The Relationship Between Postoperative Ligament Balance and Preoperative Varus Deformity in Total Knee Arthroplasty

Kazuyoshi Yagishita MD Takeshi Muneta MD PhD Haruyasu Yamamoto MD PhD and Kenichi Shinomiya MD PhD

Abstract
We hypothesize that in knees with severe varus deformities, varus-valgus ligament imbalance tends to remain postoperatively after total knee arthroplasty. The purpose of this study was to evaluate the correlation between preoperative varus deformity and postoperative ligament balance quantitatively measured by stress radiograph using Telos SE in total knee arthroplasty. In this study, 44 knee arthroplasties in 32 patients were evaluated. We defined the angle in varus and valgus stress as “varus angle” and “valgus angle,” and the sum of varus angle and valgus angle as “sum of varus-valgus angle.” There was a significant correlation between preoperative lateral femoral angle and varus angle (p < 0.0001, r = 0.56), which means that postoperative ligament imbalance tends to remain in knees with preoperative varus deformities. There was a significant correlation between the postoperative period and the sum of varus-valgus angle, which suggests that knees with total knee arthroplasty have potential to increase laxity postoperatively.

The importance of bony alignment and ligament balance in total knee arthroplasty is well recognized, and ligament balance in knees with total knee arthroplasty have an important bearing on the clinical outcome.1-3 Ligament balance in knees after total knee arthroplasty can be achieved by appropriate procedures for bone resection and soft tissue release, and surgical procedures to obtain ligament balance have been previously reported in several articles.4,5

In knees with severe varus deformity, it may be difficult to gain ligament balance and more attention to the technical aspects to achieve proper ligament balance is required.7 Some articles have reported that postoperative bony alignment in knees with preoperative varus deformity tends to be in mild residual bony varus,8 but little has been reported concerning the postoperative ligament imbalance in knees with varus deformity.

We hypothesize that in knees with severe varus deformities, varus-valgus ligament imbalance tends to remain postoperatively after total knee arthroplasty. To assess this hypothesis, ligament balance was measured quantitatively by means of the stress radiographic method using the Telos device (Telos, Griesheim, Germany), and the correlation between preoperative varus deformity and postoperative ligament balance was evaluated.

Materials and Methods
Forty-four knees in 32 patients with a varus preoperative lateral femoral angle of more than 175° had total knee arthroplasties at our hospital from 1987 to 1996, and these knees were evaluated in this study. These patients included 1 male and 31 females, and the preoperative diagnosis leading to arthroplasty was osteoarthritis in 37 knees and rheumatoid arthritis in 7 knees. The mean age of the patients at the time of arthroplasty was 68.9 years (range: 60 to 80 years). All arthroplasties were performed using minimally constrained, posterior-cruciate-retention prostheses.

The surgical procedure for ligament balance in knees with varus deformities involved exposure of the posterior medial aspects of the tibia with release of the attachment of the semimembranosus, removal of osteophytes from the medial distal femur and proximal...
tibia, and release of the superficial medial collateral liga-
ment if and when necessary. Complete release of the pes
anserinus was not performed to gain ligament balance
in this study. Intraoperative ligament balance for the
varus and valgus direction was carefully measured in
extension with the trial prosthesis of the femur and tibia
in place.

Postoperative ligament balance was assessed by stress
radiographs of the knees using the Telos device. Antero-

posterior stress radiographs of the knees were taken while
a valgus and varus stress of 100 N was applied to the
knee in extension using the Telos device (Fig. 1). Stress
radiographs were taken at the average of 32 months post-
operatively (range: 12 to 108 months).

From varus stress radiographs, the angles formed by
the line in contact with the bottom of the femoral pros-
thesis and the line in contact with the upper surface of
the tibial prosthesis were measured (Fig. 2). We defined
the value of this angle of the lateral joint opening in varus
stress as the “varus angle.” From valgus stress radi-
ographs, the angles were also measured as described above
(Fig. 3), and we defined the value of this angle of the
medial joint opening in valgus stress as the “valgus
angle.”

Preoperative varus deformity was radiographically as-
sessed. To assess varus deformity, standing anteroposte-
rior view radiographs of the whole lower extremity were
taken. Those radiographs were taken preoperatively and
postoperatively at the same time as the stress radiograph.
The lateral femoral angle was defined as the lateral angle
formed by the femoral and tibial anatomical axes (Fig.
4).

We also defined the sum of the varus angle and val-
gus angle as the “sum of varus-valgus angle,” and the
value of the difference between varus angle and valgus
angle as the “difference of the varus-valgus angle.” For

Figure 1 Stress radiograph of the knee using Telos device.

Figure 2 “Varus angle” measured from varus stress radiograph.

