Impact of Soft Tissue Imbalance on Knee Flexion Angle After Posterior Stabilized Total Knee Arthroplasty

Sachiyuki Tsukada, MD a,*, Tomoko Fujii, MD b, c, Motohiro Wakui, MD a

a Department of Orthopaedic Surgery, Nekoyama Miyao Hospital, Niigata, Niigata, Japan
b Epidemiology and Preventive Services, Graduate School of Medicine, Kyoto University, Kyoto, Kyoto, Japan
c Japan Society for the Promotion of Science, Roinnichi Business Center Building, Chiyoda, Tokyo, Japan

ABSTRACT

Background: This study was performed to assess the impact of soft tissue imbalance on the knee flexion angle 2 years after posterior stabilized knee arthroplasty (TKA).

Methods: A total of 329 consecutive varus knees were included to assess the association of knee flexion angle 2 years after TKA with preoperative, intraoperative, and postoperative variables. All intraoperative soft tissue measurements were performed by a single surgeon under spinal anesthesia in a standardized manner including the subvastus approach, reduced patella, and without use of a pneumatic tourniquet.

Results: Multiple linear regression analysis showed no significant correlations in terms of intraoperative valgus imbalance at 90-degree flexion or the difference in soft tissue tension between 90-degree flexion and 0-degree extension (β = −0.039; 95% confidence interval [CI], −0.088 to 0.80; P = 0.93 and β = 0.015; 95% CI, −0.29 to 0.32; P = .92, respectively). Preoperative flexion angle was significantly correlated with knee flexion angle 2 years after TKA (β = 0.42; 95% CI, 0.33 to 0.51; P < .0001).

Conclusion: Avoiding valgus imbalance at 90-degree flexion and aiming for strictly equal soft tissue tension at 90-degree flexion and 0-degree extension had little practical value with regard to knee flexion angle 2 years after posterior stabilized TKA.

© 2017 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Intraoperative soft tissue balance could affect postoperative knee flexion angle in posterior stabilized total knee arthroplasty (TKA) [1]. Classically, the ideal intraoperative soft tissue balance consists of no varus/valgus imbalance and equal soft tissue tension at 90-degree flexion and 0-degree extension [2]. However, recent studies indicated that intraoperative varus imbalances, where the medial soft tissue tension in the knee is tighter than that in the lateral soft tissue, at 90-degree flexion was preferable to the no varus/valgus imbalance because the medial side of the normal knee is tighter than that on the lateral side [3–5]. In addition, one study indicated that intraoperative tighter soft tissue tension at 90-degree flexion compared with soft tissue tension at 0-degree extension was positively correlated with better knee flexion angle after posterior stabilized TKA [5].

Many studies investigated the relationship between intraoperative soft tissue imbalance and knee flexion angle after posterior stabilized TKA [6–10]. Although these studies contributed to the improvement of surgical procedures, they had important limitations: (1) no consideration of preoperative knee flexion angle, which was demonstrated to have the greatest impact on postoperative knee flexion angle [6,8–10], (2) inadequate measurement of soft tissue balance, such as measurement with the patella everted or inverted [9,10], measurement with a pneumatic tourniquet inflated [6,8–10], and measurement under the surgical approach with vastus medialis detachment [6–10], and (3) sample sizes that were too small to assess the hypothesis [6].

This study was performed to investigate the impact of varus/valgus imbalance and the difference in soft tissue tension between 90-degree flexion and 0-degree extension on knee flexion angle 2 years after TKA using a posterior stabilized prosthesis. The hypothesis of this study was that multiple regression analyses including preoperative flexion angle as an explanatory value would show that...
valgus imbalance at 90-degree flexion was negatively correlated to postoperative knee flexion angle and that tighter soft tissue tension at 90-degree flexion compared with 0-degree extension would show a positive correlation with postoperative knee flexion angle.

Materials and Methods

The study was initiated after receiving approval from the institutional review board. The inclusion criteria were patients undergoing primary TKA performed by 1 surgeon (ST) between July 2012 and March 2014 in a single orthopedic clinic, which specialized in hip and knee surgery. We excluded patients who underwent operation using a lateral surgical approach because of valgus alignment of a lower limb.

This study focused on the relationship between knee flexion angle 2 years after TKA and intraoperative measurement of soft tissue balance.

Surgical Technique

For all study patients, we used a single design of cemented fixed-bearing posterior stabilized prosthesis, which had a single curvature radius in the sagittal plane throughout the flexion arc (Scorpio NRG; Stryker Orthopaedics, Mahwah, NJ).

