

ÖN ÇAPRAZ BAĞ YARALANMASI İÇİN BİR RİSK FAKTÖRÜ OLARAK TİBİAL TÜBERKÜL - TROKLEAR OLUK MESAFESİNİN VE PATELLAR YÜKSEKLİĞİN DEĞERLENDİRİLMESİ

EVALUATION OF THE TIBIAL TUBERCLE - TROCHLEAR GROOVE DISTANCE AND PATELLAR HEIGHT AS A RISK FACTOR FOR ANTERIOR CRUCIATE LIGAMENT INJURY

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ÖZET

AMAÇ: Bu çalışmada Ön çapraz bağ (ÖÇB)'i sağlam ve ÖÇB'si kopuk olan hastalar arasındaki patellar yükseklik ve tibial tüberkül troklear oluk mesafesi (TT-TGd) arasındaki farkların değerlendirilmesi amaçlanmıştır.

GEREÇ VE YÖNTEM: 18-40 yaşları arasında toplam 2019 hasta (1015 ÖÇB kopuk ve 1004 ÖÇB sağlam) çalışmaya dahil edildi. Patellar yükseklik ölçümünü belirlemek için Insall Salvati indeksi (ISI) kullanıldı. TT-TGd, aksiyel manyetik rezonans görüntüleri ile ölçüldü. İki ortopedi cerrahı, gözlemci içi ve gözlemciler arası güvenilirliği değerlendirmek için bağımsız olarak iki hafta ara ile 50 hastanın görüntüsünü inceledi. Ortalama patellar yükseklik ve TT-TGd ölçümleri ÖÇB'si kopuk olan hasta grubu ve sağlam ÖÇB'si olan kontrol grubu ile karşılaştırıldı.

BULGULAR: Gözlemci içi ve gözlemciler arası uyum her iki ölçüm için de mükemmeldi (tüm ölçümler için $p=0.001$ ve $k>0.850$). Patellar yükseklik ve TT-TGd, ÖÇB kopuk olan hastalarda kontrol grubuna göre anlamlı olarak daha yüksekti (sırasıyla 1.09 ± 0.37 ile 1.06 ± 0.56 , $p<0.001$, 10.0 ± 3.3 'e karşı 8.5 ± 3.0 , $p<0.001$). ISI kadınlarda erkeklere göre anlamlı olarak daha yüksekti (1.13 'e karşı 1.07 , $p<0.001$). TT-TGd açısından cinsiyetler arasında anlamlı fark yoktu (9.5 'e 9.3 , $p=0.792$).

SONUÇ: ÖÇB'si kopuk olan hastalarda patella yüksekliği ve TT-TGd anlamlı olarak artmış olmasına rağmen, bu farklılıklar normal aralıkta oldukları için klinik olarak önemli değildir.

ANAHTAR KELİMELE: Ön çapraz bağ yaralanması, Patella yüksekliği, Risk faktör

ABSTRACT

OBJECTIVE: This study aimed to evaluate the differences in patellar height and tibial tubercle- trochlear groove distance (TT-TGd) between patients with an intact anterior cruciate ligament (ACL) and ruptured ACL.

MATERIAL AND METHODS: A total of 2019 patients (1015 with ruptured ACL and 1004 with an intact ACL) aged between 18-40 years were included. The Insall Salvati index (ISI) was used to determine the patellar height measurement. The TT-TGd was measured based on axial magnetic resonance images. Two orthopedic surgeons independently studied 50 patients' images for two weeks to assess intra-observer and inter-observer reliability. The mean patellar height and TT-TGd measurements were compared between patients with ruptured ACL and those with an intact ACL.

RESULTS: Interobserver and intraobserver agreement were excellent for both measurements ($p=0.001$ and $k>0.850$ for all measurements). Patellar height and TT-TGd were significantly higher in ACL ruptured patients than in the control group (1.09 ± 0.37 vs. 1.06 ± 0.56 , $p<0.001$, 10.0 ± 3.3 vs. 8.5 ± 3.0 , $p<0.001$, respectively). The ISI was significantly higher in women than in men (1.13 vs. 1.07 , $p<0.001$). There was no significant difference between the sexes regarding the TT-TGd (9.5 vs. 9.3 , $p=0.792$).

