Relationship between Meniscal Tears and Tibial Slope on the Tibial Plateau

Abstract

Objective: The geometry of the tibial plateau has a direct influence on the translation and the screw home biomechanics of the tibiofemoral joint. Little information on the relationship between the tibial slope and meniscal lesions is available. The objective of this retrospective study was to examine the effect of the tibial slope on the medial and lateral meniscus injuries in patients with intact ACLs.

Materials and Methods: The MRIs and lat roentgenograms of 212 patients with meniscus lesions were examined to determine the possible effect of the tibial slope on meniscal tears. First, the anatomic axis of the proximal tibia was established. Then, the angle between the line drawn to show the tibial slopes (medial and lateral) and the line drawn perpendicular to the proximal tibial anatomic axis was estimated on MRI. The patients with previously detected meniscus lesions were classified into three categories: patients with only medial meniscal tear (Group 1, 90 patients); patients with only lateral meniscal tear (Group 2, 15 patients); and patients with both medial and lateral meniscal tears (Group 3, 19 patients). Group 4 had no meniscal tear (88 patients). The MRIs of the patients who had applied to the Orthopedic Outpatient Clinic with patellofemoral pain and no meniscal tear were included as the control group.

Results: The average tibial slope of the medial tibial plateau was 3.18° in group 1, 3.64° in group 2, 3° in group 3, and 3.27° in group 4. The average tibial slope of the lateral tibial plateau was 2.88° in group 1, 3.6° in group 2, 2.68° in group 3, and 2.91° in group 4. The tibial slope on the medial tibial plateau was significantly larger than the lateral tibial plateau in group 1 and group 4 (p<0.05). In group 2, there was no statistically significant difference between the tibial slopes of the two sides (p>0.05). In addition, the tibial slope on the lateral side of group 2 was significantly larger than that of groups 1, 3, and 4 (p<0.05).

Conclusion: An increase in the tibial slopes, especially on the lateral tibial plateau, seems to increase the risk of meniscal tear.

Key Words: Knee injury, Meniscal tear, Tibial slope

Özet

Amaç: Tibial eğimin geometrisi dizi tranşasyonu ve vida-yuva mekanizmasını da içeren tibiofemoral eklemin biyomekanikisi üzerindeki etkisi hakkında çok az bilgi vardır. Bu retrospektif çalışmanın amacı çapraz bağ sağlanan hastalarda tibial eğimin medial ve lateral menisküs lezyonu oluşumuna etkisini araştırmaktır.

Gereç ve Yöntem: Menisküs lezyonu olan 212 hastanın dizlerinin lateral grafileri ve manyetik rezonans incelemeleri, tibial eğimin menisküs yırtığı üzerine etkisinin olup olmadığını araştırmak amacıyla incelendi. İlk olarak proksimal tibianın anatominın dikişli olduğu ile tibial eğimleri gösteren doğru arastırmada geçirildi. Menisküs lezyonuna göre hastalar 3 gruba ayrıldı: Medial menisküs yarıçapı olan hastalar (grup 1), lateral menisküs yarıçapı olanlar (grup 2), hem medial hem de lateral menisküs yarıçapı olan hastalar (grup 3). Menisküs yarıçapı olmayan hastalarda grup 4 olarak kabul edildi. Poliklinikte deki ön ağırsız nedeni ile başvuran ve menisküs yarıçapı olmayan hastaların manyetik rezonans incelemeleri kontrol grubu oluşturdu.

Bulgular: Medial tibial platonun ortalama tibial eğimi grup 1’dede 3.18’, grup 2’de 3.64’, grup 3’tede 3.00’, grup 4’tede ise 3.27’ idi. Lateral tibial platonun ortalama tibial eğimi grup 1’dede 2.88’, grup 2’de 3.60’, grup 3’tede 2.68’, grup 4’tede ise 2.91’ idi. Medial platonun tibial eğimi, grup 1 ve grup 4 de lateral tibial platonun tibial eğiminden istatistiksel olarak daha büyük bulundu (p<0.05). Grup 2 de, medial ve lateral platonun tibial eğimleri arasında istatistiksel olarak fark yoktu (p>0.05). İlave olarak, grup 2 deki lateral platonun tibial eğimleri grup 1, 3 ve 4 tekterin lateral platonunun tibial eğiminden istatistiksel olarak daha büyük (p<0.05).

Sonuç: Tibial eğimin artması, menisküs yarıçapı oluşumuna yatkınlık oluşturur.

Anahtar Kelimeler: Diz yaralanmaları, Menisküs yarıçapı, Tibial eğim
The contact mechanics of the tibiofemoral joint play an important role in controlling the biomechanical behavior of the joint [1, 2]. The geometry of the tibial plateau has a direct influence on the location of the immediate center of rotation, the biomechanics of the knee ligaments (such as the anterior cruciate ligament), and the translational biomechanics of the tibiofemoral joint [1]. As the slope of the tibial plateau increases during weight bearing, the magnitude of the anteriorly directed shear force component that is associated with the compressive joint force on the tibia also increases [1, 3, 4].

