ORIGINAL ARTICLE

Medial pivot vs posterior stabilized total knee arthroplasty designs: a gait analysis study

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ABSTRACT

Aim To compare a medial pivot (MP) total knee arthroplasty (TKA) with posterior stabilized (PS) TKA designs from a subjective, clinical and biomechanical point of view, in a single-centre, single-surgeon, case-control non-randomized trial.

Methods Sixteen patients were randomly picked up from case series into each group. Subjective outcome was assessed using the Forgotten Joint Score Questionnaire (FJSQ). Clinical evaluation included range of motion (ROM). All patients underwent gait analysis by a treadmill with force-measuring plaques and video-recording device; data were recorded for 30 seconds and included cadence, step length, stance time and walking speed. A blinded qualitative analysis of the pattern of gait was defined as biphasic or non-biphasic. Descriptive statistics for the continuous study variables and statistical significance were calculated for all parameters with independent-samples t-test and χ^2 test to analyse difference in pattern of gait between groups.

Results Mean FJSQ in the MP group was 91.87 (CI 95%: 88.12-95.46) and 75.31 (CI 95%: 67.97-81.56) in the PS group (p=0.029). Mean post-operative ROM was 117° (CI 95%: 113°-122°) in the MP group and 112° (CI 95%: 108°-117°) in the PS group (p=0.14). No statistical difference was found between groups regarding all gait analysis parameters which have been recorded.

Conclusion MP TKA design showed better subjective results using the FJSQ, but it did not improve significantly clinical and functional outcomes compared to PS TKA design, at a short-term follow-up.

Key words: forgotten joint, mid-flexion instability, PROMs, subjective results, TKA

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INTRODUCTION

Total knee arthroplasty (TKA) is one of the most performed surgical procedures in orthopaedics. It is the most effective operative treatment for end-stage knee osteoarthritis (OA), and it has been designed to allow patients to regain an acceptable function of the operated knee while treating pain-related symptoms (1,2). In France, more than 100.000 TKAs were implanted during 2017 only (3), and some authors predict that by 2030, the number of primary TKA will raise by 600% (4). However, up to 25% of the patients report unsatisfactory subjective outcomes after TKA, mostly a subset of younger population who are not satisfied with the inability to perform high level activities after surgery (5,6).

Since 1974, when the total condylar knee prosthesis was firstly used, several prosthetic designs have been introduced, among them the posterior stabilized (PS) design, the cruciate retaining (CR) design and the medial pivot (MP) design introduced in 1994. In the United States, in 2016, approximately 50% of TKAs were PS and 42% were CR in design (7).

One possible explanation of the unsatisfactory reports after TKAs might be found in the altered biomechanics. The TKAs do not reproduce physiological knee biomechanics, in particular with PS and CR designs: several studies have demonstrated paradoxical anterior movement of the femur in respect of the tibial plateau from 5° of extension to 90° of flexion with a phenomenon called mid-flexion instability (7–11). Normal knee kinematics studies have demonstrated that the medial condyle has minimal to no rollback while the lateral condyle can show more rollback movements (12–16). The rationale of the MP design is to better reproduce the normal knee kinematics. The design is characterized by a ball and socket geometry, a high congruence in the medial side between condyle and tibial insert, and the morphology of the tibial insert which prevents from paradoxical anterior translation of the femur on the tibial plateau. The MP design seems not to increase the risk of post-operative complications such as aseptic loosening, and it showed similar survival rates compared to PS and CR designs also at long-term follow up (FU) (17–22). In vitro, biomechanics of MP prostheses have been proven to be similar to that of the native knee joint. Some authors have reported good clinical outcomes of MP TKAs without a control group (17,19–21,23). In literature there are few direct comparisons between MP and other designs (24,25). These reports showed some advantages of the MP design as a better range of motion (ROM) or better results at patient-reported outcomes measurements (PROMs), but a recent paper by Benjamin et al. showed no difference in the *in vivo* kinematics and clinical results between MP and PS TKAs (26).

The aim of this study was to investigate if in our hands a MP design could lead to better *in vivo* kinematics and clinical outcomes compared to a PS design at short-term FU.

