# Dependence of knee range of motion on the alignment of femoral and tibial components after medial unicompartmental knee arthroplasty

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**Abstract**

**Introduction**

This study evaluated the relationship between postoperative knee flexion angles and the position of femoral and tibial components in unicompartmental knee arthroplasty (UKA).

**Materials and methods**

Eighteen patients (a total of 22 knees: 3 men, 4 knees; 15 females, 18 knees) who underwent navigation-assisted UKA were included. Pre- and post-operative computed tomography images were applied on 3D software, which were matched and used to calculate the position of femoral and tibial components. Correspondingly, we investigated the relationship between the knee range of motion (ROM) at one-year postoperative follow-up and the position of femoral and tibial components.

**Results**

At one-year post-UKA, the knee flexion angle was associated with the posterior flexion angle of tibial components. This particular angle was significantly greater in the group with equal or greater postoperative knee ROM compared to preoperative ROM (5.2 ± 2.1°) than in the group with less postoperative knee ROM compared to preoperative ROM (2.6 ± 1.6°, $p < 0.01$). There was no significant difference between both groups in the femoral component position, preoperative posterior slope of the medial tibial plateau, change in the pre- to postoperative posterior tibial slope, and postoperative knee society score.

**Conclusion**

The posterior flexion angle of the tibial component affected the improvement/deterioration of the post-surgery knee flexion angle following navigation-assisted UKA. For improved outcomes after UKA using navigation systems, surgeons should aim to achieve a 5° to 8° posterior flexion angle of the tibial component.

Keywords

Unicompartmental knee arthroplasty, navigation assisted surgery, posterior flexion angle, tibia, range of motion, medial tibial plateau.

**Disclosures**

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**Conflict of Interest: None**

**Ethical Approval:** All procedures performed during studies involving human participants were in accordance with the ethical standards of the institution (Hamamatsu University School of Medicine, No. 19-261) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Author Contributions**

M. Hanada: Acquired and analyzed the data, Wrote the manuscript.

K. Hotta: Designed the study, Wrote the manuscript.

Y. Matsuyama: Advised on the study, Approved the submission.

## 1 Introduction

Unicompartmental knee arthroplasty (UKA) is a surgical procedure used to treat isolated medial compartmental osteoarthritis or osteonecrosis of the knee. The advantages of UKA over total knee arthroplasty (TKA) include less invasiveness [1], earlier postoperative recovery [2], superior functional outcomes [3], and preserved normal knee kinematics [4]. However, some studies compared clinical data between UKA and TKA and showed contradictory results [5-7]. Several reports described unsatisfactory outcomes for UKA, which were caused by early loosening of components [8], poor longevity compared to TKA [9-12], fracture of medial tibial condyle [13-16], and insert dislocation in mobile bearing type UKA [17,18]. Intraoperative technical errors or UKA performed for contraindicated cases was deemed attributable for these undesirable outcomes. Conversely, various studies described good outcomes following appropriate implant alignment [19,20] and operative indication for UKA [21,22]. Therefore, proper positioning of femoral and tibial components is critically related to the clinical outcomes and durability; valgus alignment in the coronal plane and significant posterior slope in the sagittal plane at the tibial component should be avoided [19,23]. In addition, Barbadoro et al. reported that >5° of a varus misalignment has the risk of loosening the tibial component [8]. Likewise, a greater posterior slope could be detrimental to the long-term success rates of UKA [23], and Hernigou and Deschamps reported that a tibial implant slope > 7° should be avoided [19].

Navigation systems have been developed for TKA, which were also used in UKA recently. In particular, computer-navigated systems developed to improve the accuracies of alignment showed satisfactory results in the coronal and sagittal planes [24,25]. Therefore, several reports showed that the position and mechanical alignment of tibial components in UKA were improved by navigation, compared to the conventional technique [26-33]. Furthermore, some of these reports showed that patients undergoing navigation-assisted UKA tended to have better clinical outcomes [28,30,31]. However, the effects of femoral and tibial component positions on knee kinematics and knee range of motion (ROM) after UKA remain unknown, and few reports demonstrated the relationship between the postoperative knee ROM and post-UKA outcomes. Since patients often gain a reasonable knee ROM, such as ≥130° after UKA [21,22,34], one reason is that the postoperative knee ROM might not be significantly different among patients who underwent UKA. However, the post-UKA knee ROM can decrease in several cases. Hence, this study aimed to evaluate the effects of femoral and tibial component positions on knee kinematics including knee ROM after navigation-assisted UKA.

## 2 Methods

The study was performed retrospectively and was approved by the ethics committee of the Hamamatsu University School of Medicine (No. 19-261). From April 2015 to March 2019, consecutive patients who underwent primary UKA for isolated medial compartmental osteoarthritis of the knee and osteonecrosis were included.

