Outcome	Triathlon	SAIPH	p-value*
OKS	40.4 (25 to 48)	39.6 (28 to 48)	0.85
KSS	87.2 (55 to 100)	85.1 (53 to 100)	0.81

*Calculated using independent-samples *t*-test OKS, Oxford Knee Score; KSS, Knee Society Score

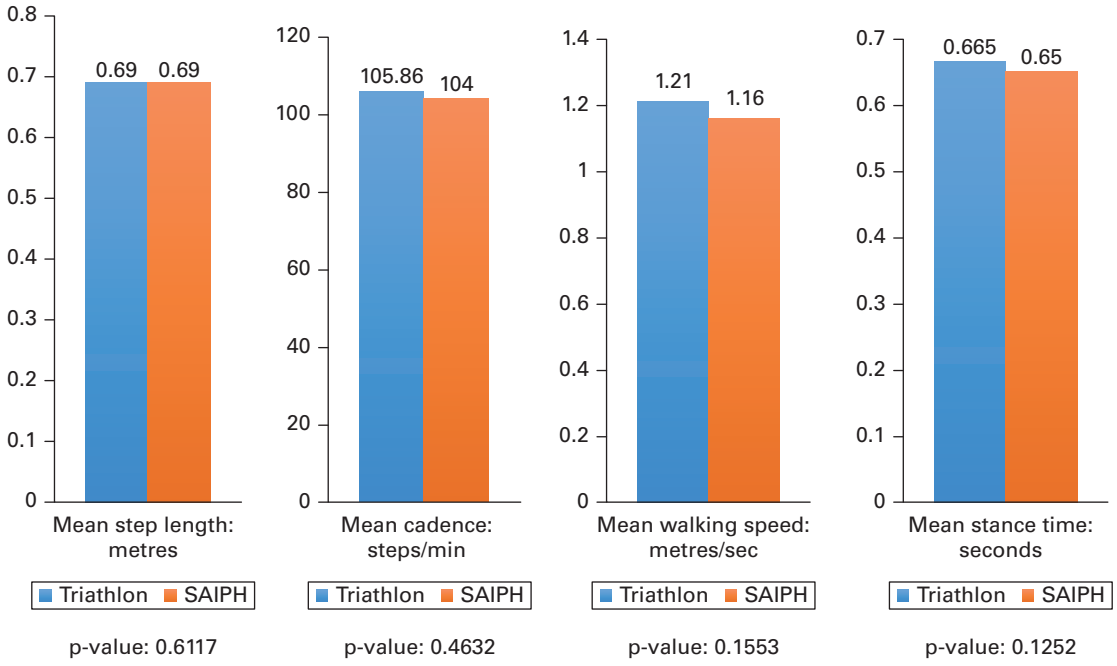

Fig. 4

Analysis of parameters of gait.

group (Table I). The differences were not statistically significant (p = 0.85 and 0.81, respectively).

Analysis of the parameters of gait showed that the mean cadence was higher in the single radius group (105.9 *vs* 104) but the difference was not statistically significant (p = 0.46). The mean step length was equal in both groups (0.69 *vs* 0.69). The mean walking speed was higher in the single radius design (1.21 *vs* 1.16) but the difference was not significant (p = 0.16). The mean stance time was also higher in the single radius group (0.67 *vs* 0.65), but again was not significant (p = 0.13) (Fig. 4).

There was also no statistical significance in the mean peak force in stride (p = 0.34), mean mid support force in stride (p = 0.17) and mean push-off force (p = 0.74) (Fig. 5).

Discussion

During a ROM from -10° to 110° flexion, the normal medial femoral condyle does not move anteroposteriorly, but the lateral femoral condyle can translate posteriorly between 0 and 15 mm.[44] The stability of the native medial compartment is due to: 1) the concavity of the tibial condyle (spherical dish); 2) the fact that the femoral condyle does not move anteroposteriorly with flexion to 120° (no femoral 'roll-back') and 3) the fact that the medial meniscus is fixed and the medial collateral ligament is broad and on average has no more than 3 mm laxity.[45]

The aim of constraining designs such as the PS and MCBS is to reduce paradoxical movement during mobilisation.[33] Anteroposterior stability in PS designs occurs when the post of the tibial insert engages the cam of the femoral component. Different authors have reported that this occurs at various angles of flexion, between 20° to > 90°.[33,46] On the other hand, the MCBS design, with a conforming, congruent, medial tibiofemoral articulation and a raised anterior and posterior lip, provides stability throughout the ROM to prevent anteroposterior translation. The lack of congruence on the lateral side allows lateral femoral rollback similar to the normal kinematic profile of the knee.[46] This specific design feature may translate as more efficient kinematics contributing to better ROM.

