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Rotational mismatch between femoral and tibial components should be avoided in JOURNEY II bi-cruciate stabilized total knee arthroplasty

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Abstract

Background: JOURNEY II bi-cruciate stabilized (BCS) knee system, a guided motion total knee arthroplasty (TKA), has been reported to reproduce physiological knee kinematic motion with good clinical outcomes. However, this guided system may be sensitive to the femorotibial rotational alignment.

Method: Forty-four patients (50 knees) who underwent JOURNEY II BCS TKA were included in this retrospective study. The 2011 Knee Society Score (KSS) and range of motion, were assessed pre-operatively and one year postoperatively. The femoral component rotational angle relative to the surgical epicondylar axis and the tibial component rotational angle relative to Akagi's line were measured postoperatively. The absolute difference between the femoral and tibial component rotational angles was defined as femorotibial component rotational mismatch. The correlation between the parameters of these rotational alignments and postoperative clinical outcomes was evaluated. Additionally, receiver operating characteristic curve analysis was performed to determine the optimal cut-off point of the femorotibial component rotational mismatch.

Results: Mean femoral and tibial component rotational angles were 0.4° (internal rotation) and 0.7° (external rotation), respectively. The rotational mismatch of the femorotibial component was 3.2°. There were negative correlations between femorotibial rotational mismatch and clinical outcomes, including objective knee indicators, patient satisfaction, functional activities, and total 2011 KSS. The area under the curve of the femorotibial component rotational mismatch was 0.768 and the cut-off value identified by the Youden index was 2.8°.

Conclusions: Excessive rotational mismatch between the femoral and tibial components can negatively influence the clinical outcomes of JOURNEY II BCS TKA.

1. Introduction

Total knee arthroplasty (TKA) is an established procedure with good clinical outcomes for end-stage knee arthritis. Recently, as a different concept of conventional posterior-stabilized (PS) and cruciate-retaining (CR) TKA, guided motion TKA has been utilized to achieve better knee kinematics [1-4]. The JOURNEY bi-cruciate stabilized (BCS) knee system (Smith & Nephew, Memphis, TN, USA) was released in 2005. However, the JOURNEY BSC TKA showed a high rate of early complications due to high joint restraint, such as iliotibial band syndrome via excessive femoral rollback [5] and posterior dislocation in varus-knee flexion via the rounded post design and relative position of the cam and the height of the post [6]. The second-generation design, JOURNEY II BCS (Smith & Nephew, Memphis, TN, USA), improved to reduce tension in the lateral retinaculum and decrease the pushing of the tibia anteriorly in knee flexion [3], was released in 2011. Clinical complications were overcome by reducing the anterior-posterior translation of the femorotibial joint, and good outcomes with JOURNEY II BCS TKA have been recently reported [7, 8].

Appropriate rotational alignment of the component is an essential factor for successful outcomes after TKA. Previous studies have reported that malrotation of each femoral or tibial component could lead to postoperative knee pain, stiffness, and instability [9-12]. In addition, the rotational mismatch between the femoral and tibial components may negatively influence the clinical outcomes of conventional TKA designs, such as PS and CR TKA [13-15]. JOURNEY II BCS TKA has a guided motion system that may be more restrictive and sensitive to component rotational mismatches. However, the impact of component malrotation on guided motion JOURNEY II BCS TKA has not been sufficiently investigated.

Therefore, this study aimed to investigate the influences of component malrotation and femorotibial component rotational mismatch on the clinical outcomes of patients undergoing JOURNEY II BCS TKA. We hypothesized that femorotibial component rotational mismatch would negatively influence the clinical outcomes of JOURNEY II BCS TKA.