CONCLUSIONS: Although significantly increased in patellar height and TT-TGd was detected in patients with ruptured ACL, these differences are not clinically important because they are in the normal range.

KEYWORDS: Anterior Cruciate Ligament injury, Patellar height, Risk factor

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INTRODUCTION

Injuries to the anterior cruciate ligament (ACL) and the related tibiofemoral instability are associated with loss of function (1). However, even if the ACL is reconstructed, the risk of osteoarthritis development is high (1, 2). Therefore, prevention and identifying risk factors are important. Although ACL rupture is multifactorial, some anatomic risk factors like the femoral intercondylar notch width, lower extremity alignment, Q-angle, tibial plateau slopes, medial plateau concavity, and lateral plateau convexity have become the focus of investigation (3 - 7).

The relationship of the increased tibial tubercle-trochlear groove distance (TT-TGd) and patellar height with patellofemoral instability has been previously documented (8 - 10). Based on the current literature, there are two conflicting studies that have evaluated the relationship between patellar height and ACL tear (11, 12).

The primary aim of this study was to evaluate the role of TT-TGd and patellar height in ACL rupture in a large group. The secondary aim was to determine the role of sex in patellar height and TT-TGd.

MATERIALS AND METHODS

After receiving approval from the local ethics committee, medical records of patients who underwent ACL reconstruction between 2013 and 2018 were investigated using the International Classification of Diseases, Tenth Revision, codes. The inclusion criteria of the current study were: the patients had satisfactory axial magnetic resonance (MR) images and lateral radiographs to evaluate the TT-TGd and patellar height. The exclusion criteria were history of previous knee surgery, preexisting deformity, and multiple ligament injury (including posterior cruciate ligament and posterolateral corner injury). Finally, 1015 patients (973 male, 42 female) were included in the study (**Figure 1**).

As a control group, we selected 1004 age-matched randomized patients (960 male and 44 female) diagnosed with chondral lesion, degenerative meniscal injury, or plicae with intact ACL. The mean ages of the ACL ruptured and ACL intact groups were 29 ± 9.4 (range, 18 to 40)

years and 31 ± 9.8 (range 18 to 40) years, respectively. The need for informed consent was waived because of the study's retrospective design. TT-TGd measurement was performed as previously described by Schoettle et al. (13). First, the deepest point in the cartilaginous trochlear groove was determined. Then, a line was drawn through the deepest point of the trochlear groove perpendicular to the cartilaginous posterior condylar tangent line (**Figure 2**).

