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Postoperative Knee Flexion Angle Is Affected by Lateral Laxity in Cruciate-Retaining Total Knee Arthroplasty

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ABSTRACT

Background: Although many studies have reported that postoperative knee flexion is influenced by preoperative conditions, the factors which affect postoperative knee flexion have not been fully elucidated. We tried to investigate the influence of intraoperative soft tissue balance on postoperative knee flexion angle after cruciate-retaining (CR) total knee arthroplasty (TKA) using a navigation and an offset-type tensor.

Methods: We retrospectively analyzed 55 patients with osteoarthritis who underwent TKA using e.motion-CR (B. Braun Aesculap, Germany) whose knee flexion angle could be measured at 2 years after operation. The exclusion criteria included valgus deformity, severe bony defect, infection, and bilateral TKA. Intraoperative varus ligament balance and joint component gap were measured with the navigation (Orthopilot 4.2; B. Braun Aesculap) while applying 40-lb joint distraction force at 0° to 120° of knee flexion using an offset-type tensor. Correlations between the soft tissue parameters and postoperative knee flexion angle were analyzed using simple linear regression models.

Results: Varus ligament balance at 90° of flexion ($R = 0.56$; $P < .001$) and lateral compartment gap at 90° of flexion ($R = 0.51$; $P < .001$) were positively correlated with postoperative knee flexion angle. In addition, as with past studies, joint component gap at 90° of flexion ($R = 0.30$; $P < .05$) and preoperative knee flexion angle ($R = 0.63$; $P < .001$) were correlated with postoperative knee flexion angle.

Conclusion: Lateral laxity as well as joint component gap at 90° of flexion is one of the most important factors affecting postoperative knee flexion angle in CR-TKA.

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Total knee arthroplasty (TKA) is a successful surgical procedure for treatment of osteoarthritis. One of the primary goals of TKA is to improve the functional range of motion (ROM) without introducing instability to the midflexion angle. Range of flexion is reported to be associated with postoperative patient satisfaction [1,2]. Many factors affect postoperative range of flexion, such as preoperative range of flexion, body mass index, sex, age, prosthetic design and size, and surgical technique [3-6]. Among these factors, several studies have recognized the importance of preoperative range of flexion [7-11]. Intracapsular factors such as implant design, varus/valgus ligament balance, flexion-extension gap balance, height of joint line, posterior condylar offset, tibial slope, and patella resurfacing, have also been discussed by several authors [8,12-18]. Among intracapsular factors, little is known about the direct relationship between intraoperative soft tissue balance and postoperative outcomes, although soft tissue balancing has been recognized as an essential surgical intervention for improving TKA outcome [19-24]. We have previously reported on intraoperative soft tissue balance using novel offset-type tensor for TKA that enables assessment of soft tissue balance throughout the ROM of knees with reduced patellofemoral (PF) joint and femoral component placement [25-27]. This offset-type tensor permits intraoperative reproduction of postoperative alignment of the PF and tibiofemoral joints; the accuracy of measurement and clinical relevance of this tensor in TKA has been reported [28,29].

Our recent series of cruciate-retaining (CR) TKA studies showed that postoperative flexion angle was positively correlated with intraoperative joint component gap [30]. Kobayashi et al [31] also reported in a study with a limited number of patients that lateral laxity at 80° of knee flexion 1 year after surgery was positively correlated with postoperative flexion angle after CR-TKA. On the other hand, our group reported that intraoperative soft tissue balance reflected postoperative ligament balance at the 5-year midterm follow-up [32]. Based on these observations, it was hypothesized that intraoperative lateral laxity, in other words, tensor-assessed varus ligament balance, influences postoperative knee flexion angle after CR-TKA. In the current study, we analyzed the

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correlation between tensor-assessed intraoperative varus ligament balance and postoperative knee flexion angle.

Materials and Methods

The inclusion criteria were substantial pain and loss of function due to varus type osteoarthritis of the knee. In addition to the knee condition, patients who agreed to participate and whose knee flexion angles could be measured in the outpatient clinic 2 years after their operations were included in the study. The exclusion criteria included knees with valgus deformity, severe bony defect requiring bone graft or augmentation, revision TKA, active knee joint infection, and bilateral TKA. Our institution's internal review board approved this study, and informed consent was obtained from all patients. Between 2005 and 2009, 550 TKAs were done at our institution. Among them, 64 patients met the above criteria for floating platform mobile-bearing CR-TKA (e.motion CR; B. Braun Aesculap, Melsungen, Germany) according to the condition of the posterior cruciate ligament (PCL). Among these cases, 9 TKAs without use of a tensor or a navigation system were excluded from the study. Eventually, 55 patients were investigated in the study. The design of the femoral component follows a 2-radius model: a fixed trochlear radius along the patellar groove and a fixed condylar radius from 5° hyperextension to 90° flexion, with a smooth transition between the 2 radii at the condylotrochlear junction. The patient population was composed of 43 women and 12 men with a mean age of 74.2 years (SD, 7.3). Among these patients, the average preoperative coronal plane alignment on standard weight-bearing anteroposterior radiographs was 10.5° ± 0.7° in varus. All CR-TKA procedures were performed by the same senior author. A CT-free navigation system (Orthopilot 4.2.; B. Braun Aesculap) was used to ensure implantation accuracy and to measure the flexion angle of the knee during soft tissue balance measurement with an offset-type tensor. The amount of bony cut and varus/valgus/flexion/extension alignment on the screen of the navigation system was determined based on soft tissue balance measured using the tensor.

