Arthroplasty Today 23 (2023) 101178

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

Postoperative Medial Tilting of the Joint Line and Preoperative Kinematics Influence Postoperative Medial Pivot Pattern Reproduction in Total Knee Arthroplasty

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A R T I C L E I N F O

Article history:
Received 29 March 2023
Received in revised form
2 June 2023
Accepted 3 July 2023
Available online xxx

Keywords:
Total knee arthroplasty
Medial pivot pattern
CT-Free navigation system
Kinematics
X-ray

A B S T R A C T

Background: Reproducing the medial pivot pattern after total knee arthroplasty (TKA) is known to improve patient satisfaction. However, the factors affecting the postoperative medial pivot pattern in TKA are controversial. The purpose of this study was to examine the factors affecting the postoperative medial pivot pattern in posterior-stabilized TKA.

Methods: This study involved 30 cases with knee osteoarthritis who underwent primary posterior-stabilized TKA. The preoperative and postoperative kinematics were measured using a computed tomography—free navigation system, and the patients were divided into the following 2 groups: the medial pivot pattern (MP) group and non—medial pivot pattern (non-MP) group. In addition, we measured each of the following angles on X-ray films (preoperative and postoperative femorotibial angle, hip-knee-ankle angle, mechanical lateral distal femoral angle, medial proximal tibial angle). We examine the factors affecting the postoperative medial pivot pattern.

Results: There were 14 cases in the MP group and 16 cases in the non-MP group at the preoperative knee kinematic assessment and 17 cases in the MP group and 13 cases in the non-MP group at the postoperative knee kinematic assessment. The preoperative kinematic pattern was conserved after the surgery at a rate of 76.7%. The postoperative MP-group showed a significantly smaller preoperative femorotibial angle and hip-knee-ankle and a significantly smaller postoperative mechanical lateral distal femoral angle and medial proximal tibial angle in comparison to the postoperative non-MP group.

Conclusions: Preoperative kinematics and postoperative mechanical lateral distal femoral angle and medial proximal tibial angle may be important factors that affect the postoperative medial pivot pattern.

Introduction

The medial pivot pattern (ie, femoral external rotation relative to the tibia with the medial condyle as the center of rotation throughout knee flexion) is known as the kinematic motion pattern of the normal knee [1—5]. However, this kinematic pattern may not be observed in patients with knee osteoarthritis. The knee kinematics involve not only the skeletal structure, but also the ligaments, muscles, and cartilage [6,7]. The medial pivot pattern is considered important because it has been reported to affect patient-reported outcomes in total knee arthroplasty (TKA) [8].

One of the problems with total knee arthroplasty is that the normal knee kinematics are difficult to reproduce. Several studies have reported that in conventional TKA, several variations are observed in the intraoperative knee kinematics, including medial pivot [9,10], lateral pivot [11,12], and the parallel motion pattern [11,13]. The intraoperative and postoperative kinematics in TKA vary according to the type of prosthesis, and the kinematic pattern is not always reproduced in the normal knee [14,15]. On the other hand, it is also reported that the postoperative kinematics are affected by the preoperative kinematics [16]. In addition, according

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https://doi.org/10.1016/j.artd.2023.101178

to a computer simulation, the tilt of the joint line in the coronal angle affects the postoperative kinematics in TKA [17,18]. Taken together, the factors affecting the postoperative kinematics in TKA are still controversial. Few reports have compared the association between preoperative and postoperative radiographic parameters and intraoperative kinematics using computed tomography (CT)–free navigation in TKA.

The purpose of this study is to analyze the medial pivot pattern in conventional TKA intraoperatively using a CT-free navigation system and to examine the relationship between the intraoperative kinematic pattern and radiographic parameters before surgery and at 3 months postoperatively. A previous study reported that the results of intraoperative kinematic measurement conducted in this way are strongly correlated with the in vivo postoperative kinematics [19]. We hypothesized that the tilting of the coronal knee joint in TKA is related to the medial pivot pattern in the intraoperative kinematics analysis.

