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Femoral matched tibia component rotation has little effect on the tibial torsion after total knee arthroplasty

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Abstract

Purpose Tibiofemoral synchronization technique matches the rotational alignment of the tibial component to the femoral component during the total knee arthroplasty (TKA). The rotational axis of the proximal tibia can be changed by this technique, which affects tibial torsion postoperatively. The purpose of this study was to investigate whether the tibiofemoral synchronization technique affect the tibial torsion, and the lower limb rotation after primary TKA. It was hypothesised that the tibial torsion would change after primary TKA.

Methods Ninety-three posterior stabilised TKAs from 89 patients were included from January 2017 to December 2018. Mechanical hip–knee–ankle axis (mHKA), in plain radiographs, femoral anteversion, tibial torsion, femoral neck-malleolar angle (FNMA), and rotational alignment of the femoral and the tibial components in pre- and postoperative CT scans were measured by two blinded observers. The primary outcome was a postoperative change in femoral anteversion, tibial torsion and FNMA. Clinical outcomes were evaluated using the American Knee Society Knee Score (AKSKS)/Function Score (AKSFS), and Oxford Knee Score (OKS) preoperatively and at 1 year after TKA. Patients' perception of changes in the foot progression angle after TKA was investigated. Statistical significance was set at $p < 0.05$.

Results The mean rotational mismatch between the femoral and the tibial component was 0.6 ± 3.2°. There was a significant decrease in femoral anteversion (9.5 ± 6.7° vs. 5.2 ± 6.6°, $p < 0.001$), and a significant increase in the FNMA (17.6 ± 9.7° vs. 21.8 ± 10.5°, $p = 0.005$) after TKA, while no significant change in tibia torsion was observed (25.4 ± 8.8° vs. 24.9 ± 9.3°, $p = 0.739$). AKSS (37.8 ± 15.1 vs. 92.8 ± 8.8, $p < 0.001$), AKSFS (53.9 ± 18.1 vs. 89.9 ± 5.3, $p < 0.001$), and OKS (18.0 ± 7.3 vs. 39.9 ± 4.8, $p < 0.001$) were significantly improved at 1 year after TKA. Ten knees (11%) had changes in tibial torsion greater than ± 10° postoperatively. Four of five patients who had changes in FNMA greater than 15° perceived the external rotation of the foot progression angle after TKA. All four patients had an increase in tibial torsion larger than 10°.

Conclusion Our study shows that the tibiofemoral synchronization technique less likely affects the tibial torsion after primary TKA.

Keywords Total knee arthroplasty · Tibial torsion · Component rotation

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Introduction

Various surgical techniques are used to determine the rotational alignment of the tibial component during total knee arthroplasty (TKA) [1, 3, 7, 10, 11, 16, 24]. Possible anatomical landmarks for determining rotational alignment are tibial tuberosity, anterior tibia crest, tibial eminence, anterior or posterior tibial condylar line, patellar tendon, and second metatarsal bone. However, fixed landmarks may cause a rotational mismatch between the femur and tibia, potentially leading to suboptimal outcomes [25, 26]. This problem can be overcome using tibiofemoral synchronization techniques, such as self-alignment and the linker technique [4, 5, 11, 13, 17].

Tibiofemoral synchronization technique matches the rotational alignment of the tibial component to the femoral component. Moreover, tibiofemoral synchronization technique provides adequate tibiofemoral rotational alignment, which may prevent impingement of polyethylene bearing and improve patellar tracking. However, the tibiofemoral synchronization technique is independent of proximal tibial anatomy, and therefore, the tibial component can be placed in an external or internal position relative to the native rotational axis of the proximal tibia. As a result, the rotational axis of the proximal tibia after TKA may be changed according to the tibia component rotation. Postoperative changes in the rotational axis of the proximal tibia cause compensatory inverse tibial rotation in TKA with a fixed-bearing design [19], which affects the foot progression angle distally and the patellofemoral alignment proximally. Tibial component internal rotation relative to native anteroposterior axis of the proximal tibia causes the external torsion of the tibia, increasing the external rotation of the foot progression angle and Q-angle, and vice versa. A previous study investigated the effect of the rotational alignment of the femur and the tibia on lower limb rotational alignment using cadavers [19]. However, in vivo data are lacking.