The indications for medial UKA were as follows: 1) patients with anteromedial osteoarthritis and osteonecrosis with severe medial knee pain [35]; 2) patients without symptoms in the patellofemoral joint and lateral compartment of the femorotibial joint; 3) correctable coronal alignment under valgus stress; 4) intact cruciate and collateral ligaments; 5 ) preoperative flexion contracture < 15°; and 6) preoperative knee flexion > 90°.

The study population included 18 patients (22 knees) with an average age of 73.1 years (range, 59–89 years) who completed the minimum 1-year follow-up period. Magnetic resonance imaging examination was performed on all the patients before surgery for the evaluation of their anterior cruciate ligament.

***2.1 UKA surgical procedures***

All UKA procedures were performed with a computed tomography (CT)-free navigation system (Stryker Knee Navigation System version 4.0; Stryker Leibinger, Freiburg, Germany). We used the medial subvastus approach to expose the knee joint and ensured minimal ligamentous and soft tissue release in the medial collateral ligament for osteotomy.

Based on previous reports [19,36], we aimed for 3° varus alignment and 5° posterior slope in the medial tibial plateau for the tibial component while performing osteotomy of the tibial plateau. On the femoral side, a gap technique was used with the spacer block. Then, fixed-bearing implants (Triathlon

PKR; Stryker Kalamazoo, MI, USA) were cemented for UKA.

### *2.2 3D data preparation*

CT examinations were performed pre- and postoperatively. Digital imaging and communications in medicine data from CT examinations were applied to 3D image software (ZedView, LEXI, Tokyo, Japan). The femoral head center was defined by four reference points. The functional axis of the femur in the coronal and sagittal planes was set with respect to two reference points: the center of the femoral head and center of the knee. The femoral sagittal plane was defined as the plane with the perpendicular line between the medial and lateral condyles of the femur. The functional axis of the tibia in the coronal and sagittal planes was set with respect to two reference points: the center of the bone marrow at one-third and two-thirds of the tibial shaft. The tibial sagittal plane was defined as the plane with the line from the middle of the posterior cruciate ligament to the middle edge of the patellar tendon attachment to the tibial tuberosity. In this sagittal plane, the posterior tibial slope of the medial tibial plateau was measured relative to the tibial axis (Fig. 1). Finally, using the ZedKnee program under ZedView, the positions of femoral and tibial components were measured by matching among pre- and postoperative CT images (Fig. 2).

### *2.3 Postoperative procedure and evaluation*

Patients were hospitalized the day before surgery. On the first postoperative day, the suction drain was removed, and patients were allowed to start range of motion rehabilitation and ambulation. Exercises were performed for approximately 2 weeks during hospitalization. After discharge, all patients had monthly outpatient follow-up visits, and their knee ROM was examined with a goniometer.

The relationship between the knee ROM at 1 year after surgery and the position of femoral and tibial components was investigated. The new Knee Society score (KSS) [37,38] at 1 year after surgery was evaluated and compared with the knee ROM, and its relationship with the position of femoral and tibial components was investigated.

Varus, flexion, and internal rotation of the component positions were shown as positive values, whereas valgus, extension, and external rotation of the component positions were shown as negative values.

### *2.4 Statistical analysis*

The correlation between knee ROM at 1 year after surgery and the position of the femoral and tibial components was calculated with Pearson's correlation coefficient. The relationship between the KSS at 1 year after surgery and knee ROM and component positions were also evaluated with Pearson's correlation coefficient.

After classifying the patients into two groups based on the change between pre- and postoperative

ROM values, we compared the position of the femoral and tibial components and the KSS using the Student's t-test between both groups.

SPSS version 21 (IBM Corporation, Armonk, NY) was used for all statistical analyses, and $p<0.05$ was considered statistically significant.

**4 Results**

Patients' demographic data with measurements of their femoral and tibial component positions are shown in Table 1. The ROM including knee extension and flexion had no significant correlation with the position of the femoral and tibial components. Postoperative knee flexion angle was associated with the preoperative knee flexion angle ($p<0.01$) only, although there was no significant correlation between pre- and postoperative knee extension. There was also no significant correlation between the KSS and knee ROM or the position of femoral and tibial components.

For patients with equal or greater postoperative knee ROM than preoperative ROM (Group G), the posterior flexion angle of the tibial components was significantly greater than that in patients having less postoperative knee ROM than preoperative ROM (Group L) ($p<0.01$) (Table 2). The scatter plot shows the difference in the sagittal plane position of the tibial component between groups (Fig. 3). Furthermore, there was no significant difference in the femoral component position, preoperative posterior slope of the medial tibial plateau, change between the preoperative posterior slope of the medial tibial plateau and the flexion angle of the tibial component, and postoperative KSS between the groups (Table 2).

