

Comparison of femoral sagittal axis between navigated total knee arthroplasty and conventional total knee arthroplasty in patients with knee osteoarthritis

Sung ho Lee, MD^a, Young Jae Cho, MD^b, Won Kee Choi, MD^{b,*} 

Abstract

To compare femoral sagittal axis between navigated total knee arthroplasty (TKA) and conventional TKA.

A total of 136 cases were assigned to group 1 (navigated TKA) and 77 cases were assigned to group 2 (conventional TKA). Specifically, this study targeted patients with degenerative osteoarthritis. Only patients with primary TKA were analyzed. Hip knee ankle angle and lateral femoral bowing were measured using preoperative scanogram. Anterior femoral bowing was measured using preoperative femoral lateral X rays. The presence of anterior femoral notching and the insertion angle of the femoral implant with respect to the anatomical sagittal plane of the distal femur were checked using postoperative lateral knee X rays. Student t-test was used to compare the difference in the position of the sagittal plane of the femoral implant between the navigated TKA group and the conventional TKA group.

When comparing the 2 groups, the sagittal axis of the femoral implant was more extended than the anatomical sagittal plane axis of the distal femur in group 1 than in group 2 ($P = .01$). There was a significant negative correlation between the value of anterior femoral bowing and the degree of flexion to the sagittal plane of the femoral implant in group 1 (correlation coefficient: -0.40 , $P = .01$). The occurrence of anterior femoral notching was significantly higher in group 1 than in group 2.

During navigated TKA, imageless navigation does not consider the anatomical variation of the femoral shaft. Therefore, surgeons should take into consideration that when performing navigated TKA, a femoral implant could be inserted more extended for the anatomical sagittal axis of the distal femur than for the conventional TKA. Also, surgeon should know that the degree of extension insertion of the femoral implant increases as femoral anterior bowing increases.

Abbreviations: HKA = hip knee ankle, TKA = total knee arthroplasty.

Keywords: femoral bowing, navigation, sagittal axis.

1. Introduction

Total knee arthroplasty (TKA) using computer navigation was developed with the theoretical advantage of obtaining stable coronal axis compared to conventional TKA.^[1-4] Especially, it has been found that femurs of Asians have more lateral bending on the coronal plane and more anterior bending on the sagittal plane.^[5,6] In general, navigation determines coordinates of coronal and sagittal plane axes using the bony index of the distal femur along with the femoral head.^[7] For this reason, if navigated TKA is performed for patients with large anterior bowing, theoretically, the femoral implant may be inserted in an extended state than the anatomical sagittal plane of the distal femur and may cause anterior notching.^[7-9] However, studies on the sagittal plane axis have not been conducted more actively than studies on the acquisition of the optimal coronal axis.

Thus, the objective of this study was to retrospectively compare and analyze radiological results of conventional TKA and navigated TKA. First, we wanted to know whether the femoral implant tended to be inserted in a more extended posture than the anatomical sagittal axis of the distal femur as the anterior femoral bowing increases during navigated TKA. Second, we wanted to know whether the sagittal plane of the femoral implant could be determined regardless of the presence of anterior femoral bowing during conventional TKA. Third, we wanted to find out if more severe anterior femoral bowing would cause higher occurrence of anterior notching of the distal femur during navigated TKA. The authors hypothesized that when performing navigated TKA, a femoral implant would be inserted more extended for the anatomical sagittal axis of the distal femur than for the conventional TKA. In addition, the authors hypothesized that this trend would increase as the

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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anterior femoral bowing increased. As a result, it was expected that anterior femoral notching would occur more in navigated TKA than in conventional TKA.

2. Methods

TKA surgeries performed by 2 surgeons from January 2020 to August 2021 were retrospectively analyzed. Specifically, this study targeted patients with degenerative osteoarthritis. Only patients with primary TKA were involved. Exclusion criteria were: the absence of useful radiological data before and after surgery, previous surgery of the ipsilateral femur causing it impossible to measure the bony indices of the femur, revision TKA, and TKA for diseases other than degenerative knee osteoarthritis. This study was conducted after obtaining approval from our IRB (Daegu catholic university medical center CR-21-162).

2.1. Study participants

Among a total of 152 cases of navigated, primary TKA performed by surgeon no. 1 from January 2020 to August 2021, 16 cases were excluded due to exclusion criteria. A total of 136 cases were assigned to group 1. In the same period, a total of 85 cases underwent conventional TKA performed by surgeon no. 2. Of these, 8 cases were excluded for the same reason. Thus, a total of 77 cases were assigned to group 2. Demographic and basic characteristics of participants are summarized in Table 1.