2. Materials and methods

2.1. Study design

The hospital ethics committee approved the study protocol, and written informed consent was obtained from all patients who participated in the study. Patients who underwent JOURNEY II BCS TKA at our institution between October 2018 and August 2020 were included in this retrospective study. The inclusion criteria were full-thickness cartilage defect, severe pain, and difficulty performing activities of daily living despite conservative treatments for ≥3 months before surgery. The exclusion criteria were valgus knee deformity, history of knee joint trauma, active knee joint infection, severe bony defects requiring bone graft or augmentation, revision TKA, and patients with insufficient radiographic and clinical data. A total of 44 patients (50 knees, five men and 45 women; mean age, 74.0 years; mean body mass index, 26.7%; mean hip-knee-ankle angle, 7.2˚ of varus) were included in the analysis. Of the 50 knees, 18 knees had a history of contralateral TKA, and ten knees had a history of unicompartmental knee arthroplasty (UKA) on the contralateral side; however, all surgeries on the contralateral side were performed ≥1 year preoperatively, and all patients had no complaints on the contralateral side. Patient demographic data included age, sex, diagnosis, body mass index, and preoperative deformity (Table 1).

2.2. Operative procedures

All operative procedures were performed by an orthopedic surgeon with >10 years of experience in knee arthroplasty. In BCS-TKA, the kinematics are reproduced in guided motion by the anatomically matched thigh component and the insert and joint surface shapes. Thus, bone osteotomy was performed perpendicular to the femoral and tibial mechanical axes according to mechanically aligned TKA. Distal femoral osteotomy was performed perpendicular to the femoral mechanical axis after the resection of the anterior cruciate ligament and the posterior cruciate ligament. Proximal tibial osteotomy was performed with a 10-mm bone resection in the lateral tibial plateau and a 5° posterior slope along the sagittal plane perpendicular to the mechanical axis in the coronal plane. After confirming neutral alignment with each osteotomy, posterior femoral resections were performed via a 3° external rotation of the posterior condylar axis using a conventional guide. The rotation axis of the tibia was determined by referencing the Akagi line [16].

2.3. Clinical outcomes and radiographic assessment

The 2011 Knee Society Score (KSS) and knee range of motion (ROM) were assessed preoperatively and one year postoperatively. Computed tomography (CT) scans were used to assess the rotation of the femoral and tibial components. Scanning was performed with the patients in the supine position with the knee extended and the patella facing upward. Rotational alignment of the femoral and tibial components relative to the bone landmarks and mismatch between the components were measured using CT scans. The femoral component rotational angle was defined as the line perpendicular to the surgical epicondylar axis, the line between the lowest point of the medial epicondyle and the midpoint of the lateral epicondyle [17]. The tibial component rotational angle was defined as Akagi's line, the line between the center of the posterior cruciate ligament and the medial border of the tibial tuberosity [16]. A positive value represents external rotation, and a negative value represents internal rotation of the femoral and tibial components. The absolute value of the angular divergence of the femoral component relative to the tibial component is defined as the rotational mismatch [15].

2.4. Statistical analysis

Clinical outcomes are reported as the mean ± standard deviation. To evaluate the intra- and inter-observer reliabilities, radiographic measurements were performed twice by a surgeon at intervals ≥1 month and once by another examiner. The intra-class correlation coefficients for the femoral component rotation, tibial component rotation, and rotational mismatch were 0.90, 0.88, and 0.86, respectively. The inter-class correlation coefficients for femoral component rotation, tibial component rotation, and rotational mismatch were 0.88, 0.87, and 0.85, respectively. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software (version 16.0, IBM Corp., Armonk, NY, USA). Comparisons between the preoperative and postoperative clinical outcomes were analyzed using paired Student's t-test. Potential correlations between the component rotational angles and clinical outcomes were assessed using Spearman's correlation coefficient. The statistical significance level was set at $p < 0.05$. A power analysis using the G*Power 3 analysis program [18] indicated that the minimum sample size required to achieve a modest correlation between component rotational angles and clinical outcomes was 29 patients when using a type I error (a) of 0.05, power (1 − b) of 0.80, and a correlation q H1 of 0.5. The receiver operating characteristic (ROC) curve was constructed and used to determine the optimal cut-off point of the femorotibial component rotational mismatch; patients were divided into two groups based on this (postoperative KSS total score of >70% or <70%). The Youden index was used to identify the cut-off point as the coordinate on the ROC curve for which there was the highest combination of sensitivity and specificity [19].