Figure 3 “Valgus angle” measured from valgus stress radiograph.
and the varus angle, valgus angle, sum of the varus-valgus angle, and difference of the varus-valgus angle. In addition, the correlation between the postoperative period and varus angle and valgus angle were statistically analyzed. Statistical analyses were carried out with Pearson’s correlation coefficients.

**Results**

The preoperative lateral femoral angle averaged 188.9° ± 5.7° (range: 180° to 202°) and the postoperative lateral femoral angle averaged 175.4° ± 2.6° (range: 170° to 181°). The varus angle averaged 4.9° ± 2.7° (range: 1° to 13°), valgus angle averaged 3.2° ± 1.4° (range: 0° to 8°), the sum of varus-valgus angle averaged 8.0° ± 3.1° (range: 4° to 17°), and the difference of varus-valgus angle averaged 1.7° ± 3.0° (range: -2° to 9°) (Table 1).

There was a significant correlation between preoperative lateral femoral angle and varus angle (p < 0.0001, r = 0.56). But there was no significant correlation between the preoperative lateral femoral angle and the valgus angle (p = 0.64, r = 0.074). There was a significant correlation between the preoperative lateral femoral angle and sum of the varus-valgus angle (p = 0.0018, r = 0.45), and there was a significant correlation between the preoperative lateral femoral angle and difference of the varus-valgus angle (p = 0.0001, r = 0.54) (Table 2).

There was a significant correlation between postoperative period and sum of varus-valgus angle (p = 0.0015, r = 0.50) and varus angle (p = 0.011, r = 0.38). There was a tendency toward positive correlation between the postoperative period and the valgus angle (p = 0.062, r = 0.28), but there were no significant correlations between the postoperative period and the difference of the varus-valgus angle (p = 0.19, r = 0.20) (Table 3).

In order to assess the association of the preoperative severity of the varus deformity to the postoperative ligament imbalance, the patients were divided into two subgroups, a subgroup of the knees with preoperative lateral femoral angle of less than 190° (n = 24) and another subgroup of those with knees with a lateral femoral angle of more than 190° (n = 20). The patients were divided into two subgroups according to the mean value of the preoperative lateral femoral angle. The values of the postoperative lateral femoral angle in the two subgroups were almost the same (175.3° and 175.6°) (Table 4). The varus angle and valgus angle in the subgroup of the knees with less than 190° were 3.8° ± 1.6° and 3.3° ± 1.2°, and the varus angle and valgus angle in subgroup of the knees with greater than 190° were 6.2° ± 3.1° and 3.1° ± 1.7°. Statistical analyses with Mann-Whitney’s U-test were performed between the two subgroups for the postoperative lateral femoral angle. The values of the postoperative lateral femoral angle in the two subgroups were almost the same (175.3° and 175.6°) (Table 4). The varus angle and valgus angle in the subgroup of the knees with less than 190° were 3.8° ± 1.6° and 3.3° ± 1.2°, and the varus angle and valgus angle in subgroup of the knees with greater than 190° were 6.2° ± 3.1° and 3.1° ± 1.7°. Statistical analyses with Mann-Whitney’s U-test were performed between the two subgroups for the postoperative lateral femoral angle, varus angle, and valgus angle. There was a significant difference in the varus angle (p = 0.03). In addition, statistical analyses were
carried out on the correlation between the preoperative lateral femoral angle and the varus angle, valgus angle, sum of the varus-valgus angle, and the difference of the varus-valgus angle in two subgroups (Table 5). The correlation coefficient between the preoperative lateral femoral angle and the varus angle in the subgroup of the knees with greater than 190° was 0.52 (p = 0.018).

There was no statistical difference between the patients with osteoarthritis and rheumatoid arthritis.

Discussion
The importance of bony alignment and ligament balance in total knee arthroplasty is well recognized, and the surgical procedure to obtain ligament balance has been previously described.

In knees with severe varus deformity, the surgical procedure to gain proper ligament balance involves exposure of posterior medial aspects of the tibia with release of the attachment of the semimembranosus, removal of osteophytes from the medial distal femur and proximal tibia, release of the superficial medial collateral ligament, and release of the pes anserinus if necessary.4-6

Though the surgical procedure in knees with severe varus deformity has been the subject of many reports, some investigators report that the postoperative bony alignment in knees with preoperative varus deformity

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**Table 1** Results – Mean Angle, Standard Deviation, and Range (in degrees)