## 5 Discussion

The primary finding of this study was that the flexion angle of the tibial component affected the improvement or deterioration of the knee flexion angle after navigation-assisted UKA. In contrast, no linear correlation existed between the flexion angle of the tibial component and the flexion angle of the knee in our study, even though the postoperative knee ROM is strongly influenced by the preoperative ROM [39-41]. Since we used a navigation system for performing tibial osteotomy, we could achieve an almost accurate position of the tibial component in the coronal and sagittal planes with negligible error. However, by using the navigation system, the postoperative knee flexion angle might be worse than preoperative knee flexion if the flexion angle of the tibial component was limited. To our knowledge, only a few studies investigated the influence of the post-UKA knee flexion angle on clinical outcomes. Takayama et al. reported that an increased tibial slope reduced the postoperative extension angle of the knee, although the tibial slope change did not affect the postoperative knee flexion angle [42]. As in this study, the osteotomy was accurate in the coronal plane to approximately 3° of varus by using the navigation system, the knee ROM and KSS were considered as not associated with varus degrees of the tibial components and there were no differences between the two groups. Furthermore, it was considered that the preoperative limitation of knee extension was influenced by knee pain; hence, the postoperative knee extension improved in almost all cases. Inui et al. reported that knee flexion angles ≥140° influenced the superior clinical results of UKA, and were associated with the posterior flexion angle of the tibial component [43].

In this study, patients with postoperative knee flexion angles equal or more than the preoperative knee flexion (Group G) had greater flexion angle of tibial components compared to patients with less postoperative knee flexion (Group L). However, even if the flexion angle of tibial components increases, we believe that the knee ROM does not directly improve because the flexion angle of the tibial component did not have any linear correlation with the postoperative flexion angle of the knee per the results of this study. Sekiguchi et al. reported that the preferred tibial component alignment is between the neutral and 2° varus in the coronal plane, and between 3° and 7° tibial posterior slope in the sagittal plane using a musculoskeletal computer simulation [44]. Based on our results, because the error of tibial component position was within 3° in our procedure, we consider that the aim of tibial osteotomy in the sagittal plane should be 5° or greater and less than 8° posterior flexion with the navigation system.

There were several limitations to this study. First, we had a significantly small study size. Second, the follow-up time of 1 year was relatively short. A longer follow-up period might be required to evaluate patients' satisfaction, expectations, and activity using the KSS score, although a follow-up period of 1 year has been reported as sufficient for predicting the knee ROM after TKA [41]. Thus, it may be sufficient for evaluating postoperative outcomes of UKA as well. Third, the fixed bearing-type implant for UKA was used in this study. Therefore, outcomes may differ with the application of mobile bearing-type implants.

Overall, the current report was unique and had important implications as the flexion angle of the tibial component significantly influenced the postoperative knee flexion angle. When a navigation system is used for UKA, surgeons should aim to achieve 5–8° of the flexion angle of the tibial component to ensure better outcomes after UKA.

## 6 Conclusion

The posterior flexion angle of the tibial component affected the improvement or deterioration of the postoperative knee flexion angle after the patients underwent UKA with a navigation system. The aim of 5–8° posterior flexion of tibial components would ensure better outcomes of navigation-based UKA.

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**Figure captions**

**Fig. 1.** Preoperative planning for UKA.

The preoperative planning shows that the femoral component position is in 0° of varus in coronal plane, 0° of flexion in sagittal plane, and 0° of rotation in axial plane (A) or the tibial component position is 3° of varus, 5° of flexion, and 0° of rotation (B). When the tibial component was placed parallel to the tibial plateau, preoperative tibial posterior slope of medial plateau was measured from the flexion angle of the tibial component in sagittal plane.

**Fig. 2.** Images obtained by matching the preoperative planning and postoperative CT images using three-dimensional software.

Postoperative three-dimensional positions of femoral component (A) and tibial component (B) were measured from the errors between these preoperative planning and actual component positions.

**Fig. 3**. Postoperative posterior tibial slope.

The scatter plot compares the postoperative posterior tibial slope between patients with equal or greater postoperative knee ROM than preoperative ROM and patients with less postoperative knee ROM than preoperative ROM. There was a significant difference between the groups ($p$<0.01), and the group that had equal or greater postoperative knee ROM than preoperative ROM had greater postoperative tibial posterior slope that means tibial component flexion. ROM, range of motion

**Table 1**

The demographic data of patients and the position measurements of femoral and tibial components.

| | |
|---|---|
| Gender (male / female) | 3 (4 knees) / 15 (18 knees) |
| Age (yr) | 73.2 ± 9.0 |
| Preoperative knee extension (°) | -2.7 ± 3.3 |
| Preoperative knee flexion (°) | 132.9 ± 9.2 |
| Postoperative knee extension (°) | -3.0 ± 4.4 |
| Postoperative knee flexion (°) | 130.5 ± 9.4 |
| Femoral component position in coronal plane (°) (varus, valgus) | +1.1 ± 2.3 |
| Femoral component position in sagittal plane (°) (flexion, extension) | -2.5 ± 2.7 |
| Femoral component position in axial plane (°) (internal rotation, external rotation) | +1.2 ± 4.0 |
| Tibial component position in coronal plane (°) (varus, valgus) | +2.5 ± 1.0 |
| Tibial component position in sagittal plane (°) (flexion, extension) | +4.1 ± 2.2 |
| Tibial component position in axial plane (°) (internal rotation, external rotation) | +2.0 ± 6.8 |
| Preoperative tibial posterior slope of medial plateau (°) | +11.4 ± 2.8 |
| The change in tibial posterior slope of medial plateau (°) | 7.3 ± 3.2 |
| Postoperative KSS (pt) | 98.8 ± 23.2 |

Values are presented as numbers, or mean and standard deviation.