The aim of this study was to compare the clinical and functional scores, and parameters of gait of the MCBS design of TKA with a more natural femoral rollback profile

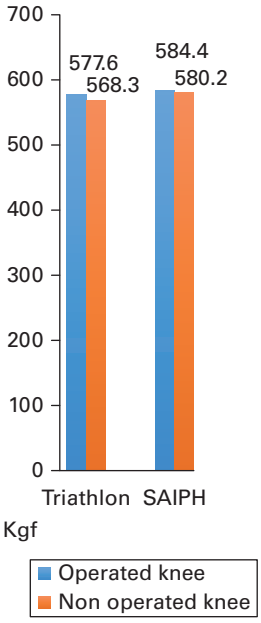

Fig. 5a

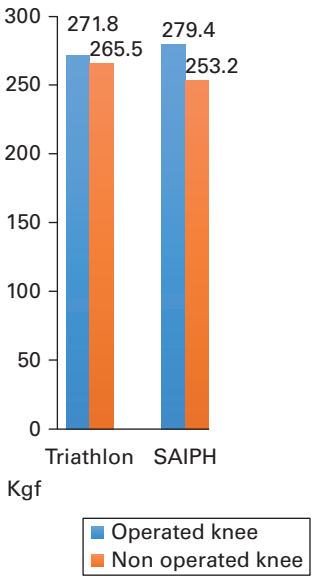

Fig. 5b

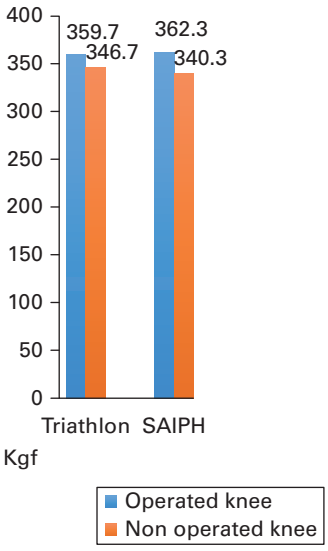

Fig. 5c

Analysis of parameters of force in gait: a) peak force in stride (p = 034); b) mid support force in stride (p = 0.17); c), push-off force (p = 0.74).

to a conventional PS fixed-bearing design. We chose to compare the MCBS with an anatomical single radius design in which the anatomical radius about the transepicondylar axis provides isometry of the ligaments throughout the ROM from full extension to full flexion (Press Fit Triathlon knee system, Stryker, Kalamazoo, Michigan).

Spatiotemporal parameters, in particular the speed of gait, can affect angular motion and moments of the joints in the lower leg.[47,48] Greater length of stride and walking speed can increase the ROM of the joints. Increased speed will increase the forces applied to the ground and consequently will increase joint moment.[48] A decreased stance time may reflect a strategy to avoid extra-loading and may be a post-operative accommodation.[49] We found no statistically significant differences between the two designs in any of the spatiotemporal parameters. Peak force in stride can be considered as an indicator of overall muscular support during contact with the ground. A balance between stability of the knee and shock absorption is achieved by eccentric quadriceps contractions during loading.[50] The knee extension moment is important to decrease the reaction force from the ground to the body at mid-stance and to increase the ground reaction force during weight acceptance as well as the push-off force. In our study, all parameters of force were also not significantly different in the two designs.

There was an overall improvement in function after surgery, which is consistent with reports for both designs.[32,51,52] The KSS and OKS in the two groups were not significantly different, as has been previously reported.[21]

The main limitation of the study is that pre-operative gait data were not collected. It would have been useful to confirm that both groups had a similar gait prior to surgery. Also, while gait analysis is accurate and objective, we measured the various parameters at the patients' self-selected speed. The favourable kinematic profile of the MCBS design could have probably functioned better at higher speeds or when walking up an incline and this is the focus of our future studies.

The MCBS design offers potential for better movement and tracking, good function and satisfaction, leading to increasing interest in this design. Compared to a conventional PS design, it provides anteroposterior stability throughout the entire ROM. However, it is unclear whether this difference in design translates to clinical and functional improvement. We have previously reported excellent results in terms of ROM with a medial pivot designed knee.[21] The findings in this study corroborate this earlier report, with no significant difference, and therefore equally good results in clinical outcome and gait between the conventional single radius and medial pivot designs under stringent testing conditions.[21] It is to be noted that our previous study was a comparison of the MCBS design with the Press Fit Condylar Sigma PS (PFC; DePuy, Warsaw, Indiana) design and not the Triathlon design. This could be the reason why we have not seen superiority of the MCBS design. Further studies are required to investigate the long-term survivorship and satisfaction.

Take home message:

- This study showed equally good results in clinical outcome for patients who had undergone total knee arthroplasty with the conventional single radius design and the medial pivot design.
- Under stringent testing conditions, there was no statistically significant difference in gait analysis between single radius design and medial pivot design.

Author contributions:
B. Benjamin: Writing the paper.
J. R. T. Pietrzak: Statistical analysis.
J. Tahmassebi: Collecting outcome scores.
F. S. Haddad: Principal surgeon.

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