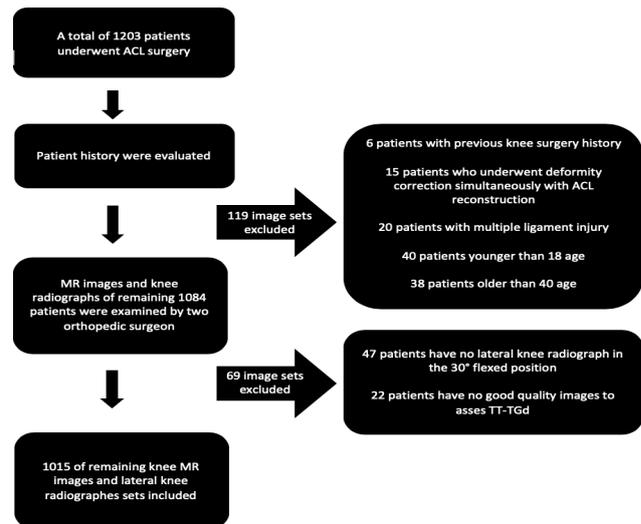


Figure 1: The flowchart showing the process of patient inclusion and exclusion

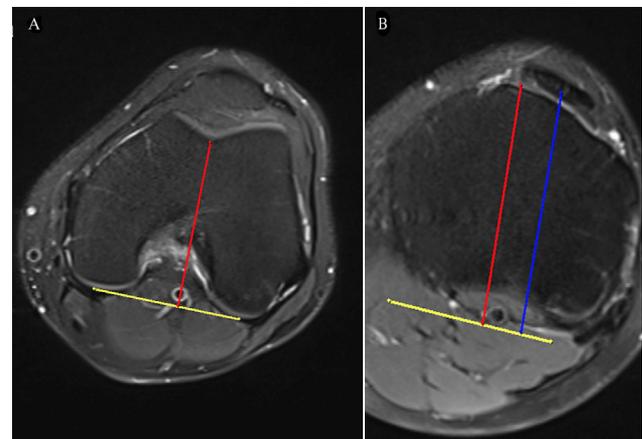


Figure 2: Measurement of TT-TGd on axial MR images of the knee. **A)** The red line is the perpendicular line from the posterior condylar tangent line (yellow line) extending to the deepest point of the TG. **B)** The blue line is the parallel line at the level of insertion of the patellar tendon onto the TT. The distance between these two lines is defined as TT-TGd

Second, the middle point of the patellar tendon at the level of insertion to the tibial tubercle was determined. Then, a second line was drawn from this point parallel to the trochlear groove line. The distance between these two parallel lines was determined as the TT-TGd. Radiographs were obtained with the knee joint in the 30°

flexed position. The Insall Salvati index (ISI) is the length ratio of the patellar tendon to the greatest diagonal length of the patella (**Figure 3**) (14).

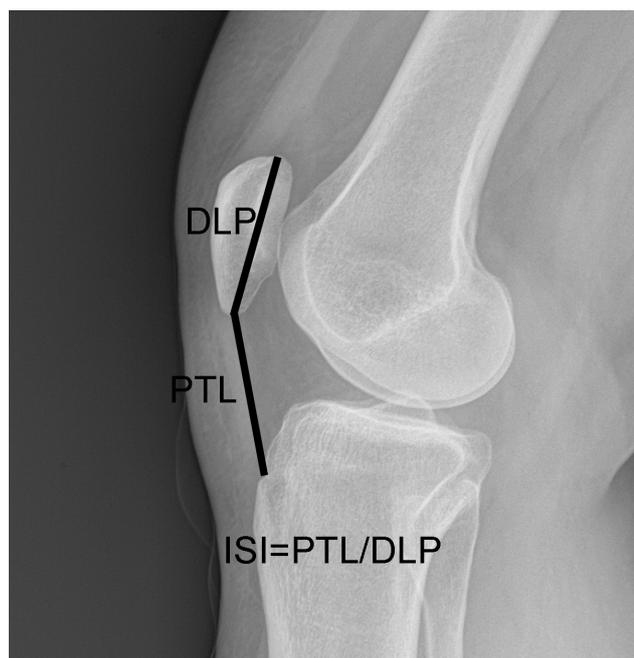


Figure 3: The Insall–Salvati index (ISI) is the ratio of patellar tendon length (PTL) to the greatest diagonal length of the patella (DLP)

The normal ISI is between 0.8–1.2. If the ISI > 1.2, it is defined as patella alta and if the ISI < 0.8, it is defined as patella baja (8, 14).

The mean patellar height and TT-TGd were compared between ACL intact and ACL ruptured groups. The patellar height and TT-TGd were compared between sexes. Measurements were performed in a blinded manner by two orthopedic surgeons with 5 years of experience who did not know the patients' diagnoses or the study's purposes.

Fifty randomly selected radiographs and axial MR images were measured twice for two weeks apart to assess the inter- and intra-observer reliability.