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
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<tbody>
<tr>
<td>Preoperative lateral femoral angle</td>
<td>188.9 ± 5.7</td>
<td>180 to 202</td>
</tr>
<tr>
<td>Postoperative lateral femoral angle</td>
<td>175.4 ± 2.6</td>
<td>170 to 181</td>
</tr>
<tr>
<td>Varus angle</td>
<td>4.9 ± 2.7</td>
<td>1 to 13</td>
</tr>
<tr>
<td>Valgus angle</td>
<td>3.2 ± 1.4</td>
<td>0 to 8</td>
</tr>
<tr>
<td>Sum of the varus-valgus angle</td>
<td>8.0 ± 3.1</td>
<td>4 to 17</td>
</tr>
<tr>
<td>Difference of the varus-valgus angle</td>
<td>1.7 ± 3.0</td>
<td>-2 to 9</td>
</tr>
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</table>

**Table 2** Correlation Between Preoperative Lateral Femoral Angle and Varus Angle, Valgus Angle, Sum of Varus-Valgus Angle, and Difference of Varus-Valgus Angle

<table>
<thead>
<tr>
<th>Correlation between preoperative lateral femoral angle and...</th>
<th>p</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varus angle</td>
<td>&lt; 0.0001</td>
<td>0.56</td>
</tr>
<tr>
<td>Valgus angle</td>
<td>0.64</td>
<td>0.074</td>
</tr>
<tr>
<td>Sum of the varus-valgus angle</td>
<td>0.0018</td>
<td>0.45</td>
</tr>
<tr>
<td>Difference of the varus-valgus angle</td>
<td>0.0001</td>
<td>0.54</td>
</tr>
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</table>

**Table 3** Correlation Between Postoperative Period and Varus angle, Valgus Angle, Sum of Varus-Valgus Angle, and Difference of Varus-Valgus Angle

<table>
<thead>
<tr>
<th>Correlation between postoperative period and...</th>
<th>p</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varus angle</td>
<td>0.011</td>
<td>0.38</td>
</tr>
<tr>
<td>Valgus angle</td>
<td>0.062</td>
<td>0.28</td>
</tr>
<tr>
<td>Sum of the varus-valgus angle</td>
<td>0.0015</td>
<td>0.50</td>
</tr>
<tr>
<td>Difference of the varus-valgus angle</td>
<td>0.19</td>
<td>0.20</td>
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</table>

**Table 4** Result in Two Subgroups, the Knees with Less Than 190° of Preoperative Lateral Femoral Angle and with More Than 190°

<table>
<thead>
<tr>
<th>Preoperative lateral femoral angle</th>
<th>&lt; 190° (n = 24)</th>
<th>&gt; 190° (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>postoperative lateral femoral angle (S.D.)</td>
<td>175.3 (2.8)</td>
<td>175.6 (2.5)</td>
</tr>
<tr>
<td>Varus angle (S.D.)*</td>
<td>3.8 (1.6)</td>
<td>6.2 (3.1)</td>
</tr>
<tr>
<td>Valgus angle (S.D.)</td>
<td>3.3 (1.2)</td>
<td>3.1 (1.7)</td>
</tr>
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*significant difference in two subgroups; *(Mann-Whitney’s U-test), p = 0.03

**Table 5** Correlation Between Preoperative Lateral Femoral Angle in Two Subgroups

<table>
<thead>
<tr>
<th>Preoperative lateral femoral angle</th>
<th>&lt; 190°</th>
<th>&gt; 190°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>r</td>
</tr>
<tr>
<td>Varus angle</td>
<td>0.64</td>
<td>0.10</td>
</tr>
<tr>
<td>Valgus angle</td>
<td>0.31</td>
<td>0.22</td>
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<tr>
<td>Sum of the varus-valgus angle</td>
<td>0.82</td>
<td>0.050</td>
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<tr>
<td>Difference of the varus-valgus angle</td>
<td>0.32</td>
<td>0.21</td>
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</table>
tends to be in mild residual bony varus. Ewald and colleagues\(^8\) reviewed the results of 124 total knee arthroplasties (not specifically a study of varus patients) and stated that the knees with preoperative varus deformity had a tendency to remain in postoperative varus. Teeny and associates\(^7\) reported that acceptable alignment, defined as a mechanical axis between 3\(^\circ\) varus and valgus 3\(^\circ\), was obtained in 90% of the non-deformity knees but in 59% of knees with varus deformity.

There are no articles concerning the quantitative assessment of postoperative varus-valgus ligament balance in knees with varus deformity. Many questions about the postoperative ligament balance in knees with severe varus deformity still remain.