Material and methods

This study received ethical approval from our institutional review board. This retrospective study analyzed 71 patients with medial osteoarthritis (Kellgren-Lawrence grade 4) who underwent a primary TKA using a CT-free navigation system at our hospital between August 2020 and October 2022. The following exclusion criteria were applied: lateral osteoarthritis (valgus knee), rheumatic arthritis, hemophilic arthritis, posterior cruciate ligament retaining type of prosthesis, and incomplete intraoperative kinematic data or radiographic data. After applying the exclusion criteria, the remaining 30 patients were included in this study (Fig. 1). Patients were followed in our outpatient and radiographic imaging was performed preoperatively and at least 3 months postoperatively. All patients were able to extend their knee by more than −10° and were able to stand on their own at the time of postoperative radiography. Informed consent was obtained by each patient in the study.

Surgical technique

Several surgeons in our hospital performed all of the operations. In all cases, we used the same posterior-stabilized (PS) type prosthesis (Attune, DePuy Synthes, Warsaw, Indiana, USA) and performed the procedure using the CT-free navigation system (Knee3, BrainLab, Germany, Munich) to measure the intraoperative kinematics and successfully align the implants. An air tourniquet was inflated to 250 mmHg during surgery under general anesthesia. We performed the operation using a medial parapatellar approach and a measured resection technique. After making an incision of the knee joint capsule, 2 passive optical reference arrays were used to identify the orientation and the patient's distal femur and proximal tibia. After applying circular motions of the femur around the hip center until a sufficient number of points have been acquired, the key single landmarks (ie, the medial and lateral malleoli, proximal tibia and distal femur mechanical axis, medial, lateral and anterior proximal tibial contour, medial and lateral epicondyles, femoral anterior sizing point) were registered by touching appropriate bone structure. The external femoral rotation angle was determined with reference to the intraoperative clinical epicondyle axis and posterior condyle axis and preoperative CT as an angle of 3°-4° for each patient. Proximal tibial resection was determined perpendicular to the mechanical axis in the coronal plane and with a 3° tibial posterior inclination in the sagittal plane. The tibial rotation was determined with reference to the Akagi line (posterior cruciate ligament posteriorly to the medial border of the tibial tuberosity) [20]. It is reported that semimembranosus release significantly reduced the amount of tibial internal rotation [21]. In this study, soft-tissue release was performed minimally and there were no cases in which semimembranosus release was performed.

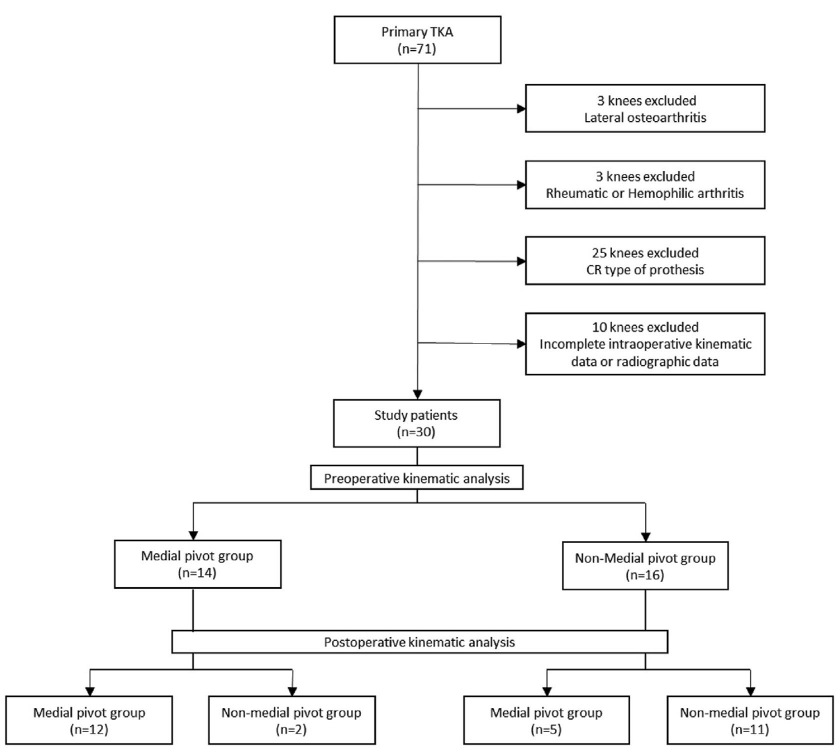

Figure 1. Flowchart of exclusion criteria in this study and results of kinematic measurements.

