EJMI

DOI: 10.14744/ejmi.2019.32718
EJMI

Research Article

Association Between Femoral Trochlear Groove Measurements and Chondral Injuries of the Patellofemoral Joint

Volkan Kizilgoz,[1] Gokhan Ragip Ulusoy[2]

[1]Department of Radiology, Kafkas University, Faculty of Medicine, Kars, Turkey
[2]Department of Orthopaedics, Kafkas University Faculty of Medicine, Kars, Turkey

Abstract

Objectives: The aim of this study was to determine the relationship of trochlear sulcus angle (TSA) and trochlear sulcus depth (TSD) of the femur with the presence of chondral injury at the patellofemoral joint (CIP).

Methods: In total, 509 knee magnetic resonance (MR) images of 436 patients were evaluated for TSA and TSD by two reviewers. The patients were divided into two groups based on the presence or absence of CIP. Two reviewers independently measured TSA and TSD on the MR images. Independent samples t-test was used to compare the results of patients with and without CIP. Analysis of variance and Tukey's tests were used to evaluate differences between the control group and patients with mild CIP and severe CIP. Receiver operating characteristics (ROCs) were used to find the possible cutoff value of TSA and TSD to determine the presence of CIP.

Results: Significant differences in TSA and TSD values were found between patients with and without CIP ($p<0.001$). ROC analysis showed that a TSA cutoff value of 141.83° had 61.5% sensitivity and 76.8% specificity for detecting CIP.

Conclusion: Patient and control groups showed significant differences in TSA and TSD values. There was no significant difference in TSA and TSD values between mild and severe CIP groups. A TSA of 141.83° may be used as the cutoff value to determine possible CIP on knee MR images.

Keywords: Articular cartilage defects, chondromalacia patella, femoral trochlea, knee instability, MRI, patella.

Cite This Article: *Kizilgoz V, Ulusoy GR. Association Between Femoral Trochlear Groove Measurements and Chondral Injuries of the Patellofemoral Joint. EJMI.*

The relationship between the patella and the trochlear groove of the femur directly affects the normal function of the patellofemoral joint (PFJ). Alterations in the surface geometry of PFJ have been shown to be related with chondromalacia patella and patellar instability.[1-5] A shallower femoral trochlear groove can affect the congruency of PFJ, and decreased trochlear depth has been associated with subluxation or dislocation syndromes of the patella.[6-7]

Femoral trochlear dysplasia has been reported in the literature and described on radiographs;[8] however, radiographs have not proven to be a useful imaging method in the diagnosis of patellar chondromalacia.[9, 10] Furthermore, computed tomography images have been used to detect trochlear dysplasia in patellar instability.[2] Magnetic resonance imaging (MRI) is a non-invasive method that could be beneficial in confirming the diagnosis of CIP. Compared with diagnostic arthroscopy, which carries a risk of complications, MRI is a more comfortable procedure that can be easily used to visualize the anatomy of PFJ and to diagnose CIP.

Herein we have reported the analysis of measurements of trochlear sulcus angle (TSA) and trochlear sulcus depth (TSD) of the femur, which represent important anatomical details of PFJ, and reported the effect of these values on CIP in a large series of patients. The aim of this study was to evaluate the association between altered trochlear anatomy in patients and their tendency to develop CIP.

Address for correspondence: Volkan Kizilgoz, MD. Kafkas Üniversitesi Tıp Fakültesi, Radyoloji Anabilim Dalı, Kars, Turkey
Phone: +90 505 799 40 13 **E-mail:** volkankizilgoz@gmail.com

Submitted Date: January 20, 2019 **Accepted Date:** February 18, 2019 **Available Online Date:** February 28, 2019

Methods

Patients

This case-control study was approved by the ethics committee. Due to the retrospective design of the study, the need for informed consent was waived by the committee. Patients aged <18 years and >50 years were not included in the study due to skeletal immaturity and severe osteoarthritis A total of 649 knee MR images of patients admitted to our orthopedics department between January 2018 and November 2018 were evaluated for the presence of CIP. All MR images were collected from the picture archiving and communication system (PACS) of our hospital. Patients included in this study had various MRI indications as shown in Table 1. Of all, 62 patients with a history of arthroscopic surgery, 11 patients with knee MR images of insufficient quality not enabling appropriate measurements or with motion artifacts, and 67 patients with missing information (time of interval between symptoms and MRI procedure or specific patient history about past arthroscopies etc.) were excluded from the study. After exclusion, 509 knee MR images of 436 patients were evaluated for the presence of CIP. The mean time of interval between the patient complaints and the MRI procedure were 6 days for both patient and control groups. Two reviewers (one radiology specialist with 13 years of experience in musculoskeletal radiology and one orthopedic surgeon with 23 years of experience) worked together to evaluate the images. Patients with and without CIP on MR images comprised the patient (n=104) and control (n=405) group, respectively. Patients with CIP were further classified into three groups based on CIP severity by the consensus of the two reviewers in accordance with the International Cartilage Repair Society Classification System (Table 2) 11: (1) no CIP, (2) mild CIP, and (3) severe CIP. After determining the presence and classification of CIP, each reviewer independently measured TSA and TSD of these patients on MR images.