Varus in coronal plane, flexion in sagittal plane, and internal rotation in axial plane of the component positions were shown as plus value. Valgus, extension, and external rotation of the component positions were shown as minus value.

ROM, range of motion

KSS, The Knee Society Score

**Table 2**

The comparison between patients with equal or greater postoperative knee ROM than preoperative ROM (Group G) and patients with less postoperative knee ROM than preoperative ROM (Group L)

| | Patients in Group G (n=12) | Patients in Group L (n=10) | *p* values |
|---|---|---|---|
| Gender (male / female) | 2 (3 knees) / 7 (9 knees) | 1 (1 knees) / 8 (9 knees) | |
| Age (yr) | 75.3 ± 9.2 | 70.4 ± 8.2 | 0.227 |
| Preoperative knee extension (°) | -2.5 ± 3.3 | -2.8 ± 3.6 | 0.884 |
| Preoperative knee flexion (°) | 131.2 ± 11.7 | 135.0 ± 4.3 | 0.374 |
| Postoperative knee extension (°) | -1.4 ± 3.2 | -5.0 ± 5.0 | 0.065 |
| Postoperative knee flexion (°) | 133.8 ± 11.1 | 126.1 ± 4.1 | 0.066 |
| Femoral component position in coronal plane (°) | +0.7 ± 2.6 | +1.7 ± 1.9 | 0.374 |
| Femoral component position in sagittal plane (°) | -3.0 ± 2.7 | -2.0 ± 2.8 | 0.447 |
| Femoral component position in axial plane (°) | +2.3 ± 4.8 | -0.3 ± 2.2 | 0.155 |
| Tibial component position in coronal plane (°) | +2.4 ± 1.0 | +2.7 ± 1.2 | 0.598 |
| Tibial component position in sagittal plane (°) | +5.2 ± 2.1 | +2.6 ± 1.6 | 0.007** |
| Tibial component position in axial plane (°) | +0.7 ± 4.5 | +3.8 ± 9.0 | 0.305 |
| Preoperative tibial posterior slope of medial plateau (°) | +12.2 ± 2.8 | +10.3 ± 2.7 | 0.146 |
| The change in tibial posterior slope of medial plateau (°) | 7.0 ± 3.9 | 7.7 ± 2.3 | 0.644 |
| Postoperative KSS (pt) | 104.7 ± 21.9 | 90.9 ±23.9 | 0.207 |

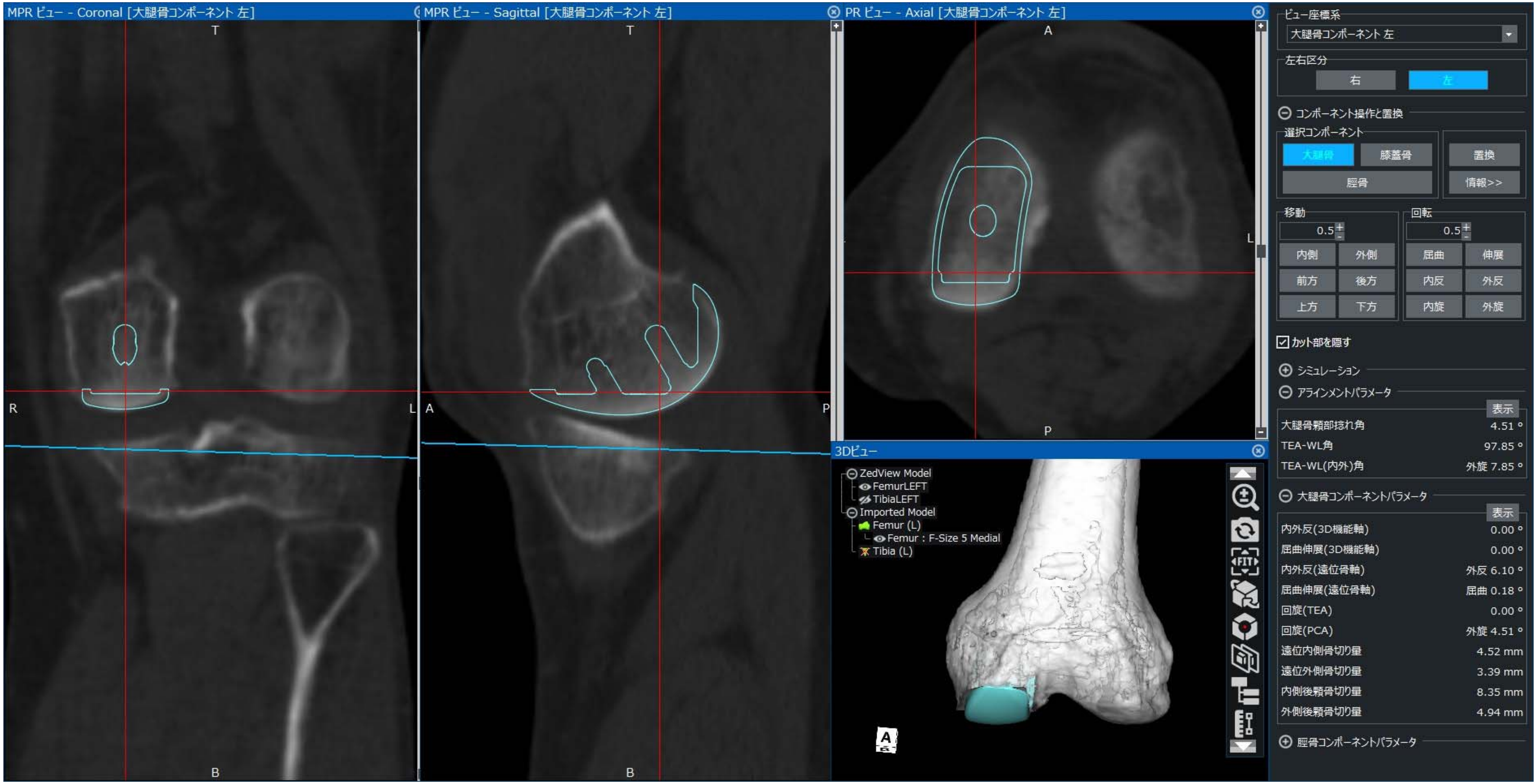
Values are presented as numbers, or mean and standard deviation.