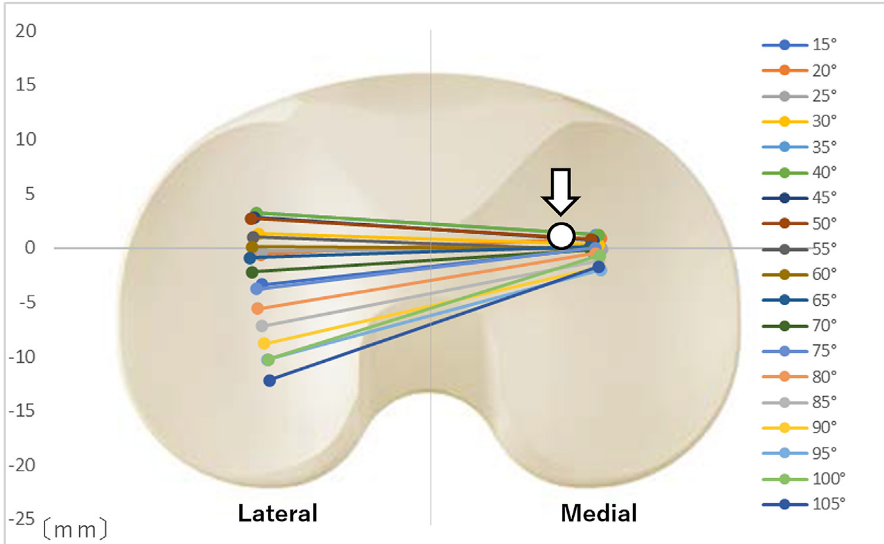

Figure 2. The lines indicate the femoral condylar axis relative to the tibia at each flexion angle. The white circle indicates the average COR in this case (arrow). COR, center of rotation.

Kinematics analysis

All kinematic patterns were measured using a CT-free navigation system. After the capsule incision (preoperative knee kinematics) and insertion of the implant (postoperative knee kinematics), the stability, alignment, and range of motion were recorded. To store the kinematics, the leg was brought to full extension without applying stress, and passive range of motion was performed from full extension to full flexion. We measured the dynamic kinematics from 0° to maximum flexion at 10° intervals, and the intersection of the axes at each angle was defined as the center of rotation (COR) based on previous reports [8,11]. We calculated the average COR between 0° and maximum flexion (Fig. 2). We divided the patients into 2 groups based on the average COR. First, we classified the average medial COR knee as the medial pivot (MP) group, then the other kinematic patterns were classified as the non-MP group. The non-MP group included patients with lateral pivot and parallel motion. Along with an average COR, all kinematic patterns were also independently evaluated by 2 senior orthopaedic surgeons before they were divided into 2 groups based on a previous report [22] (Fig. 3).

Radiography

Long-leg standing radiography was performed both preoperatively and postoperatively. Until the effects of the extension limit were removed and full weight bearing was possible without pain, at least 3 months after surgery had passed before postoperative radiography was performed. We measured the femorotibial angle, hip-knee-ankle angle, mechanical lateral distal femoral angle (mLDFA), and medial proximal tibial angle (MPTA) based on a previous report [23,24] (Fig. 4). All radiographic measurements were performed by the author.