Statistical Analyses

In the descriptive statistics of the data, the mean, standard deviation, median, lowest, highest, frequency, and ratio values were used. The distribution of the variables was measured with the Kolmogorov Smirnov test. In the analysis of quantitative independent data, the Mann-Whitney test was used. The Chi-square test was used for the analysis of qualitative independent data. An intraclass correlation coefficient (ICC)

was calculated to assess inter and intra observer reliability. A p value less than 0.05 was considered significant. All data were analyzed by an independent professional statistician using IBM SPSS Statistics for Windows, version 22.0 (Armonk, NY: IBM Corp, USA.).

Ethical Committee

The ethical approval for the study was obtained from the Metin Sabancı Baltalimanı Bone Health Science University Baltalimanı Bone Diseases Education and Research Hospital, the study protocol (Approval date/number 22.05.2019/47-336)

RESULTS

Agreements among the two measurements for ISI (weighted kappa, 0.853; 95% confidence interval [CI] 0.682–0.932; $p < 0.001$), TT-TGd (weighted kappa, 0.956; 95% CI 0.905–0.980; $p < 0.001$) were excellent. Agreements between two readers for ISI (weighted kappa, 0.973; 95% CI 0.941–0.987; $p < 0.001$), TT-TGd (weighted kappa, 0.974; 95% CI 0.944–0.988; $p < 0.001$) were excellent. The mean ISI in the ACL ruptured and ACL intact groups was 1.09 ± 0.37 and 1.06 ± 0.56 , respectively ($p < 0.001$).

The mean TT-TGd was 10.0 ± 3.3 in the ACL ruptured group and 8.5 ± 3.0 in ACL intact group ($p < 0.001$), (**Table 1**).

Table 1: Mean (\pm standard deviation) of tibial tubercle-trochlear groove distance (TT-TGd) and patellar height values in the ACL intact and deficient groups

| | ACL intact group | | Median | ACL deficient group | | P |
|----------------------|------------------|------------|--------|---------------------|------------|-------------------------------|
| | Mean | s.d./n-% | | Mean | s.d./n-% | |
| TT-TGd | 8,5 | \pm 3,0 | 8,3 | 10,0 | \pm 3,3 | 10,0 $p < 0.001$ ^m |
| Insall Salvati Index | 1,06 | \pm 0,56 | 1,02 | 1,09 | \pm 0,37 | 1,05 $p < 0.001$ ^m |

^m Mann-Whitney u test

Patella alta or patella baja was not observed in the ACL ruptured group. However, the patellar height was significantly higher in the ACL ruptured group ($p < 0.001$). The TT-TGd was also significantly increased in the ACL ruptured group ($p < 0.001$).

There was no significant difference between male and female patients regarding the TT-TGd ($p = 0.792$). Patellar height in women was significantly higher than in men ($p < 0.001$) (**Table 2**). No significant correlation was observed between age and TT-TGd or patellar height ($p = 0.113$ and $p = 0.083$, respectively).

Table 2: Mean (\pm standard deviation) of tibial tubercle-trochlear groove distance (TT-TGd) and patellar height values in the female and male groups

| | Female | | Male | | P | | |
|----------------------|---------------------|--------|---------------------|--------|------|------|--------------------------------|
| | Mean \pm s.d./n-% | Median | Mean \pm s.d./n-% | Median | | | |
| TT-TG d | 9,5 | 3,5 | 9,2 | 9,3 | 3,2 | 9,0 | 0,792 ^m |
| Insall Salvati Index | 1,13 | 0,18 | 1,15 | 1,07 | 0,48 | 1,03 | p<0.001 ^m |