3. Results

Table 2 lists the patients' preoperative and postoperative KSS and ROM values. Significant improvements were noted in the objective knee indicator, patient satisfaction, functional activities, and total scores of the 2011 KSS. In addition, the knee extension angle significantly improved after TKA. The femoral component rotational angle was -0.4° ± 2.7° (range, -7.9° to 9.1°), and the tibial component rotational angle was 0.7° ± 3.5° (range, -7.1° to 10.2°). The rotational mismatch between the femoral and tibial components was 3.2° ± 2.1° (range, 0.1°–9.5°).

The postoperative knee flexion angle positively correlated with the objective knee indicator and the total score of the 2011 KSS (Table 3). In contrast, the femorotibial component rotational mismatch negatively correlated with clinical outcomes including the postoperative objective knee indicator, functional activities, and total score of the 2011 KSS. It was also negatively correlated with the postoperative knee flexion angle (Table 4, Figure 3). The optimal cut-off point of the femorotibial component rotational mismatch for the postoperative KSS total score was 2.8° (AUC = 0.768, p = 0.03). The cut-off value was used to distinguish good clinical outcomes with KSS total scores of >70% and <70% (Figure 4).

4. Discussion

To our knowledge, this is the first study to show the influence of femorotibial component rotational mismatch on clinical outcomes after JOURNEY II BCS TKA. In this study, femorotibial component rotational mismatch negatively correlated with postoperative clinical outcomes, including objective knee indicator, patient satisfaction, functional activities, and total 2011 KSS. The clinical outcomes of JOURNEY II BCS TKA, similar to conventional TKA designs such as PS and CR TKA, can be negatively influenced by excessive rotational mismatch [13-15].

There were significant improvements in the 2011 KSS and ROM scores in this study. This study demonstrated that JOURNEY II BCS TKA can be used to reproduce natural knee kinematics, and some studies have similarly reported good clinical outcomes following JOURNEY II BCS TKA [7, 8]. Our results showed a significant positive correlation between the postoperative knee flexion angle and the objective knee indicator, and the total score of the 2011 KSS. Postoperative ROM is an essential factor influencing clinical outcomes following TKA; previous studies suggested a significant correlation between ROM and clinical scores [2], and the maximal flexion angle resulted in good clinical and functional outcomes [20]. However, femorotibial component rotational mismatch, postoperative 2011 KSS, and ROM were negatively correlated in this study. Previous studies have reported that a component rotational mismatch of approximately 4° to 20° has a negative correlation with the postoperative total KSS [13], and a rotational mismatch ≥10° has a negative influence on functional outcomes [14] following PS TKA. Lützner et al. reported that a rotational mismatch ≥10° resulted in different kinematics and negatively influenced clinical outcomes following CR TKA [15]. In the present study, the rotational mismatch was relatively small compared to those previously reported (<9.3°); however, there was a significant negative correlation between rotational mismatch and postoperative outcomes. These results suggest that JOURNEY II BCS TKA is sensitive to femorotibial component rotational mismatches.

Studies comparing JOURNEY BCS TKA and JOURNEY II BCS TKA reported superior clinical outcomes and a lower rate of complications with JOURNEY II BCS TKA than with JOURNEY BCS TKA [21, 22]. However, some studies have suggested the presence of structural weakness in the guided-motion design of JOURNEY II BCS TKA. Kuwashima et al. reported that the anterior post-cam contact stress was lower, but the contact area was wider in JOURNEY II BCS TKA than in PS TKA [23]. Kaneko et al. suggested that medial tightness is required for kinematic movement in JOURNEY II BCS TKA [24]. In contrast, Inui et al. found that excessive medial tightness in knee flexion could prevent kinematic movement of the tibial component in JOURNEY II BCS TKA [25]. JOURNEY II BCS TKA yields good outcomes by reproducing natural knee kinematics [26]; however, JOURNEY II BCS TKA may have joint restraint as a negative characteristic of guided-motion TKA, similar to the first generation. Therefore, when using the JOURNEY II BCS system, surgeons should be careful to avoid femorotibial component rotational mismatch because guided-motion TKA may have a higher joint restraint than conventional TKA. Kawaguchi et al. suggested that the “Range of motion-anatomical technique” could obtain the ideal tibial component rotational angle and consider the femorotibial component rotational mismatch in JOURNEY II BCS TKA. In the future, further development of the surgical procedure is desired to use the guided-motion TKA properly [27].