PATIENTS AND METHODS

Patients and study design

This retrospective case-control, single-centre, single-surgeon, double-blinded, non-randomised trial compared 16 patients who underwent TKA with a MP implant (MP group) (Evolution Medial Pivot; Microport, Shangai, CHN) and 16 patients operated on of TKA with a PS (PS group) (Persona-PS; Zimmer, Warsaw, IN, USA) prosthesis. Patients were picked up casually in both groups from the database of the Azienda Ospedaliera Universitaria Pisana and the Azienda Ospedaliera Universitaria Senese during the period 2015 – 2019 matching them for age and gender; minimum FU was set at one year post-operatively for both groups. Severity of OA or type of deformity were not matched, but all surgeries were performed by a single surgeon (SG) for primary knee OA. Exclusion criteria were rheumatoid arthritis and post-traumatic OA, comorbidities such as cognitive impairment and/or neurological deficits that could alter gait, and a pre-existing contralateral TKA.

The two groups were comparable regarding the age, gender, pre-operative alignment on the frontal plane and ROM (Table 1), and FU period (mean 25.4 months and 23.4 months for the MP and PS group, respectively). Both patients and researchers who performed gait analysis were blinded to the design of the implant.

All patients gave their written consent to the treatment and anonymous use of data and images for research and academic purposes. At our Institutions, no Ethical Committee nor Institutional Review Board approval are needed for retrospective studies.

Methods

A medial parapatellar approach was used in all cases; all implants were cruciate-sacrificing, and the patella was not resurfaced. After joint exposure, the femur was prepared using intramedullary alignment aiming to with an anatomical valgus angle between 5° and 7° and an external rotation of the femoral component of 3° for varus knees and 5° for valgus knees, using a posterior condylar referenced cutting jig. Tibial cuts were made using an extramedullary guide perpendicular to the long axis of the tibia with a posterior slope of between 0° and 3°. After osteophytes removal, soft-tissue balancing in the frontal plane and flexion-extension gaps were assessed. All components were cemented. One drainage was then inserted and left in place for a maximum of two days post-operatively.

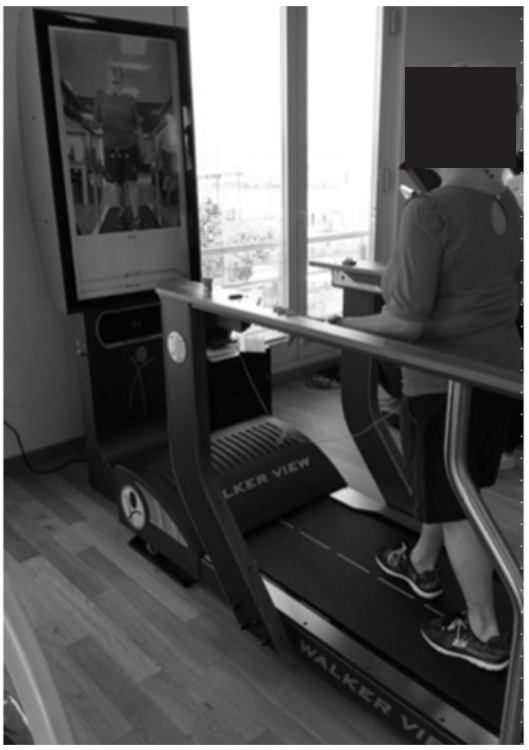

Figure 1. Patient during gait analysis on Walker View 3.0 (Gesi M, 2019)

On the first post-operative day, early passive ROM exercises began, and isometric contractions of the quadriceps were also advised. Weight-bearing and short walks were encouraged by the second post-operative day. By the fifth post-operative day, patients were expected to walk with crutches, climb stairs and have a 90° of flexion of the knee. Patients were evaluated at the outpatient clinic at 1, 2, 6 and 12 months post-operatively, and then annually, with clinical and radiological FU.

Subjective outcome was assessed using the Forgotten Joint Score Questionnaire (FJSQ) (27) at every FU. Pre- and post-operative clinical evaluation including ROM were recorded by an investigator blinded to the implant using a goniometer. All patients underwent gait analysis by a treadmill with force measuring plaques and video-