The tensor consisted of 3 parts as described previously [25-27,33]: an upper seesaw plate, a lower platform plate with a spike, and an extra-articular main body. We placed this tensor with the lower platform fixed to the proximal tibia after bony resections and soft tissue releases. After the PF joint was reduced, the medial parapatellar arthrotomy was temporarily repaired by applying stitches proximal and distal to the connection arm of the tensor. This device is designed to allow surgeons to measure joint component gaps and varus ligament balance while applying a constant joint distraction force. Joint distraction forces ranging from 30 to 80 lb (13.6-36.3 kg) can be exerted between the seesaw and platform plates using a specially made torque driver to change the applied torque. After sterilization, this torque driver was placed on a rack containing a pinion mechanism along the extra-articular main body, and the appropriate torque was applied to generate the designated distraction force. The joint distraction force in the current study was set at 40 lb (18.1 kg) for all measurements. This distraction force was selected because it recreated a joint component gap at knee full extension that corresponded to the insert thickness. To reduce potential error from creep elongation of the surrounding soft tissues, this joint distraction force was loaded several times until the joint component gap remained constant. The thigh and knee were aligned in the sagittal plane to eliminate external load on the knee at each flexion angle during each measurement. Once appropriately distracted, the distance (in millimeters to the first decimal place; joint component gap) between the center midpoints of the upper surface of the seesaw plate and the proximal tibial cut and the angle (in degrees, positive value in varus imbalance; varus ligament balance) between the tensor seesaw and platform plates obtained from the values displayed by the navigation system were measured.

All operations were performed using the navigation system according to the manufacturer's directions. After attaching passive optical reference frames from the navigation system to the medial side of the distal femur and proximal tibia with screws and inflating the air tourniquet with 280 mm Hg with the knee flexed, a medial parapatellar arthrotomy was performed. The standard registration procedure was conducted according to the system's instructions. The center of the knee and ankle was registered by a landmark-based technique. The center of the hip was registered by the circular motion of the femur around the center of hip rotation. Femoral and tibial axes in the sagittal and coronal planes were calculated using software based on data acquired by the system. These calculation methods have been described previously [34]. After removing all osteophytes, the tibial osteotomy was first performed perpendicular to the tibial axis in the coronal and sagittal plane. The insertion of PCL was preserved by a bony island. After the tibial osteotomy, the necessary medial structure releases were made in extension. After tensor measurement of the extension and flexion gaps, distal and posterior femoral osteotomies were performed with the navigation system to create an acceptable rectangular extension and flexion gap. The posterior femoral osteotomy was performed using posterior referencing, with care taken to maintain the posterior condylar offset. In this step, a residual lateral laxity of less than 3° was targeted. After bony resections and soft tissue releases, the joint component gap (millimeters) and varus ligament balance (degrees) were measured, and joint gaps of the medial and lateral compartments (millimeters) were calculated with the knee, guided by navigation system, at 0°, 10°, 30°, 60°, 90°, and 120° of flexion. After measurement, a prosthesis (e.motion) was implanted with cement. This mobile-bearing CR prosthesis achieves a large contact area, and its femorotibial articulation has a relatively conforming design. The tibial base plate has a posterior slope of 3°, and the polyethylene insert is slightly dished in the sagittal plane with a slightly elevated anterior tip. The thicknesses of the distal and posterior femoral component condyles are the same. To determine clinical outcome, we measured the knee flexion angle in the outpatient clinic using a 2-arm goniometer with the patient in the supine position before operation and at follow-up 2 years after the operation.

All measurements are expressed as mean ± SEM. The results were analyzed using Excel-Toukei 2010 software (Social Survey Research Information, Tokyo, Japan). Correlations between postoperative flexion angle and soft tissue balance parameters, including varus ligament balance, joint component gap, medial compartment gap, and lateral compartment gap as well as preoperative flexion angle, were analyzed using simple linear regression models and Pearson correlation coefficient. A statistical power analysis was performed before the study, which was expected to require a power of 0.8 based on a prespecified significance level of α less than .05 and assuming a medium effect size (effect size $f^2 = 0.15$) using G power 3 [35]. The estimated sample size was 55 patients. $P < .05$ was considered statistically significant.

Results

The average postoperative coronal plane alignment on standard weight-bearing anteroposterior radiographs was 0.4° ± 0.2° in varus, a significant change from preoperative data ($P < .001$). The mean knee flexion angle did not improve significantly after surgery ($P = .39$). The mean parameters of clinical outcome, including preoperative and postoperative coronal plane alignment and knee flexion angle, are shown in Table 1. Preoperative and postoperative knee flexion angle showed a

Table 1
Mean Clinical Outcome Parameters, Including Preoperative and Postoperative Coronal Plane Alignment, and Knee Flexion Angle.

Parameter	Preoperative Value	Postoperative Value	*P*
Coronal plane alignment	10.5 ± 0.7° in varus (2.8° in valgus to 24.0° in varus)	0.4 ± 0.2° in varus (2.0° in valgus to 4.1° in varus)	<.001
Knee flexion angle	116.2 ± 2.1° (90°-150°)	119.3 ± 1.4° (90°-135°)	.39

Values are shown as mean ± SEM with the range in parentheses.