Bi-cruciate retaining (BCR) TKA in which the anterior cruciate ligament was retained had been developed with a concept of achieving knee motion close to native kinematics similar to BCS TKA [28]. Previous studies reported good clinical results and better joint stability than traditional TKA, but some studies indicated the risk of high revision rate and negative influence on clinical outcomes by elevated ligamentous tension during BCR TKA [29-30]. Research about BCR TKA also is developing yet, and there are few studies to compare BCS and BCR TKA. In the future, further research to establish the knee prosthesis preserving native knee kinematics will be required.

This study has several limitations. First, the follow-up period was relatively short. Component wear and long-term postoperative outcomes are important factors for patient satisfaction; however, they could not be investigated in this study. Second, the populations in the present study were limited to varus knee osteoarthritis; valgus deformity was excluded. We, however, plan to conduct larger studies that will include valgus knee osteoarthritis in the future.

5. Conclusions

This study demonstrated improved clinical outcomes after JOURNEY II BCS TKA. The femorotibial component rotational mismatch and the postoperative clinical outcomes, including flexion angle, objective indicators, functional activity scores, and total score of the 2011 KSS, were negatively correlated. Therefore, when JOURNEY II BCS system is used for TKA, surgeons should avoid excessive femorotibial rotational mismatch.

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Declarations of interest

None

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Table 1. Patient demographic data (n = 50)

Age, years	74.0 ± 8.8
Women : Men	5 : 45
Right : Left	23 : 27
Weight, kg	59.4 ± 9.5
Height, cm	151.9 ± 5.8
Body mass index, kg/m^2	26.7 ± 3.9
Deformity (varus)	7.2 ± 6.6°
Diagnosis (% osteoarthritis)	100

Table 2. Preoperative and postoperative 2011 KSS and ROM

	Preoperative	Postoperative	
2011 KSS	Mean ± SD	Mean ± SD	p value
Objective knee indicator	62.7 ± 17.5	91.2 ± 8.8	< 0.01
Patient satisfaction	14.9 ± 5.4	24.6 ± 7.5	< 0.01
Patient expectations	11.8 ± 2.4	10.9 ± 3.0	0.08
Functional activities	44.4 ± 15.1	63.6 ± 20.4	< 0.01
Total	133.8 ± 28.2	190.4 ± 32.3	< 0.01
ROM	Mean ± SD	Mean ± SD	p value
Extension	-9.8 ± 6.9˚	-2.4 ± 3.5˚	< 0.01
Flexion	119.4 ± 14.4˚	125.4 ± 11.3˚	< 0.01

KSS, Knee Society Score; ROM, range of motion; SD, standard deviation

Table 3. Correlation coefficients between the 2011 KSS and ROM

	Postoperative extension		Postoperative flexion	
Postoperative 2011 KSS	r	*p*-value	R	*p*-value
Objective knee indicator	0.18	0.21	0.41	< 0.01
Patient satisfaction	0.19	0.19	0.16	0.26
Patient expectations	0.14	0.32	0.26	0.07
Functional activities	-0.16	0.27	0.19	0.18
Total	0.03	0.82	0.29	0.04

KSS: Knee Society Score; ROM: range of motion

Table 4. Correlation coefficients between the component malrotation and postoperative 2011 KSS and ROM

	Femoral component malrotation		Tibial component malrotation		Rotational mismatch	
Postoperative 2011 KSS	r	*p*-value	r	*p*-value	r	*p*-value
Objective knee indicator	-0.06	0.65	0.10	0.47	-0.44	< 0.01
Patient satisfaction	0.11	0.42	0.11	0.44	-0.38	< 0.01
Patient expectations	0.05	0.74	-0.08	0.58	-0.19	0.18
Functional activities	-0.09	0.53	-0.02	0.87	-0.39	< 0.01
Total	-0.05	0.72	0.06	0.69	-0.46	< 0.01
Postoperative ROM	r	*p*-value	r	*p*-value	r	*p*-value
Extension	-0.18	0.22	0.49	0.73	0.01	0.95
Flexion	-0.05	0.74	0.20	0.15	-0.31	0.03