All surgeries were performed under spinal anesthesia. A pneumatic tourniquet was not applied to any patient. The arthroplasties were performed with an anteromedial longitudinal incision and through the subvastus approach without detaching the vastus medialis. For a valgus knee, we used an anterolateral incision and lateral approach.

We routinely released the deep layer of the medial collateral ligament. Both tibial and femoral osteotomies were carried out referencing anatomic bony landmarks. After osteotomies, we adjusted soft tissue balance when needed. We maintained the amount of soft tissue release to the minimum required during the study period. Therefore, if the surgeon regarded the tightness on the medial side to be unacceptable (too tight varus soft tissue balance) after the thorough removal of osteophytes, only the semimembranosus was released. Other soft tissue, including the superficial layer of the medial collateral ligament or the pes anserinus, was not released. The thickness of the tibial insert was determined to obtain complete extension, no medial instability at 0-degree extension, and no inordinate tightness in flexion. After manually confirming acceptable soft tissue balance, the soft tissue balance was measured at both 0-degree extension and 90-degree flexion using a tensor/balancer instrument (Offset knee balancer and JDK−mini torque wrench; Stryker Orthopaedics).

Measurement of Soft Tissue Balance

After completion of soft tissue release before implantation of the prosthesis, we measured the soft tissue balance including (1) varus/va

gus imbalance and (2) soft tissue tension using a tensor/balancer instrument (Fig. 1). The Offset knee balancer had an offset arm allowing measurement with the patella reduced (Fig. 1A).

The Offset knee balancer had 2 plates: an upper seesaw plate and a lower platform plate (Fig. 1A). The surgeon positioned the 2 plates on the surfaces of the resected tibia and femur, and distracted the knee joint open using a JDK−mini torque wrench at an arbitrary width with the 2 plates (Fig. 1B,C). The Offset knee balancer had a central scale on the balancer that measures the degree of distraction in millimeters between the 2 plates (Fig. 1A). The Offset knee balancer also indicates the degree of varus-valgus imbalance based on the tilting angle between the 2 plates (Fig. 1A). When the tilting angle showed that medial soft tissue tension was tighter than that on the lateral side, the deviation was defined as varus and given a negative value [11]. In the case of tighter lateral soft tissue tension compared with the medial soft tissue, the deviation was defined as valgus and given a positive value [11].

The JDK−mini torque wrench showed the distraction force, and we recorded the force as soft tissue tension (Fig. 1B). The opened width was similar to the aggregate thickness of the femoral component, tibial polyethylene insert, and tibial component [10]. For the Scorpio NRG prosthesis, the aggregate thickness was 18, 19, 21, 24, and 27 mm when the package-described thickness of the tibial polyethylene insert was 8, 10, 12, 15, and 18 mm, respectively, at both 90-degree flexion and 0-degree extension [10]. The package−described thickness of the tibial polyethylene insert was different from its true thickness [10].

Clinical Outcome Measurements

The primary outcome was knee flexion angle 2 years after TKA. All measurements were performed using a goniometer by a single orthopedic surgeon (MW), who was not the operating surgeon for the study patients. The knee extension angle was also measured in the same manner.
Radiographic Measurements

Preoperative and postoperative X-rays were reviewed to measure lower limb alignment and posterior condylar offset. Lower limb alignment was evaluated with femorotibial angle, defined as the lateral angle between the anatomic axes of the femur and tibia, measured on standing anteroposterior radiographs. The posterior condylar offset was measured as maximum thickness of the posterior condyle projected posteriorly to a line tangential to the posterior cortex of the femoral shaft.

Statistical Analysis and Sample Size Calculation

Baseline characteristics were summarized as numbers and percentages for categorical variables and means and standard deviations for continuous variables.

The primary goals of this study were to assess the impact of valgus imbalance at 90-degree flexion and the difference in soft tissue tension between 90-degree flexion and 0-degree extension on the knee flexion angle 2 years after TKA. Multiple regression analyses were performed to assess the association of knee flexion angle 2 years after TKA with preoperative, intraoperative, and postoperative variables, including age, gender, body mass index, diagnosis, history of diabetes mellitus, preoperative flexion angle, intraoperative imbalance at 90-degree flexion, the difference in soft tissue tension between 90-degree flexion and 0-degree extension, and postoperative posterior condylar offset. Standardized coefficients ($b$) and $P$ values are presented. We used complete case analysis to deal with missing data. The multiple regression analyses were performed using JMP Pro 11.2.0 (SAS Institute Inc, Cary, NC).