The primary purpose of this study was to investigate whether the tibiofemoral synchronization technique affect the tibial torsion, and the lower limb rotation after primary TKA. It was hypothesised that the tibial torsion would change after primary TKA using a tibiofemoral synchronisation technique.

Methods

Patients

This prospective observational study was conducted after obtaining the approval of the institutional ethical review board (IRB No: 2016GR0311) and informed consent from patients. Patients who scheduled to undergo primary TKA (posterior cruciate ligament stabilised, cemented, fixed-bearing, ATTUNE, DePuy Synthes, USA) were screened from January 2017 to December 2018. The exclusion criteria were preoperative flexion contracture > 10° or flexion < 90°; mechanical hip–knee–ankle axis (mHKA) varus > 15° or valgus > 5°; extra-articular deformity of the involved limb, including hip or ankle joints affecting limb alignment or rotation; previous fractures or previous high tibial osteotomy on the operated knee, use of cemented intramedullary stems, and patellar resurfacing. A total of 168 knees from 132 patients were screened and 75 knees were excluded (Fig. 1). Finally, 93 knees from 89 patients were enrolled in this study (Table 1).

Surgical techniques

All TKAs with a medial parapatellar approach were performed by a senior surgeon. The measured resection technique for reproducing the implant thickness (distal 9 mm, symmetric posterior condyle 9 mm) was used in all patients. Distal femoral resection was performed using an intramedullary guide in 6° valgus relative to the anatomical axis of the femur. Femoral component rotation was aligned 3–5° external rotation relative to the posterior condylar axis according to preoperative measurement on CT. Proximal tibial cut was made perpendicular to the mechanical axis of the tibia

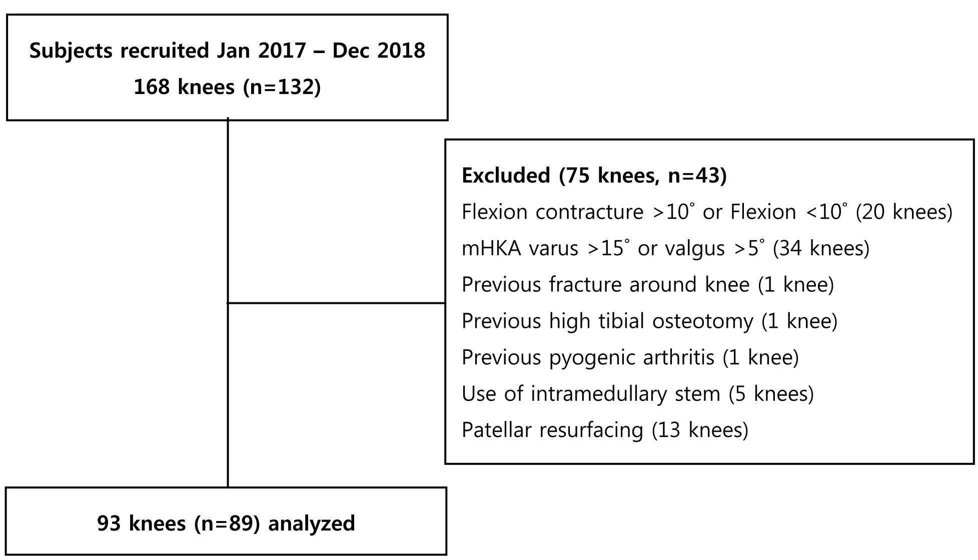

Fig. 1 A CONSORT diagram showing enrolled patients in this study

Table 1 Patient demographics

	Preoperative	Postoperative 1 year	*P* value
Age at operation (years)	69.8 ± 8.2		
Male:female (*n*)	10:79		
Body mass index (kg/m^2)	25.6 ± 3.5		
Rt:Lt	53:47		
mHKA (°)*	8.6 ± 3.6	2.1 ± 2.3	< 0.001
AKSKS	36.6 ± 15.5	91.9 ± 8.1	< 0.001
AKSFS	53.5 ± 16.9	90.2 ± 5.8	< 0.001
OKS	18.3 ± 6.8	40.1 ± 10.2	< 0.001

mHKA mechanical hip–knee–ankle axis; *AKSKS* American Knee Society Knee Score; *AKSFS* American Knee Society Function Score; *OKS* Oxford Knee Score

Values are presented as mean ± standard deviation

with 3° posterior slope using an extramedullary guide. With the femoral trial in place, the tibial tray with a PS insert was placed. After the center of tibial tray was aligned to the center of femoral trial box in extension, the orientation was marked on the edge of proximal tibia. The keel was cut into the tibia according to this orientation. Full extension (< 5° flexion) was achieved in all patients intraoperatively.