A large tibial slope may lead to a larger anterior tibial translation via stress to the knee joint and may consequently induce stretching and rupture of the anterior cruciate ligament [5]. Radiographic studies have shown a linear relationship between the tibial slope and tibial translation during unilateral weight bearing [1]. The greater the slope of the medial tibial plateaus, the greater the anterior tibial translation, in both ACL-intact and ACL-deficient knees [1, 6].

Tibial slope is one of anatomic structures most frequently mentioned as potentially causing ACL injury, but empirical results have failed to demonstrate a direct effect of tibial slope on ACL lesions [2, 6].

Meniscus lesions also result from non-contact traumas. There are no studies in the literature examining the effect of tibial slope on meniscal tears. The aim of this study was to determine the degree of tibial slope in patients with meniscal tears and intact anterior cruciate ligaments.

Materials and Methods

The clinical files and the magnetic resonance images of the 212 patients (123 female, 89 male) who had applied to the Outpatient Clinic of the Orthopedics Department with patellofemoral knee pain were retrospectively studied. All of the patients had clinical signs of meniscal tears, such as a positive McMurray test. All the roentgenograms and MRI investigations were performed using the same equipment. A single radiologist and orthopedic surgeon performed all of the evaluations. The patients who had gonarthrosis findings in their radiologic evaluations were excluded. All the patients had intact anterior cruciate and posterior cruciate ligaments. None of the patients had bone lesions. The average age of the patients was 41±12.

The patients with meniscus lesions were classified into three groups: the patients with medial meniscal tear (90 patients), the patients with lateral meniscal tear (15 patients), and the patients with both medial and lateral meniscal tears (19 patients). The MRIs of the patients with patellofemoral pain and no meniscal tears were included in group 4 (88 patients).

We used the tibial anatomic axis to establish the tibial slope. It has been shown to have the best correlation with the tibial shaft anatomic axis [7, 8].

The tibial anatomic axis was examined using lateral X-rays and a previously described technique [7]. Two midpoints between the anterior and posterior tibial cortex, 5 and 15 cm distances below the tibial tuberosity, were defined and used to examine the tibial anatomic axis.

These anatomical landmarks on the radiographies were transferred to the sagittal sections of the patient’s knee MRIs using the Vitera 2 program (Vital Images Inc., Plymouth, Minnesota). Two sagittal sections of the knee joint were examined by magnetic resonance imaging. To measure the medial and lateral tibial slopes, the shortest femorotibial distance on the medial and lateral plateaus were found. A line from the anterior tibial cortex to the posterior tibial cortex on the sagittal plane was drawn at these levels (the 1st line).

A second line vertical to the proximal tibial anatomic axis was transferred to the MRI section of the medial and lateral plateau. The angle of the tibial slope on the medial and lateral tibial condyle was measured by the angle between the two lines: one representing the tibial slope (on the medial and lateral condyle) and the other perpendicular to the line parallel to the proximal tibial anatomic axis (Figure 1 and 2). These angles were automatically measured by the Vitera 2 program.

The data were analyzed using the SPSS 17.0 program. The differences between the two groups were tested using the paired Student’s t test. The Student’s t test was used because of the similar measurements in all the groups. All of the groups were tested for the following differences:

i) The difference between the tibial slope and medial and lateral tibial plateau in each group;

ii) The difference between the tibial slopes on the lateral tibial plateau of groups; and

iii) The difference between the tibial slopes on the medial tibial plateau of groups.

The significance level was set at 5% (p<0.05).

Results

In group 1 (the medial meniscal tear group), the average tibial slope on lateral tibial plateau was 2.88 (from 1.5 to 6.2), and the slope on medial side was 3.18 (from 1.5 to 6.6). The average difference between the tibial slopes on the lateral and medial tibial plateau was 0.27, and the difference was statistically significant (p<0.05, p=0.02) (Table 1).

In group 2 (the lateral meniscal tear group), the average tibial slope of the lateral plateau was 3.60 (from 1.1 to 7.0), and the slope on the medial side was 3.64 (from 1.9 to 6.1). The difference between the tibial slopes of the lateral and the medial plateaus was not statistically significant (p>0.05; p=0.8891) (Table 1).
In group 3 (with both medial and lateral meniscal tears), the average tibial slope of the lateral plateau was 2.68 (from 1.8 to 4.5), and the medial slope was 3 (from 1.8 to 5). Although the difference between the lateral tibial slope and the medial tibial slope was not statistically significant (p=0.053), it was on the borderline; the medial tibial slope was greater than the lateral slope (the average difference was 0.31±0.62) (Table 1).