2.2. Radiologic measurement

Hip knee ankle angle and femoral lateral bowing were measured using scanograms taken before surgery.^[10] Femoral lateral bowing was defined as an acute angle formed between the line drawn at the center of the femur below the level of the lesser trochanter to pass the center of the femur at a point 5 cm distal to the starting point and the line extending from the center of the femoral distal condyle through the center of the femur at a 5 cm proximal portion and a 5 cm further proximal point (Fig. 1). Lateral bowing was expressed in a positive value while medial bowing was expressed in a negative value. Femoral anterior bowing was measured using femoral lateral X rays taken before surgery.^[11] Femoral anterior bowing was defined as an acute angle formed between the line drawn at the anterior cortex of the femur below the level of the lesser trochanter to pass the anterior cortex of the femur at a point 5 cm distal to the starting point and the line extending from the anterior cortex of the femoral distal condyle through the anterior cortex of the femur at a 5 cm proximal portion and a 5 cm further proximal point (Fig. 2). Anterior bowing was expressed in a positive value. The presence or absence of femoral anterior notching and the insertion angle of the femoral implant with respect to the anatomic sagittal plane of the lower femur were checked using a knee lateral

X-ray taken after surgery^[12] (Fig. 3). Extension position of femoral implant for the anatomical sagittal axis of the distal femur was expressed in a negative value while flexion position was expressed in a positive value. The measurement was performed by a senior resident and a junior resident. Values measured by senior resident were used.

2.3. Reliability analysis of radiation measurement

Two researchers (1 senior resident and 1 junior resident) who were blinded to the objective of this study performed measurements after receiving training on radiographic measurements. After completion of measurement, the interobserver reliability was analyzed. Based on the observed reliability, measurements taken by a single investigator (senior resident) were used in the analysis.

2.4. Surgical techniques

Tourniquets were applied in all surgeries. Midline skin incision and the medial parapatellar approach were applied in all cases. Measured gap technique was used for bone resections. Both femoral and tibial components were fixed with bone cement. Posterior cruciate substituting (PS) type of implant was used for all TKAs. Surgeon 1 performed TKAs using navigation for 143 cases. The Imageless Navigation System version 2.6 (BrainLAB, Feldkirchen, Germany) was used in all navigated TKA cases. Surgeon 2 performed manual TKAs for 80 cases. In manual TKA cases, the entry point for femoral intramedullary rod was closed by an autologous bone plug. All patients had drainage catheter which was removed at postoperative day 2 (POD 2) or postoperative day 3 (POD 3) depending on the amount of drainage. The same postoperative rehabilitation protocols for TKA were applied in all patients. Surgeon 1 used Nexgen (Zimmer, Warsaw, IN, USA) and surgeon 2 used Attune (DePuy Synthes, Warsaw, IN, USA) for all cases. In both instruments, it was confirmed that angles formed by the anterior flange and the joint surface at the end of the femur were the same.

2.5. Statistical analysis

All analyses were performed with IBM SPSS version 19.0 software (SPSS Inc., Chicago, IL, USA) for Windows. Student t-test was used to compare the difference in the position of the sagittal plane of the femoral implant between the navigated TKA group and the conventional TKA group. Pearson test was conducted to determine the correlation between the degree of the anterior femoral bowing and the position of the sagittal plane of the femoral implant. Chi-square test was performed to compare the degree of occurrence of anterior femoral notching after surgery of the navigated TKA group and the conventional TKA group. The G*power was used to analyze the verification power of the results. *P* value of 0.05 or less was considered to indicate statistical significance.

Table 1

The demographics and basic characteristics of the participants.

Variables	Total (N = 213)	Group 1 (N = 136)	Group 2 (N = 77)	<i>P</i>
Age (yrs)	70.65 ± 6.91	70.33 ± 6.83	71.21 ± 7.06	.38
Gender (F/M)	(182/31)	(121/15)	(61/16)	.05
Body mass index (m/kg ²)	25.91 ± 3.72	25.70 ± 3.64	26.02 ± 3.19	.27
Pre operation HKA angle (°)	171.63 ± 4.84	171.64 ± 4.65	171.62 ± 5.19	.97
Preoperation lateral femoral bowing (°)	2.67 ± 3.74	2.83 ± 3.78	2.42 ± 3.68	.45
Total operative time (min)	81.35 ± 5.53	81.38 ± 4.65	81.30 ± 6.82	.92

F = female, HKA = hip knee ankle, M = man, N = numbers.



