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Insertion of a spacer block translates the tibia anteriorly during evaluation of soft tissue balance in cruciate-retaining total knee arthroplasty

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ABSTRACT

Background: Soft tissue balance is an important determinant of the outcome of total knee arthroplasty (TKA). However, there are differences in the joint gap and ligament balance between the osteotomized femoral and tibial surfaces and those after TKA. The aim of this study was to compare the relationship between the femur and tibia at insertion of a spacer block with that after cruciate-retaining (CR) TKA.
Methods: Thirty knees in 30 patients (26 women, 4 men) who underwent primary CR TKA with a navigation system were enrolled. Mean age at surgery was 76.3 (range, 63–87) years. After osteotomy of the femur and tibia, the flexion–extension gap and ligament balance were evaluated using a spacer block. The location of the tibial center in relation to the femoral center in the sagittal plane calculated from navigation data at insertion of an appropriately sized spacer block in knee flexion was compared with that after CR TKA using the paired *t*-test.
Results: The mean sagittal location of the tibial center relative to the femoral center in knee flexion was 5.16 (range, −2.4, 16.3) mm at insertion of the spacer block and 6.60 (range, −1.4, 15.1) mm after CR TKA, and this difference was significant ($p = 0.016$).
Conclusion: Assessment of soft tissue balance using a spacer block in CR TKA during knee flexion changes the location of the tibia. Surgeons should be aware of the potential for overestimating the postoperative flexion gap in CR TKA when using a spacer block to assess the flexion gap.

1. Introduction

Total knee arthroplasty (TKA) is a well-established surgical treatment for knee arthrosis [5,8,13] and has favorable long-term outcomes [9,14,17]. Some studies have suggested that soft tissue balance is one of the important determinants of the

Abbreviations: CR, cruciate-retaining; PCL, posterior cruciate ligament; PS, posterior stabilized; TKA, total knee arthroplasty.

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outcome of TKA [11,15,16]. The soft tissue balance in the femorotibial joint is typically evaluated using a spacer block or tensor device. However, there is some debate about whether measurements of the joint gap and ligament balance between osteotomized femoral and tibial surfaces are the same as those between the surfaces of the trial femoral component and tibial osteotomy. As pointed out by Jhurani et al., a spacer block lacks the posterior condyles present on the trial femoral component and thus cannot accurately measure the knee extension space [10]. Muratsu et al. found significant differences in the intraoperative soft tissue balance in knee extension before and after placement of the trial femoral component because the posterior condyles of the trial femoral component tensed the posterior structures of the knee [12].

Previous studies have found that the soft tissue balance achieved with tensors is different from that after cruciate-retaining (CR) TKA even in knee flexion because the joint distraction force affects repositioning of the femur and tibia [3,7,19]]. The posterior cruciate ligament (PCL), which runs obliquely in the sagittal plane in knee flexion [2,4,6]], might be an important factor in the soft tissue balance. The PCL may be verticalized during evaluation of soft tissue balance using a tensor device or a spacer block. Therefore, the sagittal relationship between the femur and tibia during evaluation of soft tissue balance using a spacer block might also be different from that after CR TKA.

The purpose of this study was to test the hypothesis that the tibia locates more anteriorly against the femur during insertion of a spacer block than it does after CR TKA.

2. Materials and methods

This study was a retrospective analysis of routinely collected data and was approved by our institutional review board (Approval No. JAYMC2014OR1).

Thirty-eight consecutive knees in 38 patients who underwent primary CR TKA for osteoarthritis at our hospital between April 2017 and August 2018 were screened for eligibility. In all cases, navigation (Stryker OrthoMap Version 2.0 Knee Navigation ©2012; Stryker, Mahwah, NJ)-assisted TKA was performed using Persona® CR (Zimmer-Biomet, Warsaw, IN) by any of four senior orthopedic surgeons. Persona CR is available with polyethylene inserts ranging in thickness from 10 to 14 mm in 1-mm increments.

2.1. Surgical procedure

Each surgery was performed using a standard medial parapatellar approach. Soft tissue release was not performed except for portions that required osteotomy. The anterior cruciate ligament was sacrificed, and the PCL was preserved. Osteophytes were resected as much as possible before registration of the navigation system. The navigation system was registered for each case according to the manufacturer's protocol. During registration, surgeons need to digitize the positions of anatomic landmarks, namely, the medial and lateral malleolus of the ankle, the center of the proximal tibia, and the center of the distal femur. The center of the femoral head was identified by kinematics. The femoral rotational axis was set perpendicular to the surgical epicondylar axis, and the tibial rotational axis was directed along the line from the medial border of the tibial tubercle to the middle of the posterior cruciate ligament [1]. Both the distal femoral center and the proximal tibial center were identified using points determined on computed tomography scans during preoperative planning. After registration, bone