Femoral component malrotation: component rotational angle from the surgical epicondylar axis; tibial component malrotation: the component rotational angle from Akagi's line; rotation mismatch: the absolute value of the difference between the femoral and tibial component malrotation; KSS: Knee Society Score; ROM: range of motion

Figure legends

Figure 1. Femoral component rotational angle.

Axial computed tomography image of the left femur. The surgical epicondylar axis (SEA) connects the lowest point of the medial epicondyle to the midpoint of the lateral epicondyle. The prosthetic posterior condylar line (PCL) connects the medial and lateral prosthetic posterior condylar surfaces. The femoral component rotational angle was defined as the angle between the SEA and the PCL.

Figure 2. Tibial component rotational angle.

Axial computed tomography image of the left tibia. Akagi's line connects the center of the posterior cruciate ligament and the medial border of the tibial tuberosity. The tibial component rotational angle was defined as the angle between the centerline of the tibial component and Akagi's line.

Figure 3. Correlation between the femorotibial component rotational mismatch and clinical outcomes.

There were significant correlations between the femorotibial component rotational mismatch and the postoperative objective knee indicator, patient satisfaction, functional activities, total KSS score, and knee flexion angle.

Figure 4. Receiver operating characteristic curve analysis.

The femorotibial component rotational mismatch yielded an area under the curve of 0.768. The cut-off value identified by the Youden index, which is the highest combination of sensitivity and specificity, was 2.8°.

Figure 1.