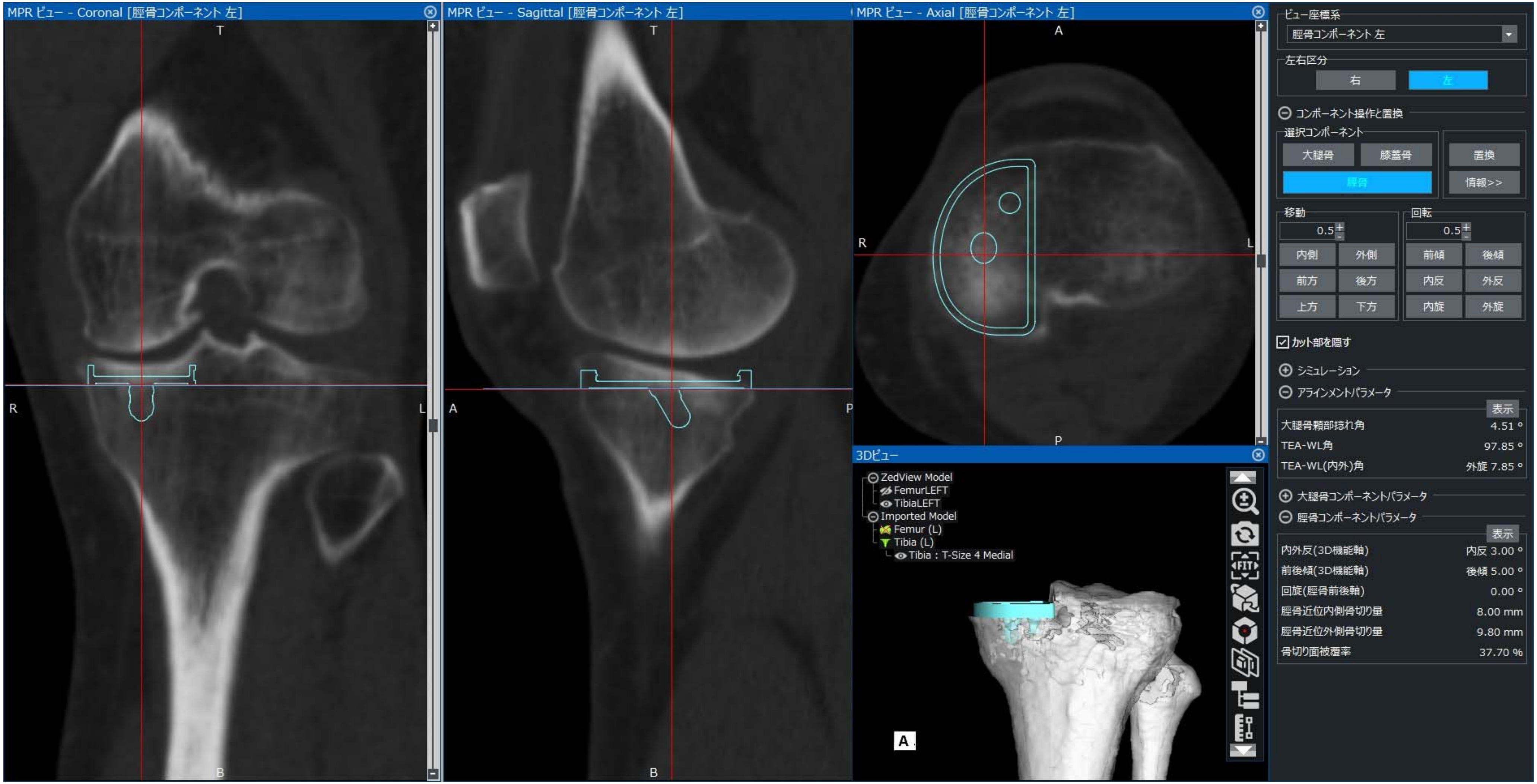
Varus in coronal plane, flexion in sagittal plane, and internal rotation in axial plane of the component positions were shown as plus value. Valgus, extension, and external rotation of the component positions were shown as minus value.