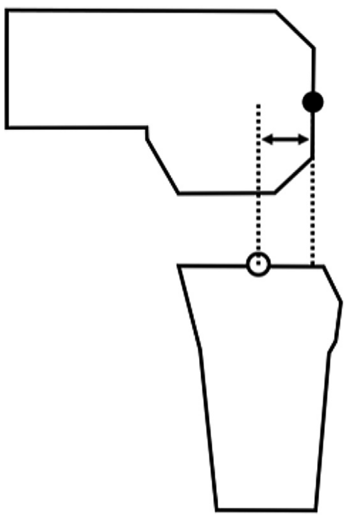

Figure 1. Schema showing a lateral view of the knee in flexion. The black dot indicates the femoral center. The white dot indicates the tibial center. The distance between the two broken lines indicates the location of the tibia in relation to the femur in the sagittal plane.

resection was performed using a measured resection technique. Using the navigation system, the distal femur and proximal tibia were resected perpendicular to the mechanical axis in the coronal plane. The femoral flexion angle was set at 3° and the tibial posterior slope at 5° in the sagittal plane using the navigation system. The amount of bone resection was based on component thickness.

After resection of the femur and tibia, the flexion–extension gap and ligament balance were evaluated using a spacer block of an appropriate size. During insertion of the spacer block, the patella was reduced, and care was taken to avoid intentional rotation of the tibia. The sagittal location of the tibial center in relation to the femoral center at 98° of knee flexion where the bone surfaces were parallel was calculated using data obtained by the navigation system as reported previously [18]. After the femoral and tibial implant trial was conducted, the patella was resurfaced in all cases. The tibial and patellar components were cemented, and the cementless femoral component was assembled. The thickness of the polyethylene insert was determined using a trial insert and considering the soft-tissue balance, aiming for a tight fit on the medial side and a slightly loose fit on the lateral side, both in knee extension and flexion. After the polyethylene insert was inserted, the knee was flexed twice by placing the patient's heel on the surgeon's palm, according to a previously reported method [20]. During flexion, the location of the tibial center in relation to the femoral center in the sagittal plane after implantation was calculated at 98° of knee flexion, using the navigation system (Fig. 1).

2.2. Data collection

Of the 38 knees, 8 were excluded because the thickness of the polyethylene insert differed from the size of the spacer at the time of osteotomy by $\geq$ 2 mm, leaving 30 knees (30 patients) for analysis. The patients were 26 women and 4 men with a mean age at surgery of 76.3 (range, 63–87) years.

2.3. Statistical analysis

Test–retest reliability of the measurements of the location of the tibial center in relation to the femoral center in the sagittal plane after implantation was assessed using intra-examiner correlation coefficients. Differences in the sagittal location of the tibial center between the time of insertion of the spacer and that after CR TKA were examined using the paired *t*-test. All statistical analyses were performed using IBM SPSS statistical software (version 21.0 for Mac OS X; IBM Corp., Armonk, NY). A p-value < 0.05 was considered statistically significant.

3. Results

Intra-examiner reliability of the measurements was excellent for the location of the tibial center in relation to the femoral center in the sagittal plane after implantation; the intra-class correlation coefficients for each surgeon were > 0.9. The mean femoral flexion angle was 2.95° (2.0–4.5) and the mean tibial posterior slope was 4.71° (2.5–6.0).

The mean location of the tibial center in relation to the femoral center at 98° of knee flexion in the sagittal plane was 5.16 (range, −2.4, 16.3) mm during insertion of an appropriately sized spacer block and 6.60 (range, −1.4, 15.1) mm after CR TKA (Fig. 2), and this difference was significant (p = 0.016).

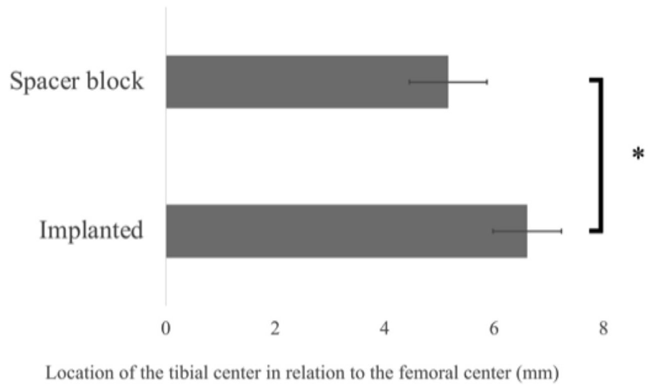

Figure 2. Comparison of the location of the tibia in relation to the femur in the sagittal plane when a spacer block is inserted and after cruciate-retaining total knee arthroplasty. Error bars indicate the standard error. *p < 0.05.

4. Discussion

The most important finding of this study was that there was a significant difference in the sagittal location of the tibial center between insertion of a spacer block and after CR TKA (Fig. 3). The mean femoral flexion angle and mean tibial posterior slope were 2.95° and 4.71°, respectively, indicating that it is appropriate to perform the comparison at 98° of flexion. To our knowledge, this is the first report to compare the location of the femur and tibia in knee flexion in the sagittal plane when a spacer block is inserted with that after CR TKA using a navigation system.