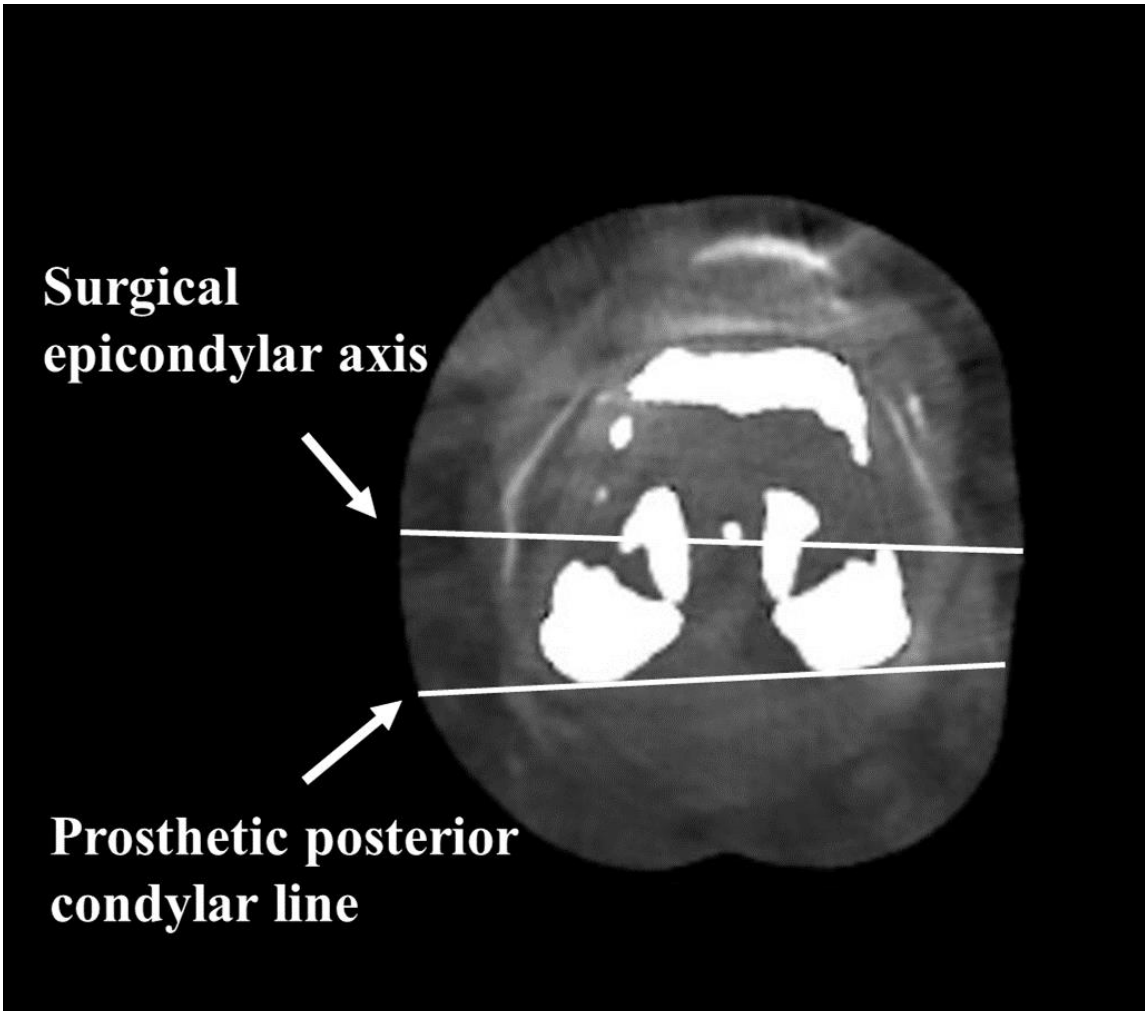

Surgical
epicondylar axis
Prosthetic posterior
condylar line

Figure 2.