**: $p<0.01$

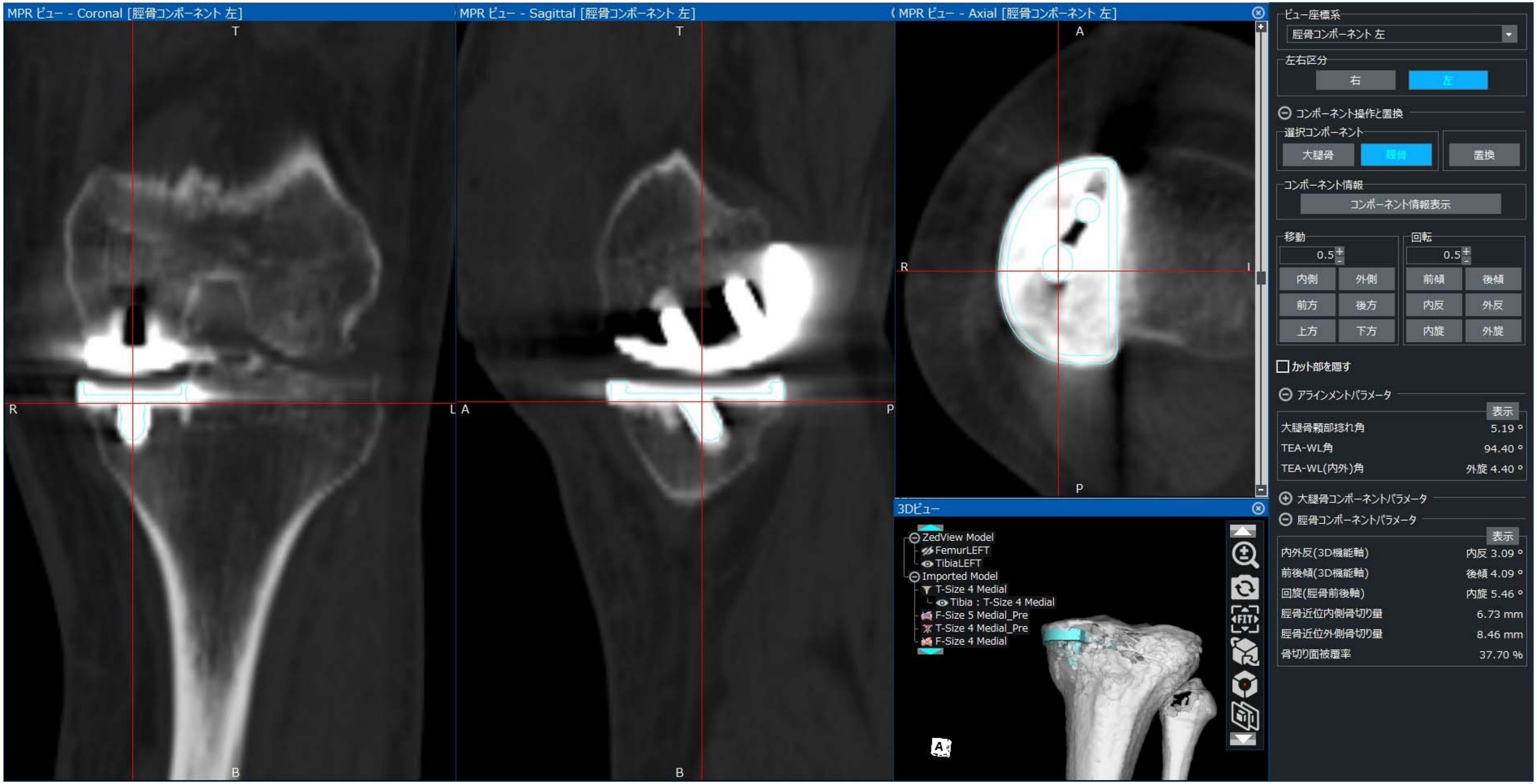
ROM, range of motion

KSS, The Knee Society Score

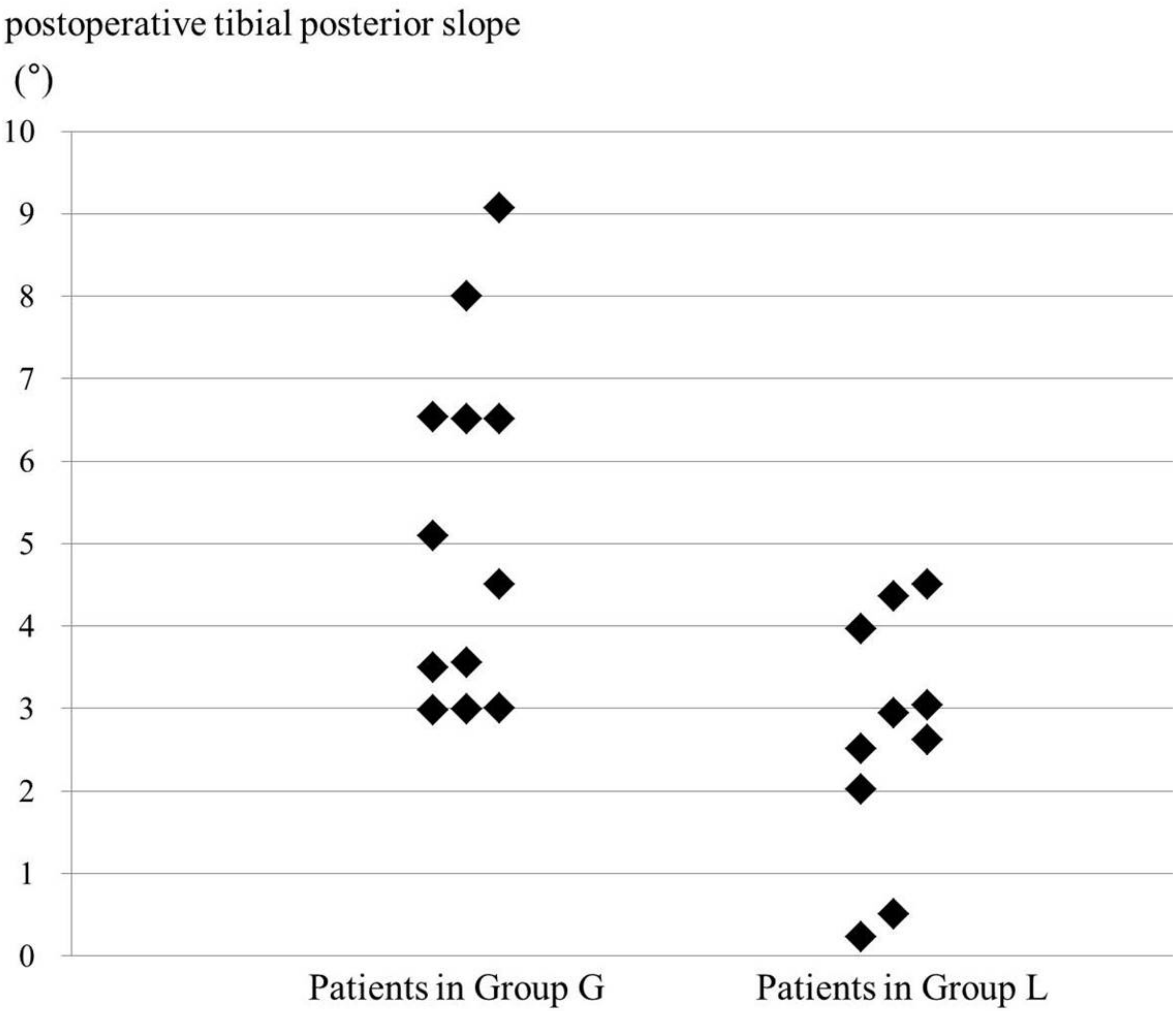

MPR ビュー - Coronal [大腿骨コンポーネント 左]
MPR ビュー - Sagittal [大腿骨コンポーネント 左]
PR ビュー - Axial [大腿骨コンポーネント 左]
T
R
L
B
A
P
3Dビュー
ZedView Model
FemurLEFT
TibiaLEFT
Imported Model
Femur (L)
Femur : F-Size 5 Medial
Tibia (L)
ビュー座標系
大腿骨コンポーネント 左
左右区分
右
左
コンポーネント操作と置換
選択コンポーネント
大腿骨
膝蓋骨
置換
脛骨
情報>>
移動
0.5
回転
0.5
内側
外側
屈曲
伸展
前方
後方
内反
外反
上方
下方
内旋
外旋
カット部を隠す
シミュレーション
アライメントパラメータ
表示
大腿骨顆部捻れ角 4.51 °
TEA-WL角 97.85 °
TEA-WL(内外)角 外旋 7.85 °
大腿骨コンポーネントパラメータ
表示
内外反(3D機能軸) 0.00 °
屈曲伸展(3D機能軸) 0.00 °
内外反(遠位骨軸) 外反 6.10 °
屈曲伸展(遠位骨軸) 屈曲 0.18 °
回旋(TEA) 0.00 °
回旋(PCA) 外旋 4.51 °
遠位内側骨切り量 4.52 mm
遠位外側骨切り量 3.39 mm
内側後顆骨切り量 8.35 mm
外側後顆骨切り量 4.94 mm
脛骨コンポーネントパラメータ