Figure 1. We measured the femoral lateral bowing using scanograms taken before surgery.



Figure 2. We measured the femoral anterior bowing using whole femoral lateral X-ray taken before surgery.

3. Results

3.1. Intraclass correlation coefficients of radiologic measurements

Intraclass correlation coefficients of radiographic measurements were all above 0.8 (Table 2).

3.2. Results of anterior femoral bowing and implant sagittal axis for distal femoral anatomical axis

The average anterior femoral bowing of 213 cases was $9.59^\circ \pm 3.03^\circ$. The average value of the sagittal plane axis of the femoral implant with respect to the anatomical axis of the distal femur was $-0.50^\circ \pm 1.97^\circ$. The average value of the anterior femoral bowing of 136 navigation cases was $9.74^\circ \pm 3.05^\circ$. The average value of the sagittal plane axis of the femoral implant with respect to the anatomical axis of the distal femur was $-0.80^\circ \pm 1.82^\circ$. The average value of the anterior femoral

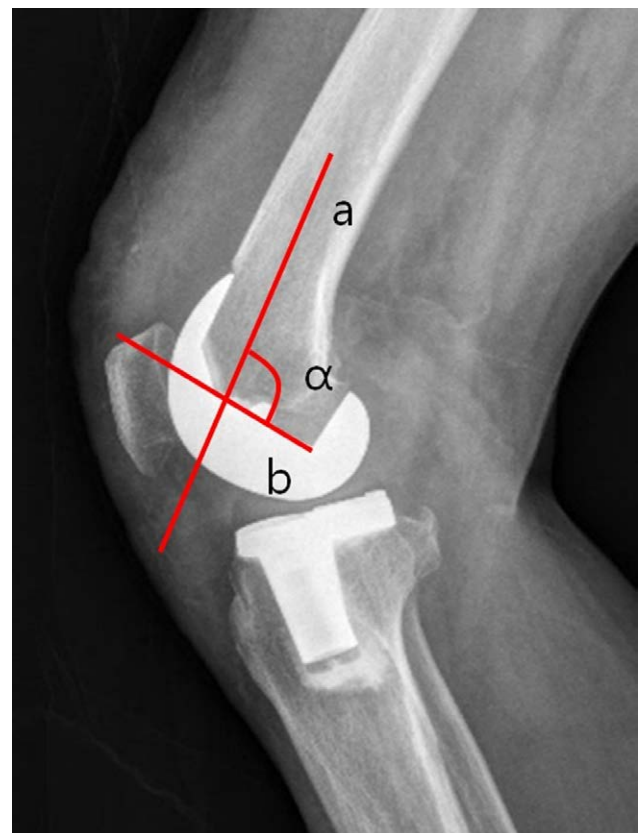


Figure 3. Line a is the femoral shaft axis; line b lies along the bottom of the femoral implant. Implant sagittal insertion angle = $90 - \alpha$, (+): flexion, (-): extension.

bowing of 77 conventional cases was $9.32^\circ \pm 3.00^\circ$. The average value of the sagittal plane axis of the femoral implant with respect to the anatomical axis of the distal femur was $0.04^\circ \pm 2.12^\circ$. When the 2 groups were compared, the sagittal plane axis of the femoral implant was significantly extended than the anatomical sagittal plane axis of the distal femur in group

Table 2
The ICCs of the radiographic measurements.

Parameter	ICCs
Lateral femoral bowing	0.92
Anterior femoral bowing	0.91
Hip knee ankle axis	0.92
Femoral implant sagittal axis	0.90

ICCs = intraclass correlation coefficients.

1 than in group 2 ($P = .01$). The post hoc power of the result was 0.94.

3.3. Relationship between anterior femoral bowing and postoperative femoral implant sagittal axis

There was a statistically significant negative correlation between the value of anterior femoral bowing and the degree of flexion to the sagittal plane of the femoral implant in the group using navigation (correlation coefficient: -0.40) (Table 3). The post hoc power for this result was 0.80. However, in the conventional TKA group, there was no statistically significant correlation between the value of anterior femoral bowing and the extension value of the sagittal plane axis of the femoral implant.