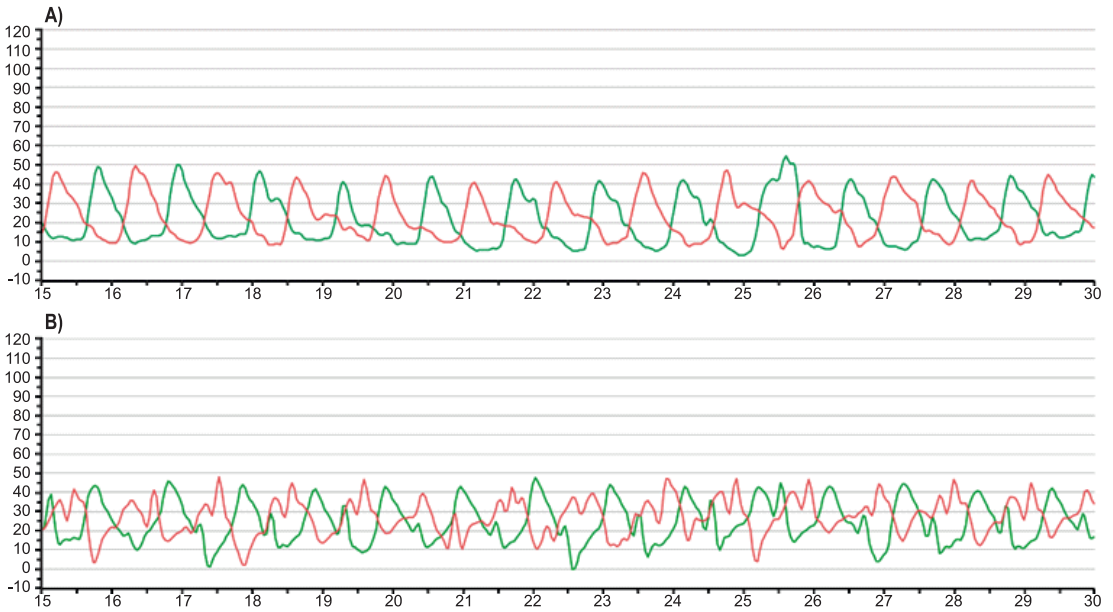

Figure 2. Knee range of motion (ROM) during 30' gait on the Walker view (gait analysis from second 15 to 30 is presented). A) Patient with right total knee arthroplasty (TKA) presenting a biphasic pattern of gait; B) Patient with left TKA presenting a non-biphasic gait. Time (s) in the horizontal axis and knee flexion degrees (°) in the vertical axis. Red is left knee ROM, Green in right knee ROM

recording device (Walker View 3.0, Tecnobody, Dalmine, I) (Figure 1) at 2-years FU. Patients were told to walk at a comfortable speed. Data about gait were taken for 30 seconds and included cadence, step length, stance time and walking speed. A qualitative analysis of the pattern of gait was also performed and we defined it as biphasic or non-biphasic (Figures 2A and 2B). All gait analyses were recorded by a specialized investigator blinded to the implant design.

Statistical analysis

Descriptive statistics for the continuous study variables was used. Statistical significance was calculated for all parameters with independent-samples t-test calculation and a χ^2 test to analyse difference in pattern of gait between groups. Statistical significance was set as $p<0.05$, the confidence interval (CI) was set at 95%.

RESULTS

In the MP group there were eight males and eight females, with a mean age of 72 (CI95%: 68 – 76) years, while in the PS group there were nine males and seven females with a mean age of 71 (CI95%: 69 – 74) years. Pre-operative ROM was 105° (CI95%: 96° – 107°) and 106° (CI95%: 95° – 109°) for the MP and PS groups, respectively. Mean pre-operative mechanical axis was 4° of varus (CI95%: 12° varus – 13° valgus) in the MP group and 6° of varus (CI95%: 13° varus – 4° valgus) in the PS group (Table 1).

Table 1. Characteristics of two groups of patients

Characteristic	MP group	PS group
Gender (No)	8 males / 8 females	9 males / 7 females
Age (years) (mean; CI 95%)	72 (68 – 76)	71 (69 – 74)
Pre-operative ROM (°) (mean; CI 95%)	105 (96 – 107)	106 (95 – 109)
Pre-operative mechanical axis (°) (mean; CI 95%)	4 varus (12 varus - 13 valgus)	6 varus (13 varus – 4 valgus)

MP, medial pivot; PS, posterior stabilized; ROM, range of motion

Mean FJQS was 91.87 (CI95%: 88.12 – 95.46) in the MP group and 75.31 (CI95%: 67.97 – 81.56) in the PS group; with a two-tailed, independent samples t-test the difference was statistically significant (p=0.029). Mean post-operative ROM was 117° (CI95%: 113°–122°) and 112° (CI95%: 108°–117°) in the MP and PS groups, respectively (p=0.14).