Computed tomography

Multidetector row computed tomography CT (64 channels) (Brilliance 64, Philips Medical System, Cleveland, USA) was used with detector collimation of 16 × 0.75 mm, tube energy and current of 100 kV and 70 mA s, respectively, beam pitch of 0.7 mm, and osteo-scanning mode. Slice thickness was 3 mm. During CT scans, each subject was in supine position with the patella forward, and hip, knee in extension. Axial CT scans of the proximal femur were obtained from the superior acetabulum to the lower border of the lesser trochanter. In the distal femur and proximal tibia, CT scans were taken from the supracondylar region to the tibial tuberosity. In the distal tibia, CT scans were obtained from the supramalleolar region to the upper talus. The following image sections were analysed (Fig. 2); the section showing (1) greater trochanter, femoral neck, and femoral head; (2) surgical transepicondylar axis (sTEA); (3) above the tip of the fibular head showing the entire anterior and posterior border of the proximal tibial condyle; and (4) immediately above the joint line showing the medial and lateral malleoli.

Radiologic evaluation

Preoperative (1 day before TKA) and postoperative (1 year after TKA) full-length lower leg weight-bearing anteroposterior radiographs were used to measure the mechanical hip–knee–ankle axis (mHKA). Preoperative (1 day before TKA) and postoperative (5–7 days after TKA) CT scans were obtained to measure axial parameters (Table 2) [9]. In cases in which the distal axis was externally rotated relative to the proximal axis, tibial torsion and femoral neck-malleolar angle (FNMA) values were expressed as positive and vice versa. The primary outcome of this study was a postoperative change in femoral anteversion, tibial torsion, and FNMA. To validate the accuracy of tibiofemoral synchronization technique, the rotational mismatch between femoral component and tibial component was measured (Table 2). The sTEA was used as a reference line for rotational alignment of femoral component and tibial component because it is considered

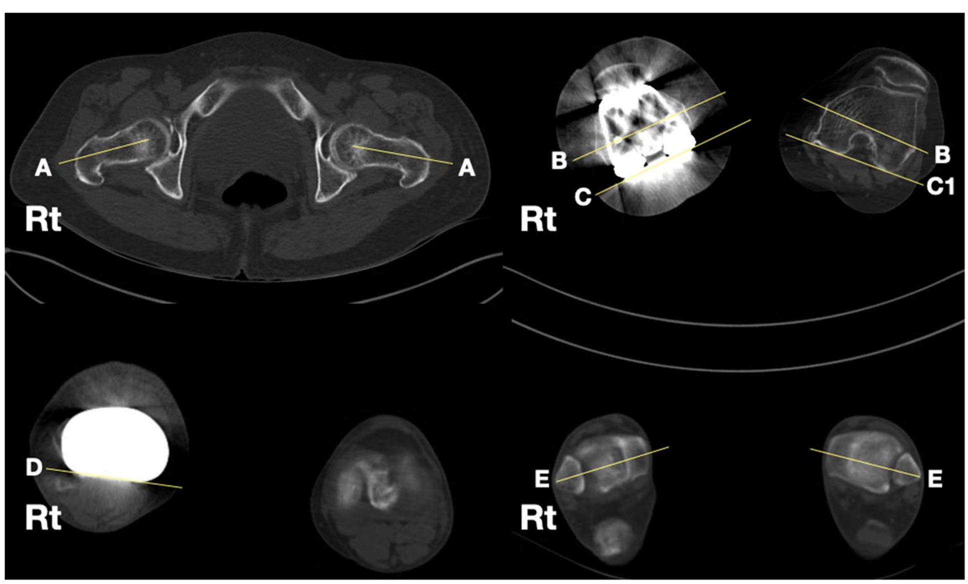

Fig. 2 Axial parameters measured by computed tomography. **a** Femoral anteversion (line A–C (C1), tibial torsion (line D–E), femoral neck-malleolar angle (line A–E); (**b**) surgical transepicondylar axis; (**c**) femoral component transverse axis; (**d**) tibial component transverse axis