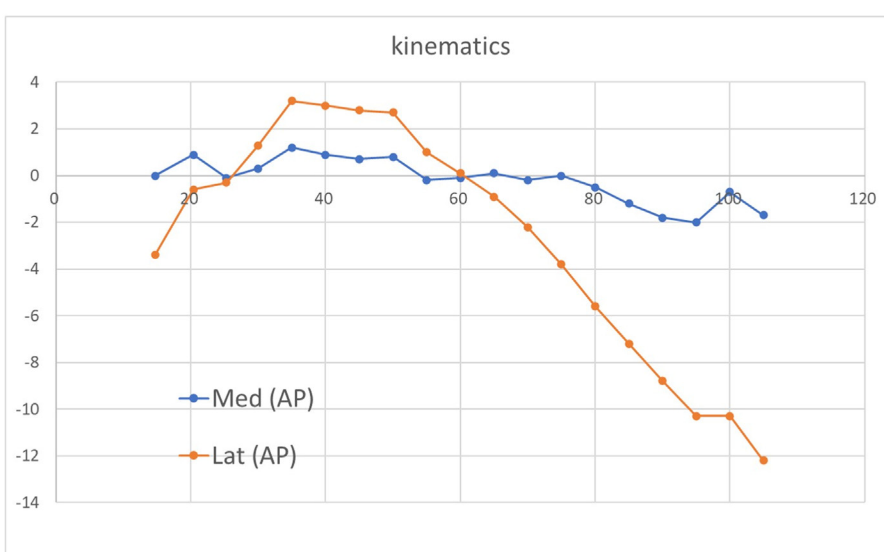

Figure 3. The anterior-posterior shift of the femoral condyle against the tibia is shown. In this case, the medial condyle shows a large degree of posterior translation in comparison to the lateral condyle.