As for gait analysis results, step length was 25.2 (CI95%: 20.7–31.7) cm in the MP group and 21.1 (CI95%: 19.2–22.7) cm in the PS group (p=0.26). Mean cadence was 0.68 (CI95%: 0.61–0.76) cycles/s and 0.62 (CI95%: 0.57–0.66) cycles/s in the MP and PS group, respectively (p=0.11). Mean stance time was 1.2 (CI95%: 1.0–1.2) s in the MP group and 1.2 (CI95%: 1.1–1.3) s in the PS group ($p = 0.19$). Walking speed was 1.24 m/s in the MP group and 1 m/s in the PS group (p=0.24). A biphasic pattern of gait was detected in 6 out of 16 patients in the MP group and in 4 out of 16 patients in the control group; a □2 test did not detect any significant difference (p=0.58) (Table 2).

Table 2. Subjective, clinical and gait analysis results of two groups of patients

Variable	MP group	PS group
FJSQ (points)	91.87 (88.12 – 95.46)	75.31 (67.97 – 81.56)
Post-operative ROM (°) (mean; CI 95%)	118 (113 – 122)	112 (107 – 117)
Walking speed (m/s)	1.24	1.00
Walking Cadence (cycle/s) (mean; CI 95%)	0.68 (0.61 – 0.76)	0.62 (0.57 – 0.66)
Step Length (cm) (mean; CI 95%)	25.2 (20.7 – 31.7)	21.1 (19.2 – 22.7)
Stance Time (s) (mean; CI 95%)	1.2 (1.0 – 1.2)	1.2 (1.1 – 1.3)
Biphasic Gait Pattern (No) (YES/NO)	YES: 6; NO: 10	YES: 4; NO: 12

P, medial pivot; PS, posterior stabilized; FJSQ, Forgotten Joint Score Questionnaire

DISCUSSION

During knee ROM, from 0° to 110° of flexion, the medial condyle does not make any antero-posterior translation while the lateral condyle usually translates 0–15 mm posteriorly (28). Stability of the medial compartment derives from bone/cartilage congruence between the medial femoral condyle and the medial tibial plateau: during ROM no rollback is observed; furthermore, the medial meniscus has little motility and adds stability to the compartment. For that reason, the medial compartment of the knee has been defined as a ball-in-socket articulation (16). Paradoxical anteposition of the femoral condyle to the tibial plateau in a ROM between 0° and 90° of flexion has been reported after implantation of a CR-design TKA; such an altered kinematics was linked to a phenomenon called ‘mid-flexion instability’ that was associated with sub-optimal outcomes following implantation of a CR implants. Also,

the subgroup of patients with CR prostheses referred to have a sensation of a non-native knee joint after surgery, and this was related also to the mid-flexion instability (29).

The PS and MP design prosthesis have been developed to give a more stable knee motion during the full ROM. To reach that goal, these designs were planned to eliminate the femoral anteposition towards the tibial plateau (30). The PS design was set to give stability preventing the anteposition of the femur by the contact of the femoral cam with the post of the tibial insert. Several authors have reported the mechanism to be effective in a ROM from 0° to more than 90° of flexion (30,31). However, when the knee passes 90°of flexion, also PS TKAs could reproduce paradoxical movements (11). On the other hand, the highly congruent design of the medial compartment in MP TKAs has been developed to maintain maximal stability during the entire ROM (10). Thanks to the congruence between femoral component and the medial part of the polyethylene insert, with a more pronounced anterior and posterior borders, femoral anteposition should be avoided during the entire knee ROM. On the lateral side, a less pronounced congruence between the femoral component and the tibial insert gives the opportunity to have rollbacks and to better reproduce the native knee joint kinematics (31).

The aim of the presented study was to compare subjective, clinical and functional outcomes of patients that underwent the implantation of a MP TKA compared to a group of patients that underwent implantation of a PS TKA. Several papers have reported favourable outcomes after implantation of a MP TKA, with satisfactory results at a medium- and long-term FU (18,19,21,32–34). Fan et al. showed significant improvements of ROM and scores to assess pain-related symptoms at 5-years FU (35). Bordini et al. reported good clinical outcomes following the implantation of a MP TKA with a 96% survival to any failure of the implant at 5-years FU (34). These authors hypothesized that the high congruence of the medial compartment could lead to less polyethylene wear and consequently to lower rates of failure due to the subsequent 'debris' osteolysis and aseptic mobilization. However, the Australian Orthopaedic Association National Joint Replacement Registry detected higher revision rates following implantation of a MP TKA compared to PS TKA for aseptic loosening or anterior knee pain (19). The present study showed similar results compared to the literature regarding ROM improvements (36,37). In particular, no significant differences between the post-operative ROM of MP or PS TKAs were found; however, a positive trend in favour of MP TKA has been detected. Shakespeare et al. have reported a mean post-operative ROM of 111° in the MP group compared to 109° in the PS group at 1-year FU (36). Another randomized trial reported higher post-operative ROM at 1- and 2-years FUs in the MP group compared to the PS group (24). Samy et al. showed a higher ROM in the MP group compared to the PS group (122° vs 116°); however, again, that result was not statistically significant (25). On the other hand, another paper reported worse outcomes in post-operative ROM in MP TKA compared to a mobile bearing design (38).