An orthopedic surgeon (ST) measured soft tissue tension twice for 40 consecutive patients undergoing TKA to test intraobserver reliability. The intraclass correlation coefficients were used to evaluate reliability of the measurement of varus/valgus imbalance and soft tissue tension at both 0-degree extension and 90-degree flexion. We used R (The R Foundation for Statistical Computing) to calculate the intraclass correlation coefficients.

The sample size calculation was based on multiple regression including 9 explanatory variables. At least 166 knees were needed with an effect size of 0.10, a type I error rate of 5%, and a type II error rate of 20% (80% power). We used G*Power software (Kiel, Germany) for sample size calculation.

Results

Participants

Figure 2 outlines the patient flow diagram. During the study period, the surgeon performed 333 consecutive TKAs. Four of the 333 TKAs were excluded because the operation was performed through the lateral surgical approach. Therefore, 329 TKAs were eligible for the analysis. Table 1 summarizes the demographic characteristics of the patients. We released only the deep layer of the medial collateral ligament in 184 of 329 TKAs (56%), and released the deep layer and semimembranosus in the remaining 145 TKAs (44%).

Of the 329 patients, 31 TKAs had missing data for the postoperative flexion angle or intraoperative measures: 21 were lost to follow-up before 2 years after TKA, 9 died before 2 years after TKA, 1 had missing data of intraoperative soft tissue balance because the femoral condyle collapsed intraoperatively because of severe osteoporosis. The remaining 298 TKAs were included in multiple regression analysis.

The mean knee flexion angle 2 years after TKA was 127.3 ± 14.7 degrees in 298 TKAs. The mean extension angle 2 years after TKA was −0.7 ± 3.0 degrees in 298 TKAs, and 270 of 298 knees (90.6%) achieved 0-degree extension.

Two hundred sixty-seven of the 333 TKAs were included in our 3 previously published randomized, controlled trials comparing early postoperative pain control regimens.

Varus/Valgus Imbalance and Soft Tissue Tension at 90-Degree Flexion and 0-Degree Extension

The mean varus/valgus imbalances at 90-degree flexion and 0-degree extension were −0.6 ± 1.8 degrees (range, −5 to 5 degree) and −1.7 ± 1.2 degree (range, −6 to 1 degree), respectively. A negative value indicates that the tilting angle showed varus balance: medial soft tissue tension was tighter than lateral soft tissue tension. The distributions of varus/valgus imbalance at 90-degree flexion and 0-degree extension were normal (skewed $<0$ degree).

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>74.6 (7.1)</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>292 (88.8)</td>
</tr>
<tr>
<td>Male</td>
<td>37 (11.2)</td>
</tr>
<tr>
<td>Height, mean (SD), cm</td>
<td>150.1 (7.5)</td>
</tr>
<tr>
<td>Weight, mean (SD), kg</td>
<td>59.8 (9.9)</td>
</tr>
<tr>
<td>BMI, mean (SD), kg/m²</td>
<td>26.5 (3.5)</td>
</tr>
<tr>
<td>Diagnosis, n (%)</td>
<td></td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>325 (98.8)</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>4 (1.2)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>69 (21.0)</td>
</tr>
<tr>
<td>Preoperative flexion angle, mean (SD), degrees</td>
<td>126.2 (17.4)</td>
</tr>
<tr>
<td>Preoperative extension angle, mean (SD), degrees</td>
<td>−8.6 (7.4)</td>
</tr>
<tr>
<td>Preoperative femorotibial angle, mean (SD), degrees</td>
<td>186.1 (5.4)</td>
</tr>
<tr>
<td>Preoperative posterior condylar offset, mean (SD), mm</td>
<td>25.6 (3.5)</td>
</tr>
<tr>
<td>Varus/valgus balance at 90-degree flexion</td>
<td>−0.5 (1.8)</td>
</tr>
<tr>
<td>Tilting angle of 2 plates of the Offset knee tensor, mean (SD), degrees</td>
<td></td>
</tr>
<tr>
<td>Equal or varus balance, n (%)</td>
<td>242 (73.6)</td>
</tr>
<tr>
<td>Valgus balance, n (%)</td>
<td>86 (26.1)</td>
</tr>
<tr>
<td>Soft tissue tension at 90-degree flexion, mean (SD), pound-force</td>
<td>24.7 (4.2)</td>
</tr>
<tr>
<td>Soft tissue tension at 0-degree extension, mean (SD), pound-force</td>
<td>23.5 (4.1)</td>
</tr>
<tr>
<td>Postoperative femorotibial angle, mean (SD), degrees</td>
<td>1.2 (4.9)</td>
</tr>
<tr>
<td>Postoperative posterior condylar offset, mean (SD), mm</td>
<td>173.8 (1.8)</td>
</tr>
</tbody>
</table>