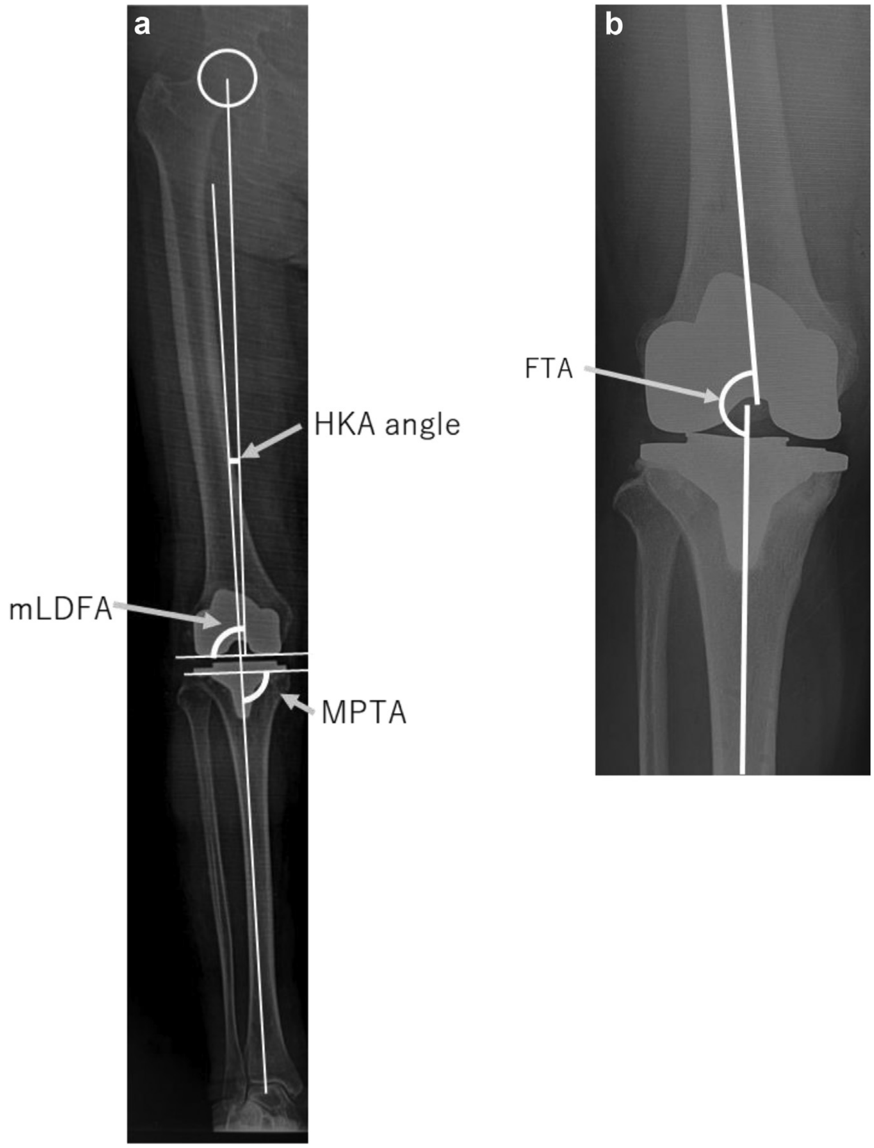

Figure 4. (a) The HKA angle measures the angulation between the mechanical axes of the femur and tibia. The MPTA measures between the axis of the articular surface of tibial plateau and the anatomical axis of the proximal tibia on the anteroposterior view of the knee. The mLDFA measures an angle formed by the mechanical axis of the femur and the line connecting the distal ends of the medial and lateral femoral condyles of the femur. (b) The FTA measures the lateral angle between the femoral anatomic axis the tibial anatomic axis. FTA, femorotibial angle; HKA, hip-knee-ankle; mLDFA, mechanical lateral distal femoral angle, MPTA, medial proximal tibial angle.

Statistical analysis

All statistical analyses were performed using IBM SPSS statistics 25 for Windows. Statistical comparisons were performed using the 2-tailed Student's *t*-test. Data are presented as the mean ± SD. Fisher's exact probability test was performed to evaluate the postoperative knee kinematic patterns *P* values of <.05 were considered statistically significant. The interobserver and intra-observer intraclass correlation coefficients of the radiographic measurements were assessed by reading 20 selected preoperative and postoperative films twice in 6 weeks.

Table 1
Postoperative patient characteristic data.

	MP group	Non-MP group	*P*-value
n	17	13	
Age (y)	72.7 ± 6.6	77.0 ± 6.1	.07
Sex (female/male)	14/3	12/1	.44
Height (cm)	153.0 ± 8.4	150.7 ± 8.4	.47
Weight (kg)	59.5 ± 8.9	62.9 ± 8.6	.30
BMI (kg/m^2)	25.4 ± 2.7	27.7 ± 3.5	.045[a]
Side (right/left)	8/9	6/7	.62

BMI, body mass index.
[a] $P < .05$.

Table 2
Preoperative radiographic data.

	MP group	Non-MP group	*P*-value
FTA	184.1 ± 2.9	187.4 ± 2.1	.01[a]
HKA	9.9 ± 5.0	14.9 ± 2.1	<.01[a]
mLDFA	88.6 ± 2.0	89.7 ± 1.4	.10
MPTA	84.3 ± 3.0	82.4 ± 4.0	.15

FTA, femorotibial angle; HKA, hip-knee-ankle; mLDFA, mechanical lateral distal femoral angle, MPTA, medial proximal tibial angle.
[a] $P < .05$.

Table 3
Postoperative radiographic data.

	MP group	Non-MP group	*P*-value
FTA	172.9 ± 2.2	173.9 ± 1.7	.17
HKA	−1.5 ± 1.8	−0.9 ± 2.5	.45
mLDFA	88.0 ± 1.4	89.7 ± 0.9	<.01[a]
MPTA	88.5 ± 0.8	89.7 ± 0.6	<.01[a]

FTA, femorotibial angle; HKA, hip-knee-ankle; mLDFA, mechanical lateral distal femoral angle, MPTA, medial proximal tibial angle.
[a] $P < .05$.

Results

Regarding the postoperative patient characteristics, there were no significant differences in age, sex, height, weight between the 2 groups and BMI was significantly higher in the non-MP group than the MP group (Table 1). According to the preoperative kinematic pattern, 14 cases were classified into the MP group and 16 cases were classified into the non-MP group. Postoperatively, 5 cases shifted from the non-MP group to the MP group and 2 cases shifted from the MP group to the non-MP group postoperatively. In 23 cases, the preoperative kinematic pattern remained postoperatively. Therefore, the preoperative kinematic pattern was conserved after surgery in 76.7% of the patients. The postoperative knee kinematics were significantly dependent on the preoperative knee kinematics.