^m Mann-Whitney u test

DISCUSSION

The most important finding of this study is that the patellar height and TT-TGd was higher in the ACL injury group. Second, patellar tendon height was found to be higher in women. Despite the increasing number of papers on anatomical risk factors for ACL rupture over the past ten years, there is still no conclusive evidence of a direct cause-and-effect relationship. Female athletes have a higher incidence of ACL rupture than their male counterparts. The risk factors for non-contact ACL injuries can be classified as intrinsic and extrinsic (15, 16). Shambaugh et al. reported that women had a significantly smaller notch width index (17). Muneta et al. stated that there was a significant difference between male and female ACL widths (18). In several studies, the ACL size was smaller in women (1, 18). Women have been reported to have larger Q-angles than men (5). However, there are still a number of risk factors and mechanisms regarding non-contact ACL injuries that are not yet well understood (19). Therefore, we hypothesized that TT-TGd and patellar height may have a role in ACL injury. According to our hypothesis, these two parameters may vary between the sexes; this may explain the differences in the ACL injury rates between sexes. We acknowledge that the TT-TGd is an established measurement to assist diagnosis and treatment of patellofemoral instability (10,20,21). Based on the current literature, a TT-TGd of 15–20 mm is classified as abnormal; a TT-TGd >20 mm is defined as pathological (20, 22 - 24).

According to our results, TT-TGd values are in the normal range in both patient and control groups. However, in the ACL injury group, the TT-TGd values were closer to the upper limit. Even though the results were statistically significant, we believe there was no clinical significance.

Another important finding of the present study was that the patellar height was also higher in the patient group. Patella alta (defined as an ISI >1.2) has been shown to be a strong predictor of the recurrent instability in patients with patella dislocation following conservative treatment (14, 25). However, there are only two published studies that evaluated the ISI measurements in individuals with an ACL injury. Lin et al. stated that there is an association between ACL tears and patella baja (11). They observed a decreased patellar height in 115 patients with ACL tears with an average ISR of 0.99 versus 1.05 in 102 patients without ACL tears. Degnan concluded that the ISI was increased in children with acute ACL tears compared to the control group (average ISR 1.16 and 0.99, respectively) (12). They stated that even if the mechanism is unclear, relative patella alta may be a risk factor for ACL injury. Based on the current literature, there is a conflict on whether increased or decreased patellar height is a risk factor for ACL tear. It is important to note that Lin et al. recommend that patellar height should be taken into consideration for the graft choice (14). We noted that the ISI was significantly increased in the ACL deficient group, close to the upper limit. However, it has no clinical relevance because the results were in the normal range in both patient and control groups and were close to each other. On the other hand, there are numerous anatomical differences between the sexes. One of the possible risk factors might be the patellar height that explains ACL injury rates between genders. Perhaps several risk factors resulting in a cumulative effect. There are some limitations of this study. First, we investigated the patients radiologically however we did not evaluate their functional situation. Second, the other anatomical risk factors for ACL injury were not excluded. The presence of other associated risk factors may make our results less reliable. Prospective studies which evaluate these measurements with clinical situation should be designed. Although significantly increased patellar height and TT-TGd were detected in ACL ruptured patients, these differences are not clinically important because of they are in normal range.