Table 2 Definition of axial parameters

	Definition
Femoral anteversion	Angle between the line joining the centres of the femoral head and the neck and posterior condylar axis of the distal femur (or femoral component)
Tibia torsion	Angle between the posterior condylar axis of the proximal tibia (or tibial component) and the transmalleolar axis
Femoral neck-malleolar angle (FNMA)	Angle between the line joining the centre of the femoral head and the neck and the transmalleolar axis
Femoral component transverse axis (FCTA)	Transverse axis connecting the medial and lateral posterior condyle of the femoral component
Tibial component transverse axis (TCTA)	Transverse axis connecting the medial and lateral posterior condyle of the tibial component
FCTA–TCTA (°)	Rotational mismatch between femoral and tibial components
Akagi's line	Line connecting the center of PCL to medial border of the patellar tendon

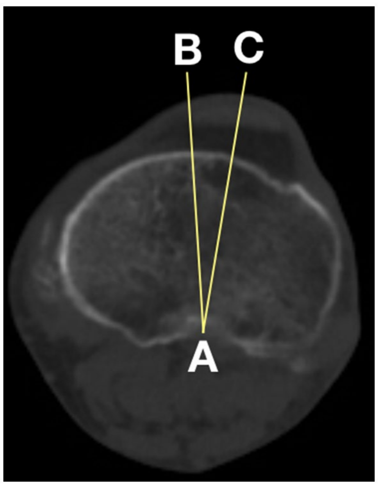

Fig. 3 Rotational mismatch between the 90° angle line to the projected surgical transepicondylar axis (line A–C) and Akagi's line (line A–B) on the proximal tibia

the flexion–extension axis of the knee joint. The rotational angle of the femoral component was defined as the angle between the femoral component transverse axis (FCTA) and the sTEA. The rotational angle of the tibial component was defined as the angle between the tibial component transverse axis (TCTA) and the projected sTEA on the cut surface of the tibia. Preoperative rotation of the 90° angle line to the sTEA was measured relative to Akagi's line [Fig. 3]). Positive values indicated that the axis was in external rotation relative to the reference line and vice versa. Measurements were recorded to the nearest 0.1° using a picture archiving and communication system (PACS) (STARPACS, INFINITT Healthcare, Seoul, South Korea), and the magnification factor was automatically corrected. The measurement accuracy of the PACS is within 0.1 mm and 0.1° [8]. The radiologic parameters were measured by two orthopaedic surgeons who did not participate in the operation.

Clinical outcomes

The clinical outcomes were evaluated using the American Knee Society Knee Score (AKSKS), American Knee Society Function Score (AKSFS), and Oxford Knee Score (OKS) preoperative and 1 year after TKA [6]. The patients' subjective perception of changes in the foot progression angle after TKA was also analysed. The patients were asked to answer the question "Did you perceive changes in the foot progression angle during walking after TKA?" A negative answer indicated no clinically relevant changes in the foot progression angle after TKA, whereas a positive answer indicated clinically relevant changes in the foot progression angle after TKA and then asked about the direction "internally or externally compared to preoperative foot progression angle?" The clinical outcomes were collected by the orthopaedic surgeons who were not involved in the operation.

Statistical analysis

For descriptive analysis, values were presented as mean and standard deviation. The Kolmogorov–Smirnov statistic was used to test the normality assumption. A paired *t* test for continuous variables was used to compare the preoperative and postoperative values. The Pearson correlation coefficient was used to determine the relationship between the amount of change in femoral anteversion, tibial torsion, and FNMA after TKA. Radiographic parameters were measured twice at a 2-week interval. Intra- and inter-observer reliability was assessed using intraclass correlation coefficients. SPSS software version 20.0 was used for statistical analysis (IBM, USA). Differences were considered statistically significant at *P* values of less than 0.05.

Results

There was a significant decrease in femoral anteversion, and a significant increase in the FNMA after TKA ($p < 0.001$, $p = 0.005$), while no significant change in tibia torsion was observed ($p = 0.739$, Table 3). Changes in femoral anteversion, tibial torsion, and FNMA were within ± 10° in 83%, 89%, and 71% of knees, respectively, after TKA. Postoperative FNMA was externally rotated (24% of cases) or internally rotated (5% of cases) more than ± 10° compared to before TKA. Changes in FNMA were weakly correlated with changes in femoral anteversion ($r = -0.481$, $p < 0.001$), and there was no significant correlation between changes in tibial torsion and FNMA ($r = 0.029$, $p = 0.777$). The mean rotational mismatch between the FCTA and TCTA was 0.6 ± 3.2°. In preoperative CT scans, all knees had an external or neutral rotation from the sTEA to Akagi's line (mean 9.2 ± 3.9°, range 0.1–19.1°). Intra-observer and inter-observer agreement was excellent (> 0.8) for all measured radiologic parameters.