A radiological evaluation showed that preoperative varus knee deformity in the non-MP group was significantly larger than that in the MP group. No significant differences were found in the preoperative mLDFA or MPTA (Table 2).

Regarding the postoperative mLDFA and MPTA, the non-MP group were significantly larger than the MP group. No significant differences were found in the postoperative femorotibial angle and hip-knee-ankle angle (Table 3). The interobserver intraclass correlation coefficients for the femorotibial angle, hip-knee-ankle angle, mLDFA, and MPTA were 0.98, 0.99, 0.95, and 0.98, respectively, while the intraobserver intraclass correlation coefficients were 0.99, 0.99, 0.97, and 0.99, respectively.

Discussion

The most important finding of this study was that the postoperative mLDFA and MPTA were larger in the non-MP group than in the MP group. This result indicated that the tilt of the joint line is important for achieving an MP pattern.

Several reports revealed that in computer simulation studies, the medial tilt of the joint line is an important factor for reproducing near normal knee kinematics [17,18]. The findings of the present study were in line with these previous studies. On the other hand, in the model simulation, a 3° tilting joint line did not restore the motion curve back to within the range of the kinematic curve of the natural knee [25]. However, these previous studies focused on the kinematic changes caused by the inclination of the joint line, other confounding factors, such as the surgical technique, the alignment of the lower extremities, and ligament release, may not have been sufficiently considered. In this study, since we measured the intraoperative biologic knee kinematics, rather than use a model simulation, these factors are also taken into consideration.

In the present study, preoperative varus knee deformity was associated with postoperative kinematics, and the postoperative knee kinematics was also significantly affected by the preoperative kinematics. This result indicated that the preoperative knee conditions, such as the range of motion, lower limb alignment, ligaments, soft-tissue balance, muscles, and other factors significantly affect the postoperative kinematics. It is reported that preoperative knee deformity and kinematics impact the postoperative knee kinematics in PS-TKA [22]. Furthermore, it is reported that preoperative varus deformity affected the intraoperative tibial rotation pattern [26]. The results of the present study are in line with these previous studies [22,26]. It was suggested that the same surgical technique using the same implant would not necessarily result in the same kinematic pattern.

Previous studies revealed that the postoperative medial pivot kinematic pattern was observed in 46%-55% of cases [13,22]. In this study, 56.7% of cases showed the medial pivot pattern postoperatively. In addition, the preoperative knee kinematics remained the same postoperatively in 76.7% of the cases. Based on our results, in knees with the medial pivot pattern before surgery, resection with medial tilt may achieve higher success in terms of reproducing a medial pivot pattern.

The present study was associated with some limitations. First, this is a single-institution study, which limits generalizability. Second, a retrospective cohort study design was employed. Third, there was only one PS implant studied. Different designs (eg, cruciate retaining, ultra-congruent, rotational platform) and implants from different manufacturers with different geometries may result in different findings. Forth, since gap balance is not considered in this study, it is unclear whether differences in medial-lateral or extension-flexion gap affected the kinematics. It is reported that the tibiofemoral contact force influences the intraoperative kinematic pivot pattern in PS-TKA [27]. Fifth, the operations were performed under general anesthesia using a tourniquet. Thus, the intraoperative kinematics were measured passively with the muscles relaxed. However, it is reported that the results of intraoperative kinematics measurement in this way are strongly correlated with the in vivo postoperative kinematics [19]. Finally, there are no outcomes mentioned, which limits the clinical implications of your findings.

Conclusions

The tilt of the joint line in the MP group was significantly larger than that in the non-MP group and the postoperative knee kinematics were significantly dependent on the preoperative knee kinematics as analyzed using a CT-free navigation system. In the case of knees with a medial pivot pattern before surgery, resection with medial tilt may more frequently reproduce a medial pivot pattern.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2023.101178.

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