BMI: body mass index; SD: standard deviation.

a Negative values indicated that the tilting angle showed varus balance (medial soft tissue tension was tighter than lateral soft tissue tension).
Multiple Regression Models

Table 3 summarizes the impact on knee flexion angle 2 years after TKA calculated by multiple linear regression analysis. The multiple linear regression model included age, gender, body mass index, diagnosis, history of diabetes mellitus, preoperative flexion angle, intraoperative imbalance at 90-degree flexion, the difference in soft tissue tension between 90-degree flexion and 0-degree extension, and postoperative posterior condylar offset as explanatory variables (F = 11.2; P < .0001; adjusted R² = 0.24).

No significant correlations were observed in terms of intraoperative varus-valgus imbalance at 90-degree flexion and the difference of soft tissue tension between 90-degree flexion and 0-degree extension (β = −0.039; 95% confidence interval [CI], −0.88 to 0.80; P = .93 and β = 0.015; 95% CI, −0.29 to 0.32; P = .92, respectively).

Preoperative flexion angle and male gender were significantly correlated with knee flexion angle 2 years after TKA (β = 0.42; 95% CI, 0.33 to 0.51; P < .0001 and β = 5.45; 95% CI, 0.48 to 10.42; P = .033, respectively).

Discussion

In analysis of the 329 TKAs using a posterior stabilized prosthesis, there were no detectable correlations between knee flexion angle 2 years after TKA and valgus imbalance at 90-degree flexion and the difference of soft tissue tension between 90-degree flexion and 0-degree extension. A difference may have been found if the outcome was more specific, such as midflexion rotational laxity.
However, because knee flexion angle is one of the important concerns associated with TKA [17,18], we believe the results of this study have important implication for knee surgeons.

Although our intraoperative setting of measuring soft tissue balance included reduced patella, no inflation of a pneumatic tourniquet, and no vastus medialis detachment, more rigorous analyses associated with TKA [17,18], we believe the results of this study do not suggest that ligament balancing is unnecessary. It should be noted that this study does not assess the usefulness of periarticular multidrug injection for pain relief in the early postoperative period [14–16]. Although all 3 studies concluded that the difference in knee flexion angle between study groups disappeared within the initial 5 days after TKA, it should be noted that differences in pain management protocol in the early postoperative period may have influenced knee flexion angle 2 years after TKA.

The major strength of our study was the measurement of a joint distraction force with opening the width similar to the implanting prosthesis. There were 2 methods to quantify the soft tissue tension. First, a certain amount of joint distraction force (eg, 30 pound-force) was applied, and the distance between the femoral and tibial surfaces was recorded as the joint gap [6–8]. Second, a certain amount of joint gap was opened and joint distraction force to obtain the joint gap was recorded as a soft tissue tension [9,10]. The second way can provide appropriate data for soft tissue tension because the distance of joint gap increases linearly, while the tension increases in a quadratic fashion relative to the increase in joint gap [10].

The soft tissue balance including no varus/valgus imbalance and equal soft tissue tension at 90-degree flexion and 0-degree extension has been considered the gold standard for soft tissue balance during TKA. The results of this study did not violate this classical target for soft tissue balance but suggested that there is a slightly greater safety range than the classical target in soft tissue balance when using a modern posterior stabilized prosthesis. It should be noted that the results of this study did not recommend valgus soft tissue balance at 90-degree flexion. In this study, the valgus angle at 90-degree flexion was within 5 degrees in all patients, and only 2 patients (0.67%) had a valgus angle >4 degrees. More valgus imbalance could result in postoperative instability. We wish to emphasize that this study does not suggest that ligament balancing is unnecessary.

The postoperative posterior condylar offset has been shown to be a predictor of knee flexion angle after posterior cruciate ligament retaining TKA [13]. However, its impact on knee flexion angle remains unclear for posterior stabilized TKA [21–23]. In the present study, using posterior stabilized prostheses, there was no association between the postoperative posterior condylar offset and knee flexion angle 2 years after TKA.

In conclusion, this study did not show a detectable impact of varus/valgus imbalance or difference in soft tissue tension between 90-degree flexion and 0-degree extension on knee flexion angle 2 years after TKA using a posterior stabilized prosthesis.

References