The most relevant result of this study is statistically significant better results in subjective outcomes as measured by PROMs. In the last 20 years of practice, patients' expectations following a TKA have changed enormously: nowadays patients want to regain high levels of functionality after TKA. In the presented study, to assess the clinical outcomes, the authors preferred to use the FJSQ, that has been tested in various reports (25,39–43). Many authors preferred to assess subjective outcomes using other scores, for example the WOMAC (44), the SF-36 (45), Knee Society Score (KSS) (46) and the Oxford Knee Score (47). Hossain et al. showed better clinical outcomes in MP patients group compared to PS using SF-36 score (24). Samy et al. detected a significantly higher FJSQ in patients that underwent implantation of a MP TKA compared to a control group that underwent implantation of a PS TKA (25). On the other hand, several authors did not find any differences in the subjective and clinical outcomes between the patients from MP or PS groups (36,37). In particular, Bae et al. did not find any differences in the outcomes detected by WOMAC and KSS. In the presented study, a statistically significantly better FJSQ was detected in the MP group compared to the PS group. Furthermore, an interesting clue was that the question with the most different reports

between MP and PS group was the following: *"Do you feel to have a TKA with a sensation of an artificial knee when you stand up from a chair?"*. During daily activities, the full load on the patient knee acts not only in extension but also when the knee is flexed (48). To stand up from a chair, a high level of mid-flexion stability is required. Mid-flexion instability is defined as a dynamic antero-posterior instability of the knee during the motion between 0° and 90° of flexion (9). When the knee is fixed at 0° or 90°, the mid-flexion instability cannot be detected; this instability is not linked to a varus-valgus laxity of the knee (9). Mid-flexion instability has been recognized as a major cause of revision. Several reports have demonstrated that the mechanism underlying mid-flexion instability could be an elevation of more than 4 mm of the articular joint line conjoined with the anterior shift of the femoral component to the tibial plateau (49–51). In a review by Ramappa, it was highlighted that the mid-flexion instability was linked to a high joint line, to a multi-ray TKA design and to a laxity of the medial collateral ligament (52). The results of the presented study, in particular the perception of stability in the mid-flexion activities such as standing up from a chair in the patients of MP group, are in favour of the MP design.

In gait analysis, several spatial-temporal parameters can be used to study the ROM and the force applied on the inferior limb joints (53,54). When the step length and walking speed increase, the knee ROM increases consequently, and when the walking cadence increases, also the force peak in stride increases and consequently the knee joint momentum (54). A decrease in the length of stride is usually associated to a post-operative adaptive strategy to decrease an excessive loading on the joint and it is associated with worse post-operative outcomes after TKA implantation (55).

In the current study, no statistical difference was found between groups regarding all gait analysis parameters which have been recorded. Also, Benjamin et al. did not show any differences in gait analysis of spatial-temporal parameters between two groups of patients treated by TKA with PS or MP design (26). As for the gait pattern (biphasic or altered), we did not detect any differences between groups being 4 patients in the PS group and 6 in the MP group that showed a biphasic pattern of gait (similar to a native joint). These results are in line with a report by Wilson et al; they found that only 25% of patients treated with a PS TKA had regained a biphasic pattern of gait at 4-years FU (56).

One of the major limitations of the current study is the lack of a pre-operative gait analysis. It would have been useful to compare pre-operative gait analysis between the two groups. Another limitation is the length of the FU, with a collection of data at a short term. This could be an important element since the expected gain in function and ROM in MP design TKA could be reached at 2 years post-operatively.

In conclusions, the results showed that patients who underwent the implantation of a MP TKA showed better subjective results compared to patients who received a PS TKA. In particular, patients who received a MP design TKA reported a better mid-flexion stability and a better perception about the prosthesis towards a sensation of a more 'natural' knee joint. As for clinical and kinematics results, the MP design did not show any improvements in ROM and gait analysis compared to the PS design at a short-term FU.

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TRANSPARENCY DECLARATION

Conflict of interest: None to declare.

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