In the control group (group 4), the tibial slope of the medial plateau was 3.27 (from 1.8 to 6.5) and was higher than that of the lateral tibial plateau, which was 2.68 (from 1.4 to 6.1). The average difference between the tibial slope of the lateral tibial plateau and that of the medial tibial plateau was 0.35, which was statistically significant (p<0.05, p=0.0013) (Table 1).

The lateral plateau tibial slope of group 2 was higher than those of group 1, group 3, and the group 4. The differences between groups 2 and 4, between groups 2 and 3, and between groups 1 and 2 were statistically significant (p<0.05) (Table 2a, b, c, d, e and f).

In all the groups, the medial tibial slope was larger than the lateral tibial slope. The average medial slope was 3.13. There were no statistically significant differences in the slope of the medial tibial plateau between the groups (p>0.05).

**Discussion**

The posterior tibial slope of the knee affects the mechanics of the joint [9-11]. It affects the resulting shear forces at the plateau and that of the medial tibial plateau was 0.35, which was statistically significant (p<0.05, p=0.0013) (Table 1).

The lateral plateau tibial slope of group 2 was higher than those of group 1, group 3, and the group 4. The differences between groups 2 and 4, between groups 2 and 3, and between groups 1 and 2 were statistically significant (p<0.05) (Table 2a, b, c, d, e and f).

In all the groups, the medial tibial slope was larger than the lateral tibial slope. The average medial slope was 3.13. There were no statistically significant differences in the slope of the medial tibial plateau between the groups (p>0.05).

**Table 1. The tibial slope values by group**

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (medial meniscal tears) (n=90)</th>
<th>Group 2 (lateral meniscal tears) (n=15)</th>
<th>Group 3 (medial and lateral meniscal tears) (n=19)</th>
<th>Group 4 (intact menisci) (n=88)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tibial slope of the lateral tibial plateau</td>
<td>2.88±0.89</td>
<td>3.60±1.60</td>
<td>2.68±0.82</td>
<td>2.91±1.01</td>
</tr>
<tr>
<td>Tibial slope of the medial tibial plateau</td>
<td>3.18±1.19</td>
<td>3.64±1.42</td>
<td>3±0.86</td>
<td>3.27±1.12</td>
</tr>
<tr>
<td>Mean value of the difference between the tibial slopes of medial and lateral tibial plateaus</td>
<td>0.27±1.13</td>
<td>0.17±1.28</td>
<td>0.31±0.62</td>
<td>0.35±1.2</td>
</tr>
<tr>
<td>Student’s t test (p)</td>
<td>p&lt;0.05 (p=0.02)</td>
<td>p&gt;0.05 (p=0.8891)</td>
<td>p=0.05</td>
<td>p&lt;0.05 (p=0.0013)</td>
</tr>
</tbody>
</table>
joint when it is loaded by muscle or external forces. A greater posterior slope increases anteroposterior laxity, rotational laxity and varus-valgus laxity in the knee [12]. A larger posterior slope loosens the posterior cruciate ligament when the knee is flexed, which results in a larger range of knee motion. Because anterior tibial translation causes a strain on the ACL, the posterior tibial slope may also affect the load that the ACL is subjected to during exercise [9]. Therefore, the degree of posterior tibial slope may be one of the determining factors in ACL rupture [7, 9].

There is no standard and accepted technique for measuring the tibial slope. Measuring the posterior slope using lateral radiograph images and measuring the meniscal insertion using sagittal MRI images have been reported to be both reproducible and reliable [7]. However, adequately determining the proximal tibial anatomic axis (PTAA) and measuring the tibial slope are quite difficult [7, 8]. A section covering a minimum of 15 cm below the joint gap of the knee is said to be necessary for determining the tibial anatomic axis. We used the method of Stijak et al., and determined the proximal tibial anatomic axis and the angle of the anterior tibial slope using sagittal X-rays [7].

Chiu et al. [13] obtained values of 14.8° for the medial and 11.8° for the lateral plateau, whereas Stijak et al. obtained 7.52° for the lateral and 5.24° for the medial slope [7]. In our study, the mean value of the medial tibial plateau over all the groups was 3.24°, and mean value of lateral tibial plateau was 2.93°. There are several possible reasons for these differences. One of these reasons is the anterior tibial cortex being used in one study and the PTAA in another [7, 13]. Another reason is the effect of aging, which is thought to increase the tibial slope of the plateau. An additional reason is possible racial differences between Chinese and European populations. Both studies suggested that the tibial slope is larger on the medial than on the lateral plateau when the ACL is intact. They concluded that the increased tibial slope of the lateral tibial plateau may be the factor that causes ACL injuries. By contrast, another study has reported significant differences in the medial and lateral tibial plateau slopes between male and female subjects, independent of age [3].