3.4. Comparison of the degree of occurrence of anterior femoral notching between navigated TKA and conventional TKA groups

As a result of Chi-square test, there were statistically significant occurrences of anterior femoral notching in the group using navigation than in the group of conventional TKA (Table 4).

4. Discussion

Results of this study revealed that the average angle formed by the anatomical axis of the distal femur and the sagittal plane axis of the femoral insert was $-0.80^\circ \pm 1.82^\circ$ in the navigated TKA group and $0.04^\circ \pm 2.12^\circ$ in the conventional TKA group, indicating that the femoral implant was inserted with an average of 0.83° extension in navigated TKA. Many previous simulation studies have revealed that femoral implants can be inserted somewhat extended and cause femoral notching due to the nature of navigation using bony indices of femoral head and distal femoral condyle, during navigation assisted TKA.^[7-9] In addition, previous studies have shown that when using navigation,

the femoral implant may be inserted more extended than the conventional method.^[11] This result is the same as results of another previous study, while the sagittal axis of the 2 surgical techniques showed a difference within 1° .^[13] In addition to this result, this study revealed that when navigation was used, the more severe the anterior femoral bowing, the more extended the femoral implant was inserted than the anatomical sagittal axis of the distal femur. In conventional TKA, there was no statistically significant correlation between values of anterior femoral bowing and the degree of extension of the femoral implant to the anatomical axis of the distal femur. In navigated TKA, the optimal sagittal alignment of the femoral component remains unknown.^[8] Most surgeons recommend to align it either perpendicular or in slight flexion ($3-5^\circ$) to sagittal mechanical axis of femur.^[14] However, studies have shown that the risk of anterior femoral notching is high if the femoral component positioning is planned perpendicular to sagittal mechanical axis of femur in navigated TKA.^[8,15]

In our study, significantly higher anterior femoral notching occurred more frequently in navigated TKA than in conventional TKA. This has already been revealed in previous studies, showing that in patient with more severe anterior femoral bowing, the femoral implant might be inserted in a more extended position and might cause anterior femoral notching.^[9] However, in this study, there was no significant difference in femoral anterior bowing between 17 anterior femoral notching cases and 126 non-notching cases in the group of navigated TKA. Although femoral notching might occur in simulation studies, in real-surgical situations, the presence of femoral notching is checked before the femoral bone cutting process is performed. Therefore, the result of no statistical difference might be caused by the bone cutting process after moving the femoral implant a little forwardly than the navigation notice to avoid anterior femoral notching when femoral anterior bowing was severe.

This study has several limitations. First, 2-dimension images were used for the measuring in this study. Depending on the femoral rotation, if the lateral femoral bowing is severe, the anterior femoral bowing can be overmeasured.^[16] Therefore, further research is needed as data obtained by simultaneously calculated both coronal and sagittal axis through 3-dimensional images.^[17] Second, we compared the femoral sagittal axis of 2 different instruments. Each company of the instrument might have its own femoral sagittal axis. Thus, it is essential to check whether the femoral sagittal axis of the 2 instruments is designed identically. We compared templates of each instrument and confirmed that the sagittal distal femoral axis of the 2 instruments was designed to be the same. Third, we did not compare the mechanical femoral sagittal axis. Instead, we compared and

Table 3
Pearson coefficient of correlation between anterior femoral bowing and postoperative femoral implant sagittal axis.

		HKA angle	Lateral femoral bowing	Implant sagittal axis
Anterior femoral bowing	Coefficient of correlation	-0.25	0.30	-0.4
	<i>P</i>	.01	.01	.01

HKA = hip knee ankle.

Table 4
Chi-square test to identify the difference of occurrences of anterior femoral notching between the group using navigation and the group of conventional TKA.

	Notching (Yes)	Notching (No)	Total	<i>P</i>
Navigation (N = 136)	17 (12.5%)	119 (87.5%)	136 (100%)	.01
Conventional TKA (N = 77)	1 (1.3%)	76 (98.7%)	77 (100%)	
Total (N = 213)	18	195	213 (100.0%)	

analyzed the sagittal axis of the femoral implant of conventional TKA and navigated TKA with respect to the distal femoral anatomical axis.^[18]

5. Conclusion

During navigated TKA, imageless navigation does not consider the anatomical variation of the femoral shaft. Therefore, when performing navigated TKA, surgeons should consider that a femoral implant would be inserted more extended for the anatomical sagittal axis of the distal femur than for the conventional TKA. Surgeon should also know that degree of extension insertion of the femoral implant increases as femoral anterior bowing increases.

Author contributions

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