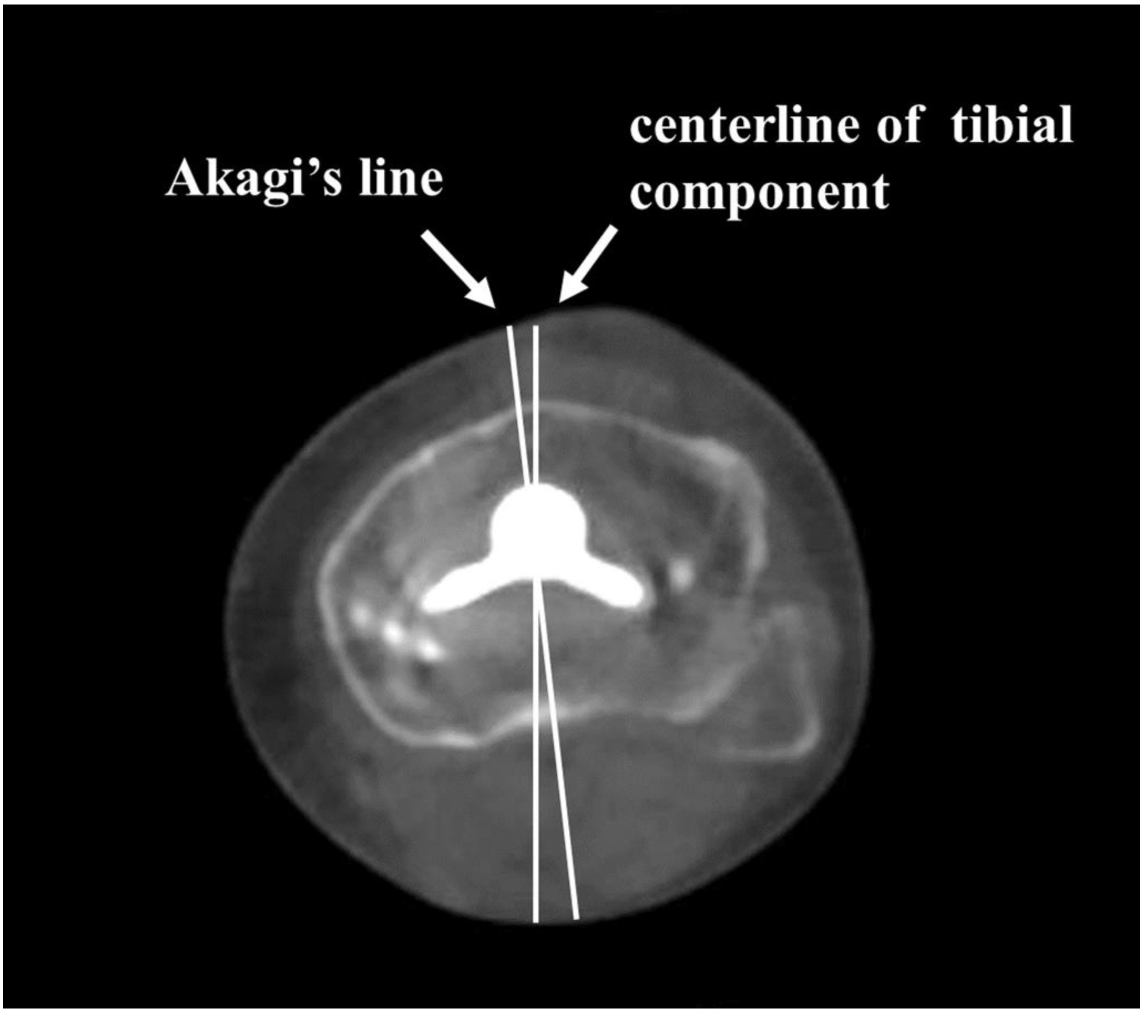


Figure 3.