Clinically, preoperative mHKA, AKSKS, AKSFS, and OKS were significantly improved at 1 year after TKA (Table 1). Four of five patients who had changes in FNMA greater than 15° perceived changes in the foot progression angle postoperatively. All these patients had an increase in tibial torsion larger than 10° and perceived the external rotation of the foot progression angle after TKA.

Discussion

The most important finding of the present study was that the tibia torsion was not significantly changed after TKA using the tibiofemoral synchronization technique. This finding suggests that the tibial component can be placed near to natural rotational axis of proximal tibia by the tibiofemoral synchronization technique. In addition, this technique provided good rotational alignment between the femoral and tibial component, which may improve tibiofemoral and patellofemoral tracking in primary TKA. The lower limb rotation as determined by the FNMA increased, which was found to be weakly correlated with a decrease in femoral anteversion. Our study did not support our hypothesis that the tibial torsion would change significantly after TKA because the tibiofemoral synchronization technique sets the rotational alignment of the tibial component regardless of proximal tibial anatomy.

Theoretically, if the femoral component is well aligned to the sTEA, synchronization of the rotational alignment of the tibial baseplate with the femoral component in extension reproduces the sTEA on the cut surface of the tibia intraoperatively. Our results showed that the mismatch between the sTEA and the mean rotational alignment of the tibial component established by the tibiofemoral synchronization technique was 1.5 ± 3.8°, which demonstrates that this technique can reproduce the sTEA on the tibia. Similarly, Berhouet et al. [4] reported that the tibial baseplate was placed in 1.9 ± 4.9° of internal rotation from the anatomic TEA using the self-alignment technique. Jung et al. [13] also reported that synchronization using a Liker system allowed rotational alignment of 0.6 ± 1.9° between the tibial component and the sTEA. Our study confirms that tibiofemoral synchronization technique accurately reproduces the sTEA on the cut surface of the tibia in cases in which the femoral component is well aligned to the sTEA.

Given the high variability in proximal tibial morphology, we assumed that it is difficult to expect whether the tibial component is positioned externally or internally using the tibiofemoral synchronization technique. Berhouet et al. [4] found that the tibial component was placed from −4.1° to 22.5° relative to the native posterior condylar axis of the proximal tibia using the self-alignment technique, which supports our assumption. In our study, a mean value of tibia

Table 3 Comparison of axial parameters between pre- and postoperative

	Preoperative	Postoperative	*P* value
Preop sTEA-Akagi's line (°)	9.2 ± 3.9 (95% CI 8.4–10.1)	Not applicable	
Post-op FCTA-sTEA (°)	Not applicable	1.3 ± 2.6 (95% CI 0.8–1.8)	
Post-op TCTA-sTEA (°)	Not applicable	1.5 ± 3.8 (95% CI 0.7–2.3)	
Post-op TCTA-FCTA (°)	Not applicable	0.6 ± 3.2 (95% CI −0.1–1.3)	
Femoral anteversion (°)	9.5 ± 6.7 (95% CI 8.1–10.9)	5.2 ± 6.6 (95% CI 3.6–6.5)	< 0.001
Tibial torsion (°)	25.4 ± 8.8 (95% CI 23.6–27.2)	24.9 ± 9.3 (95% CI 23.0–26.8)	0.739
Femoral neck-malleolar angle (°)	17.6 ± 9.7 (95% CI 15.6–19.6)	21.8 ± 10.5 (95% CI 19.7–23.9)	0.005

PS posterior cruciate-stabilized total knee arthroplasty; *sTEA* surgical transepicondylar axis; *FCTA* femoral component transverse axis; *TCTA* tibial component transverse axis

Values are presented as mean ± standard deviation. Positive values are external rotations or anteversion

† $p < 0.001$ between pre- and postoperative values

torsion was not changed significantly after TKA. However, 11% of knees had changes in the tibial torsion greater than ± 10° after TKA, suggesting that the tibial component can be placed by the tibiofemoral synchronization technique in large amount of external or internal rotation from the native posterior condylar axis of the proximal tibia (proximal reference of tibia torsion in this study) in some patients. Therefore, the rotational alignment of the tibial baseplate should be double-checked using several anatomical landmarks intraoperatively.