Previous studies have suggested that tibial translation might affect the gap measurement. Wada et al. reported that the magnitude of the joint distraction force achieved using a tensor device changed the three-dimensional positional relationship between the femur and tibia at 90° of knee flexion during CR TKA [19]. Christen et al. examined the relationship between the size of the flexion gap and anterior translation of the tibia in flexion using a tensor device during CR TKA [3]. They found a mean anterior tibial translation of 1.25 mm for each 1-mm increment in the flexion gap in the tensed knee. Heesterbeek et al. also measured the flexion gap using a tensor device in CR TKA [7] and found that for each 1-mm increment in gap height induced by the tensor device, the tibia translated forward by 1.9 mm on average. In the present study, the sagittal location of the tibial center at the time of insertion of the spacer differed from that after placement of CR TKA by 1.34 mm on average. Considering previous reports, the sagittal location of the tibia was likely affected by soft tissue evaluation with the spacer block, similar to when using the tensor. Although this difference was small, a significant difference was observed, which may affect assessment of the flexion gap. Therefore, anterior translation of the tibia during assessment of the flexion gap using a spacer block might increase the flexion gap, leading to overestimation of the gap after CR TKA.

The translation of the tibia during insertion of the spacer block also suggests that the PCL has an important role. In previous anatomical studies, the PCL is described as an obliquely oriented entity known to be the major restraining structure in 90° of knee flexion [2,4,6]. Furthermore, Heesterbeek et al. measured the orientation of insertion of the PCL and evaluated the elevation angle of the PCL. They also found that the joint distraction force moved the tibia more anteriorly when the PCL was steep than when it was flat [7]. In another study, Kinsey et al. documented posterior tibial translation during assessment of the flexion gap relative to the final implantation in posterior stabilized (PS) TKA [10]. They also reported that the tibia translates posteriorly along the long axis of the femur as the collateral ligaments seek their most direct path. In a cadaveric study, Wada et al. noted that the tibia was more internally rotated and more posteriorly located when a joint distraction force was applied to the knee after resection of the PCL than in knees with an intact PCL [19]. They also mentioned that the PCL inhibited posterior movement of the tibia when a joint distraction force was applied at 90° of knee flexion. Therefore, surgeons should be aware that the gap measured with joint distraction force does not always match the gap after implantation regardless of whether the PCL is retained.

This study has several limitations. First, four different surgeons performed the surgical procedures and collected the data, but inter-examiner reliability was not assessed. A reliability study is needed in the future. However, all these surgeons were senior doctors and used the same surgical protocol. Therefore, we believe that our data were collected using the same methodology and that inter-examiner reliability was adequate. Second, tibial translation was assessed only in 98° of knee flexion and for CR TKA, where the focus was on the function of the PCL. Future studies should evaluate tibial translation in knee extension as well as PS TKA. Third, although the aim was for a tight fit on the medial side and a slightly loose fit on the lateral side, the soft-tissue balance was not evaluated in detail. According to a previous study, the MCL and LCL also play important roles in changing 3D articulation when joint distraction force is applied [19]. Thus, objective assessment of

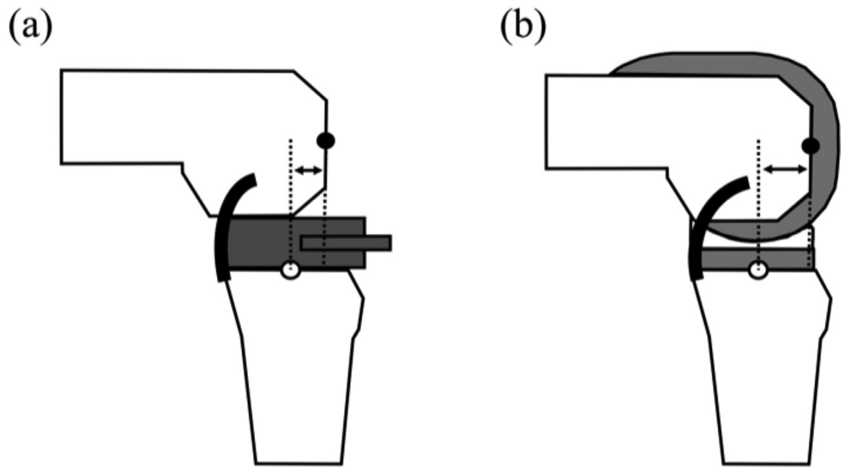

Figure 3. Schema summarizing the results. (a) Flexion in the sagittal plane when a spacer block is inserted. (b) Flexion in the sagittal plane after implantation.

the soft tissue balance is required in future studies. Fourth, the accuracy of determination of the femoral and tibial centers was not assessed in this study. However, because the points determined on computed tomography scans during preoperative planning were used for registration, the accuracy seems to be sufficient. Fifth, the location of the tibial center was assessed only in the sagittal plane. The joint distraction force might have changed the 3D articulation. Furthermore, the rotational position of the tibia relative to the femur might be affected by the inlay congruency of the implant, but not by a spacer block. Therefore, further study should include assessment of the anterior-posterior, medial–lateral, and rotational positions.

5. Conclusions

We found a change in the location of the tibia in knee flexion when soft tissue balance is assessed using a spacer block in CR TKA. Surgeons should be aware that using a spacer block to assess the flexion gap might overestimate the flexion gap after CR TKA.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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