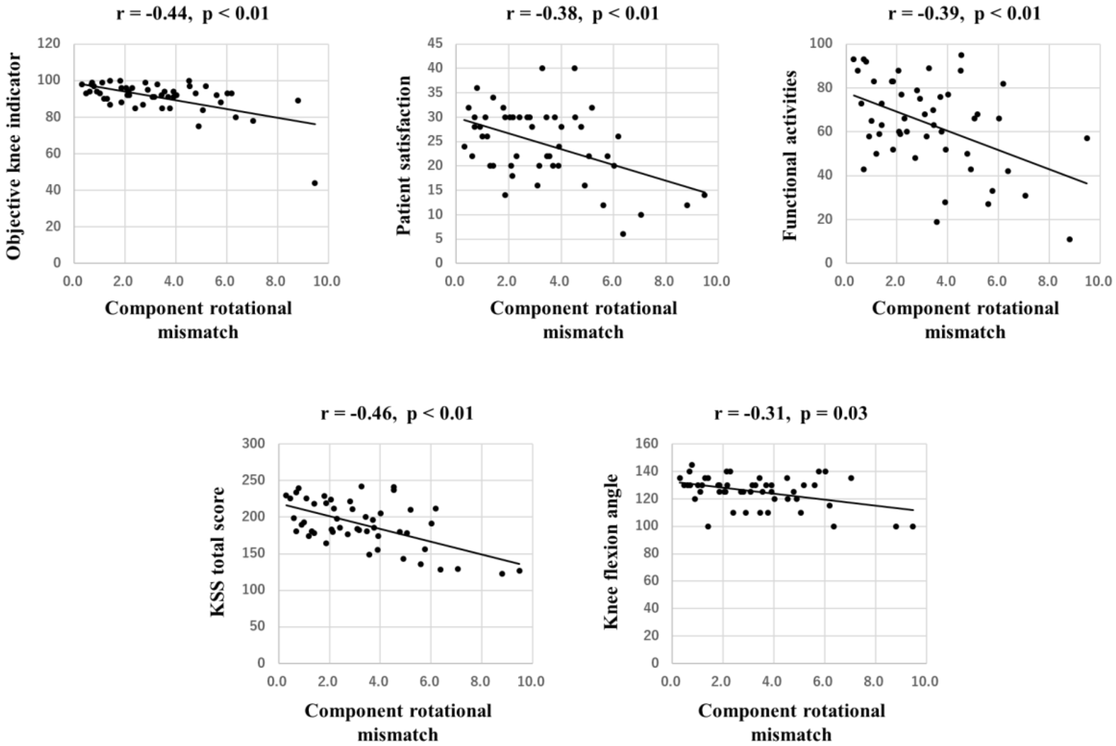
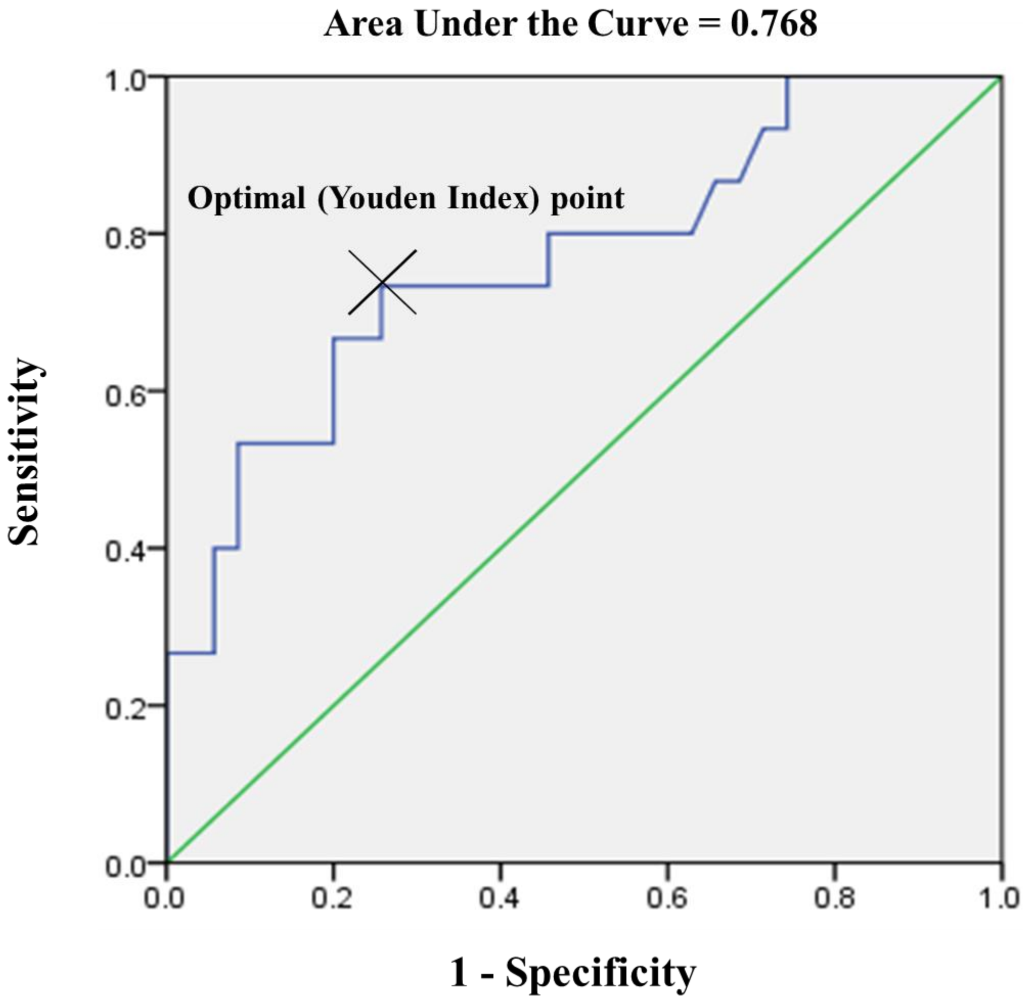

r = -0.44, p < 0.01
Objective knee indicator
Component rotational mismatch
r = -0.38, p < 0.01
Patient satisfaction
Component rotational mismatch
r = -0.39, p < 0.01
Functional activities
Component rotational mismatch
r = -0.46, p < 0.01
KSS total score
Component rotational mismatch
r = -0.31, p = 0.03
Knee flexion angle
Component rotational mismatch

Figure 4.


Area Under the Curve = 0.768
Optimal (Youden Index) point
Sensitivity
1 - Specificity
0.0
0.2
0.4
0.6
0.8
1.0