The menisci carry up to 45% of the knee joint load. The stability of the meniscus during load bearing requires firm attachment of the menisci to the tibia. This attachment is provided by the relatively loose capsular fixation at the periphery of the menisci and the strong tibial insertion of the anterior and posterior horns [14].

The meniscus serves a variety functions, such as transmission of compressive loads shock absorption, stress reduction, joint lubrication and nutrient distribution [15-20]. There are many reports on the importance of the medial meniscus for limiting anterior translation in anterior cruciate ligament-deficient knees, whereas the lateral meniscus does not perform this function [21-25]. However, an isolated medial or lateral meniscectomy in knees with an intact anterior cruciate ligament does result in increased anterior tibial translation [23]. Meniscal tears typically occur during sudden turns and loadings, with various flexion and extension angles [14, 16].

### Table 2. Comparisons of the tibial slope values between the groups

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Group 1</th>
<th>Group 2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>a: Comparison of Group 1 and group 2</td>
<td>Tibial slope of lateral tibial plateau</td>
<td>2.88±0.99</td>
<td>3.6±1.6</td>
</tr>
<tr>
<td></td>
<td>Tibial slope of the medial tibial plateau</td>
<td>3.18±1.19</td>
<td>3.64±1.42</td>
</tr>
</tbody>
</table>

| b: Comparison of Group 2 and group 3 | Tibial slope of lateral tibial plateau | 3.6±1.6 | 2.68±0.82 | p=0.05 |
|            | Tibial slope of the medial tibial plateau | 3.64±1.42 | 3±0.86 | p>0.05 |

| c: Comparison of Group 2 and group 4 | Tibial slope of lateral tibial plateau | 3.6±1.6 | 2.9±1.01 | p<0.05 |
|            | Tibial slope of the medial tibial plateau | 3.64±1.42 | 3±0.86 | p>0.05 |

| d: Comparison of Groups 1 and 4 | Tibial slope of lateral tibial plateau | 2.88±0.99 | 2.9±1.01 | p>0.05 |
|            | Tibial slope of the medial tibial plateau | 3.18±1.19 | 3±0.86 | p>0.05 |

| e: Comparison of Groups 1 and 3 | Tibial slope of lateral tibial plateau | 2.88±0.99 | 2.68±0.82 | p>0.05 |
|            | Tibial slope of the medial tibial plateau | 3.18±1.19 | 3±0.86 | p>0.05 |

| f: Comparison of Groups 3 and 4 | Tibial slope of lateral tibial plateau | 2.68±0.82 | 2.9±1.01 | p>0.05 |
|            | Tibial slope of the medial tibial plateau | 3±0.86 | 3±0.86 | p>0.05 |
Little information on the relationship between the tibial slope and meniscal lesions is available. In several studies of patients with intact anterior cruciate ligaments, the tibial slope has been found to be greater on medial than on the lateral plateau [7, 8, 13]. In our study, the medial plateau tibial slope was greater in group 1 (with medial meniscal tears), group 3 (with both types of meniscal tears) and group 4 (without meniscal tears) than in group 2 (with lateral meniscal tears). Additionally, medial meniscal tears are more common than lateral meniscal tears [14-16, 21]. In our study, 72.5% of all the meniscal tears were medial meniscal tears, and only 12% were lateral meniscal tears. Medial meniscal tears may occur more commonly than the lateral meniscal tears because most populations have larger medial tibial slopes.

We also noticed that the lateral and medial tibial slopes were nearly equal in the patients with lateral meniscal tears. In other words, the risk of lateral meniscal tears increases as lateral tibial slope approaches the medial tibial slope. The number of patients in our lateral meniscal tear group was small, which is consistent with the literature previously mentioned.

A large tibial slope can lead to greater anterior tibial translation via stress to the knee joint and can consequently induce stretching and rupture of the anterior cruciate ligament [7]. Mahfauz et al. have shown that anterior tibial translation is much greater for the lateral condyle than for the medial condyle in the normal knees at 120 degrees flexion. During complete flexion, the femoral condyle touches the medial tibial plateau at approximately the same point, while the lateral femoral condyle slowly moves in the posterior direction [2]. Thus, the lower leg makes an additional motion that results in an internal rotation during flexion [2].

In conclusion, we found that the tibial slopes of the lateral and medial tibial plateaus were significantly different (p<0.05) in patients with and without medial meniscal tears. However, there was no difference between the lateral and medial tibial slopes in those with lateral tears. In the lateral meniscal tear group, the tibial slope of the lateral tibial plateau was significantly greater than the slope in the other groups (p<0.05). The increased tibial slope of the lateral tibial plateau may be a factor that causes injury to the lateral meniscus.

Conflict of interest statement: The authors declare that they have no conflict of interest to the publication of this article.

References