MPR ビュー - Coronal [脛骨コンポーネント 左]
T
R
L
B
MPR ビュー - Sagittal [脛骨コンポーネント 左]
T
A
P
B
MPR ビュー - Axial [脛骨コンポーネント 左]
A
R
L
P
3Dビュー
ZedView Model
FemurLEFT
TibiaLEFT
Imported Model
Femur (L)
Tibia (L)
Tibia : T-Size 4 Medial
A
ビュー座標系
脛骨コンポーネント 左
左右区分
右
左
コンポーネント操作と置換
選択コンポーネント
大腿骨
膝蓋骨
置換
脛骨
情報>>
移動
0.5
回転
0.5
内側
外側
前傾
後傾
前方
後方
内反
外反
上方
下方
内旋
外旋
カット部を隠す
シミュレーション
アラインメントパラメータ
表示
大腿骨顆部捻れ角 4.51 °
TEA-WL角 97.85 °
TEA-WL(内外)角 外旋 7.85 °
大腿骨コンポーネントパラメータ
脛骨コンポーネントパラメータ
表示
内外反(3D機能軸) 内反 3.00 °
前後傾(3D機能軸) 後傾 5.00 °
回旋(脛骨前後軸) 0.00 °
脛骨近位内側骨切り量 8.00 mm
脛骨近位外側骨切り量 9.80 mm
骨切り面被覆率 37.70 %


MPR ビュー - Coronal [大腿骨コンポーネント 左]
MPR ビュー - Sagittal [大腿骨コンポーネント 左]
MPR ビュー - Axial [大腿骨コンポーネント 左]
3Dビュー
ZedView Model
FemurLEFT
TibiaLEFT
Imported Model
T-Size 4 Medial
F-Size 5 Medial_Pre
T-Size 4 Medial_Pre
F-Size 4 Medial
Femur : F-Size 4 Medial
ビュー座標系
大腿骨コンポーネント 左
左右区分
右
左
コンポーネント操作と置換
選択コンポーネント
大腿骨
脛骨
置換
コンポーネント情報
コンポーネント情報表示
移動
回転
0.5
0.5
内側
外側
屈曲
伸展
前方
後方
内反
外反
上方
下方
内旋
外旋
カット部を隠す
アラインメントパラメータ
表示
大腿骨顆部捻れ角 5.19 °
TEA-WL角 94.40 °
TEA-WL(内外)角 外旋 4.40 °
大腿骨コンポーネントパラメータ
表示
内外反(3D機能軸) 0.00 °
屈曲伸展(3D機能軸) 伸展 5.00 °
内外反(遠位骨軸) 外反 5.88 °
屈曲伸展(遠位骨軸) 伸展 5.74 °
回旋(TEA) 内旋 3.49 °
回旋(PCA) 外旋 1.71 °
遠位内側骨切り量 0.76 mm
遠位外側骨切り量 -1.06 mm
内側後顆骨切り量 6.45 mm
外側後顆骨切り量 5.27 mm
脛骨コンポーネントパラメータ



MPR ビュー - Coronal [脛骨コンポーネント 左]
MPR ビュー - Sagittal [脛骨コンポーネント 左]
MPR ビュー - Axial [脛骨コンポーネント 左]
T
B
R
L
A
P
3Dビュー
ZedView Model
FemurLEFT
TibiaLEFT
Imported Model
T-Size 4 Medial
Tibia : T-Size 4 Medial
F-Size 5 Medial_Pre
T-Size 4 Medial_Pre
F-Size 4 Medial
ビュー座標系
脛骨コンポーネント 左
左右区分
右
左
コンポーネント操作と置換
選択コンポーネント
大腿骨
脛骨
置換
コンポーネント情報
コンポーネント情報表示
移動
0.5
回転
0.5
内側
外側
前傾
後傾
前方
後方
内反
外反
上方
下方
内旋
外旋
カット部を隠す
アラインメントパラメータ
表示
大腿骨顆部捻れ角 5.19 °
TEA-WL角 94.40 °
TEA-WL(内外)角 外旋 4.40 °
大腿骨コンポーネントパラメータ
脛骨コンポーネントパラメータ
表示
内外反(3D機能軸) 内反 3.09 °
前後傾(3D機能軸) 後傾 4.09 °
回旋(脛骨前後軸) 内旋 5.46 °
脛骨近位内側骨切り量 6.73 mm
脛骨近位外側骨切り量 8.46 mm
骨切り面被覆率 37.70 %


postoperative tibial posterior slope
(°)
10
9
8
7
6
5
4
3
2
1
0
Patients in Group G
Patients in Group L