In this study, the postoperative tibiofemoral ligament balance for varus-valgus direction in extension was quantitatively assessed using the Telos device. In order to assess the ligament balance with the Telos device, we defined the varus angle, valgus angle, sum of the varus-valgus angle, and difference of the varus-valgus angle as described above. The value of the difference of the varus-valgus angle could be interpreted as the amount of varus-valgus ligament imbalance and the value of the sum of the varus-valgus angle could be interpreted as the total amount of laxity in the varus-valgus direction. Since the value of the varus angle, valgus angle, and sum of the varus-valgus angle could vary in each knee depending on some factors including the thickness of tibial liner and prosthesis design, the value of the difference of the varus-valgus angle can be considered as the most reliable assessment.

The results of this study revealed for the first time that there are significant correlations between the preoperative lateral femoral angle and the varus angle (\(p < 0.0001\), \(r = 0.56\)) and the difference of the varus-valgus angle (\(p = 0.0001\), \(r = 0.54\)). But there was no significant correlation between the preoperative lateral femoral angle and the valgus angle (\(p = 0.64\), \(r = 0.074\)). These results mean that the postoperative ligament imbalance tends to remain in knees with preoperative varus deformities, and in which the ligament imbalance involved the lateral laxity more than the medial laxity. In the subgroup of the knees with a preoperative lateral femoral angle greater than 190\(^\circ\), the correlation coefficient between the preoperative lateral femoral angle and the difference of the varus-valgus angle was 0.46 (\(p = 0.042\)) (Table 5), which was greater than that in a subgroup of the knees with a preoperative lateral femoral angle of less than 190\(^\circ\) (\(r = 0.21\)). These results suggest that there is the tendency for the postoperative ligament imbalance to remain, especially in knees with severe varus deformity preoperatively.

In the analysis of the postoperative period, there was a positive significant correlation between the postoperative period and the sum of the varus-valgus angle (\(p = 0.0015\)) (Table 3). This result suggests that the knees with a longer postoperative period had more laxity in the lateral direction. But there was no significant correlation between the postoperative period and the difference of the varus-valgus angle (\(p = 0.19\)). These results may answer the question as to whether ligament balance or laxity of the knee will change postoperatively. The results, which there was a positive significant correlation between the postoperative period and the sum of the varus-valgus angle but there was no significant correlation between the postoperative period and the difference of the varus-valgus angle, show the possibility that laxity of the knee for the varus-valgus direction could change and increase postoperatively without increasing ligament imbalance.

Late instability in knees with total knee arthroplasty is a major postoperative complication that needs revision surgery. Fehring and Valadie\(^1\) mentioned that late instability can be the result of prosthetic malalignment with chronic attritional incompetence of the collateral ligament. The subjects in this study had appropriate bony alignment with a mean postoperative lateral femoral angle of 175.4\(^\circ\), even in knees with a severe varus deformity preoperatively. However, the knees with a longer postoperative period tended to have greater laxity in the varus-valgus direction. This suggests that laxity can potentially increase in knees after total knee arthroplasty even without postoperative bony malalignment.

There was no statistical difference between the patients with osteoarthritis and rheumatoid arthritis, but this is probably due to the small number of patients with rheumatoid arthritis in this study.

We speculate that the cause of postoperative ligament imbalance in knees with preoperative severe varus deformities is that ligament balance could not be achieved during surgery in these knees, even if radical and extensive release of the medial soft tissue was performed. Another possibility is that the ligament balance changes postoperatively, even if appropriate ligament balance is achieved surgically. Additionally, another cause for this finding could be due to an inadequate intraoperative assessment of the ligament balance.

In this study, the intraoperative assessment for ligament balance was performed manually, and the accuracy of the measurement may be limited. Several instruments have been developed to aid in the intraoperative measurement of ligament balance.\(^4,9,10\) However, most intraoperative assessments of ligament balance were performed manually and ligament balance was not quantitatively assessed. In order to perform a more accurate investigation, the use of an intraoperative quantitative instrument for measurement will be necessary.

Although the importance of obtaining good bony alignment and ligament balance in total knee arthroplasty is well recognized, the effect of ligament balance for the clinical outcome is not obvious. Karachalios\(^51\) suggested that a
moderate degree of instability in extension was not uncommon, but did not significantly affect the clinical outcome. Krackow and colleagues\textsuperscript{12} have also shown that slight laxity does not usually impair the clinical result. Tew and Waugh\textsuperscript{3} stated that the highest success rate was found in knees with good bony alignment at operation and such knees were most likely to remain stable. But many failures must have been caused by factors other than malalignment, and they speculated these factors included ligament imbalance, loosening, or components wear.

However, the effect of the amount of ligament balance for the clinical outcome is still unknown since these reports were not quantitatively analyzed.

We believe that when ligament balance in total knee arthroplasty is discussed, more quantitative study of the conditions preoperatively, intraoperatively, and postoperatively will be needed.

**Acknowledgments**

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**References**