REFERENCES

1. Hashemi J, Chandrashekar N, Mansouri H, et al. Shallow medial tibial plateau and steep medial and lateral tibial slopes: new risk factors for anterior cruciate ligament injuries. *Am J Sports Med.* 2010;38(1):54-62.
2. Rodriguez MJ, Garcia EJ, Dickens JF. Primary and Posttraumatic Knee Osteoarthritis in the Military. *J Knee Surg.* 2019;32(2):134-7.
3. Brandon ML, Haynes PT, Bonamo JR, et al. The association between posterior-inferior tibial slope and anterior cruciate ligament insufficiency. *Arthroscopy.* 2006;22:894-9.
4. Tan SHS, Kripesh A, Chan CX, Krishna L. Gender Differences in Intra-articular and Extra-articular Injuries Associated with Acute Anterior Cruciate Ligament Ruptures. *J Knee Surg.* 2019;32(7):616-9.
5. Stijak L, Herzog RF, Schai P. Is there an influence of the tibial slope of the lateral condyle on the ACL lesion? A case-control study. *Knee Surg Sports Traumatol Arthrosc.* 2008;16:112-7.
6. LaPrade RF, Burnett QM. Femoral intercondylar notch stenosis and correlation to anterior cruciate ligament injuries: a prospective study. *Am J Sports Med.* 1994;22:198-203.
7. Barahona M, Guzman M, Barrientos C, et al. The Distance between Tibial Tubercle and Trochlear Groove Correlates with Knee Articular Torsion. *J Knee Surg.* 2021;34(9):918-923.
8. Bayhan AI, Kirat A, Alpay Y, et al. Tibial tubercle-trochlear groove distance and angle are higher in children with patellar instability. *Knee Surg Sports Traumatol Arthrosc.* 2018;26(12):3566-71.
9. Simmons E, Cameron JC. Patella alta and recurrent dislocation of the patella. *Clin Orthop Relat Res.* 1992;(274):265-9.
10. Escala JS, Mellado JM, Olona M, et al. Objective patellar instability: MR-based quantitative assessment of potentially associated anatomical features. *Knee Surg Sports Traumatol Arthrosc.* 2006;14(3):264-72.
11. Lin CF, Wu JJ, Chen TS, et al. Comparison of the Insall-Salvati ratio of the patella in patients with and without an ACL tear. *Knee Surg Sports Traumatol Arthrosc.* 2005;13:8-11.
12. Degnan AJ, Maldjian C, Adam RJ, et al. Di Domenica M. Comparison of Insall-Salvati ratios in children with an acute anterior cruciate ligament tear and a matched control population. *AJR Am J Roentgenol.* 2015;204(1):161-6.
13. Schoettle PB, Zanetti M, Seifert B, et al. The tibial tuberosity-trochlear groove distance; a comparative study between CT and MRI scanning. *Knee.* 2006;13:26-31.
14. Insall J, Salvati E. Patella position in the normal knee joint. *Radiology.* 1971;101(1):101-10.
15. Myer GD, Ford KR, Paterno MV, et al. The effect of generalized joint laxity on risk of anterior cruciate ligament injury in young female athletes. *Am J Sports Med.* 2008;36:1073-80.
16. Renstrom P, Ljungqvist A, Arendt E, et al. Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. *Br J Sports Med.* 2008;42(6):394-12.
17. Shambaugh JP, Klein A, Herbert JH. Structural measures as predictors of injury in basketball players. *Med Sci Sports Exerc.* 1991;23:522-7.
18. Muneta T, Takakuda K, Yamamoto H. Intercondylar notch width and its relation to the configuration and cross-sectional area of the anterior cruciate ligament. *Am J Sports Med.* 1997;25:69-72.
19. Charlton WP, St John TA, Ciccotti MG, et al. Differences in femoral notch anatomy between men and women: a magnetic resonance imaging study. *Am J Sports Med.* 2002;30: 329-33.
20. Dejour H, Walch G, Nove-Josserand L, et al. Factors of patellar instability: an anatomic radiographic study. *Knee Surg Sport Traumatol Arthrosc.* 1994;2:19-26.
21. Paiva M, Blond L, Holmich P, et al. Quality assessment of radiological measurements of trochlear dysplasia; a literature review. *Knee Surg Sport Traumatol Arthrosc.* 2017;26(3):746-55.
22. Alemparte J, Ekdahl M, Burnier L, et al. Patellofemoral evaluation with radiographs and computed tomography scans in 60 knees of asymptomatic subjects. *Arthroscopy.* 2007;23:170-7.
23. Anley CM, Morris GV, Saithna A, et al. Defining the role of the tibial tubercle-trochlear groove and tibial tubercle-posterior cruciate ligament distances in the workup of patients with patellofemoral disorders. *Am J Sport Med.* 2015;43:1348-53.
24. Hochreiter B, Michael T, Amsler F, et al. Highly variable tibial tubercle-trochlear groove distance (TT-TG) in osteoarthritic knees should be considered when performing TKA. *Knee Surg Sports Traumatol Arthrosc.* 2019;27(5):1403-9.
25. Thaunat M, Erasmus PJ. Recurrent patellar dislocation after medial patellofemoral ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2008;16:40-3.