The lower limb rotation can be affected by external or internal rotation of the tibial component in combination with a 3–5° external rotation of the femoral component—a combination often used in TKA [9, 19]. If both components are rotated externally, the lower limb rotational change would be small because the external rotation of the tibial component would decrease tibial torsion (compensatory effect of both components on lower limb rotation). However, lower limb rotation would be more externally rotated after TKA in cases in which the tibial component was rotated internally (increase in tibial torsion) in combination with the external rotation of the femoral component (synergic effect of both components on lower limb rotation). In our study, four of five patients who had changes in FNMA greater than 15° perceived changes in the foot progression angle postoperatively. All these patients had an increase in tibial torsion larger than 10°. Given that the femoral component was rotated externally after TKA, the amount of limb rotational change might be additionally affected by the large amount of internal rotation of the tibial component (increase in tibia torsion) in these patients. Even though our study showed that changes in FNMA were correlated with changes in femoral anteversion, it should be kept in mind that a synergic effect of increase in the tibial torsion by the internal rotation of the tibia component can affect the patients' perception about the lower limb external rotation after TKA.

A systematic review has shown that Akagi's line is the most reliable landmark for the rotational alignment of the TC in TKA [20]. However, it has been reported that the angles between Akagi's line and the perpendicular line to the sTEA ranged from − 19.7° (internal rotation) to 15° (external rotation) [1, 2, 12, 14–16, 22, 23]. Furthermore, our study showed that the variation in rotational mismatch between the projected sTEA on the tibia and Akagi's line was large (0.1–19.1°). Given the high interindividual variability in proximal tibial anatomy, using Akagi's line alone is not recommended for determining the rotational alignment of the tibial component. Fixed anatomic landmarks may cause tibial component malrotation in some patients. CT is useful to determine the projected sTEA on the tibia but it may not be available routinely because of its high cost. We believe that the tibiofemoral synchronization technique reproduces the sTEA on the cut surface of the proximal tibia regardless of individual tibial anatomy and may help surgeons identify the location of the projected sTEA on the tibia.

This study has a number of limitations. First, our results may not be applicable to other conditions beyond the inclusion criteria and different implant designs. In addition, axial parameters were measured in fully extended knees. Therefore, FNMA, foot progression angle, and the rotational mismatch between the femoral component and tibial component may be different at other flexion angles. Second, several methods to measure the femoral anteversion and the tibial torsion have been reported [21]. Therefore, our results might be affected by the measurement method. We selected methods showing high inter- and intra-observer reliability for each parameter. In addition, our primary interest was determining the amount of change between before and after TKA because this approach was less likely to be affected by measurement methods than determining absolute values. Third, the foot progression angle was not measured objectively. Instead, total lower limb rotation was assessed by measuring the FNMA [18]. Furthermore, the question on patients' perception of changes in the foot progression angle was not validated, which may be affected by patients' psychometric status. Fourth, most enrolled patients were female (89%). Anatomic differences between male and female could affect the results. Further study will be needed to investigate whether there is a gender difference regarding a change in limb rotation after TKA. Finally, no comparison group using other techniques, lack of power analysis for sample size calculation, and short-term clinical outcomes are also limitations of this study. Notwithstanding these limitations, we believe that our study provides clinically important information on changes in tibial torsion and lower limb rotation after TKA using the tibiofemoral synchronization technique.

Conclusions

Our study shows that the tibiofemoral synchronization technique less likely affects the tibial torsion after primary TKA. The limb rotation as determined by the FNMA can increase, which is more likely correlated with changes in femoral anteversion.

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Author contributions JHB: study concepts/design and manuscript drafting/revision, JWL: data acquisition/analysis, SHK: data acquisition/analysis, SGK: data acquisition/analysis and manuscript revision, YSJ: data acquisition/analysis and manuscript revision, and JSC: data acquisition/analysis and manuscript revision. All the authors read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest Each author certifies that he has no commercial associations (e.g. consultancies, stock ownership, equity interest, and patent/licensing arrangements) that might pose a conflict of interest in connection with the submitted article.

Ethical approval This study was approved by the institutional ethical review board (2016GR0311).

Informed consent The informed consent was obtained from each patient.

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