Table 1. Clinical indications for MRI

Clinical indication	Number of patients
Suspected anterior cruciate ligament injury	72
Suspected anterior and posterior cruciate ligament injury	27
Suspected medial meniscus injury	183
Suspected lateral meniscus injury	102
Suspected medial and meniscus injury	34
Suspected patellar tendon rupture or patellar dislocation	9
Osteoarthritic changes	53
Loose body	3
Other indications (refractory knee pain, suspected joint effusion etc.)	26
Total	509

MR Image Measurements

Each knee MR image was initially analyzed using T1-weighted (T1W) imaging in the sagittal plane to determine the most appropriate axial slice that passes through the greatest ventral trochlear prominence. Subsequently, fat-saturated proton density-weighted (PDW) images in the axial plane were used to measure TSA and TSD. For patients with no marked trochlear prominence, the anterior physeal line was used as a reference to determine the appropriate axial slice. For TSA and TSD measurements, the chondral surface was not taken into account and only the osseous surfaces were used to draw lines on axial images. The angle formed by the lines passing through the medial and lateral trochlear facet surfaces was defined as TSA. TSD was calculated as the maximum distance from the deepest point of the trochlear groove to the line connecting the most anterior edges of the medial and lateral facets (Fig. 1).

Table 2. International cartilage repair society classification system[11]

Cartilage defect	MRI finding
None	
Grade 0	Normal
Mild defect	
Grade 1	Normal contour with abnormal increased signal
Grade 2	Superficial erosion or ulceration of <50%
Severe defect	
Grade 3	Partial-thickness defect of >50% but <100%
Grade 4	Full thickness carthilage loss

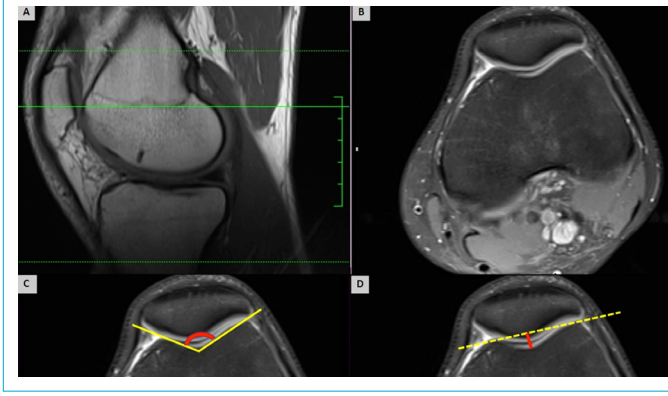

Figure 1. (a) (T1W sagittal image) shows the line of the section of the PDW axial image **(b)** which was chosen to make the measurements. **(c)** and **(d)** demonstrates the TSA and TSD measurements respectively.

MRI Protocol

All MRIs were performed using a 1.5T system (Magnetom Essenza; Siemens, Erlangen, Germany) with an 8-channel knee coil. Sagittal T1W [Repetition time (TR): 515 ms, Echo time (TE): 14 ms, Matrix: 192×256, field of view (FOV): 160 mm, slice thickness: 3.5 mm, interslice gap: 0.7 mm, echo train length (ETL): 55, number of excitations (NEX): 2], axial PDW (TR: 2500 ms, TE: 28 ms, matrix: 206×256, FOV: 170 mm, slice thickness: 3.5 mm, interslice gap: 0.7 mm, ETL: 69, NEX: 1), coronal PDW (TR: 2350 ms, TE: 26 ms, matrix: 205×256, FOV: 180 mm, slice thickness: 3.5 mm, interslice gap: 0.7 mm, ETL: 69, NEX: 1), and sagittal PDW (TR: 2670 ms, TE: 24 ms, matrix: 205×256, FOV: 190 mm, slice thickness: 3.5 mm, interslice gap: 0.7 mm, ETL: 70, NEX: 1) images were obtained for every knee MR examination. Each patient included in this study was examined in the supine position, with slight flexion of the knee (range, 10°–15°) and approximately 15° external rotation. MRI started in the area above the trochlear groove, extended to the area below the tibial tubercle, and included the entire suprapatellar joint recess.

Statistical Analysis

After image acquisition and collection of the reviewers' data, all statistical analyses were performed using IBM SPSS statistics for Windows V.20 (IBM Corp). According to the results of a power analysis (assuming type 1 error was 0.05 and the power of the test was 80%), a minimum of 21 individuals were needed in both the patient and control groups to perform an analysis to determine significant between-group differences. The homogeneity of data distribution was determined by performing Kolmogorov–Smirnov test. Histograms were used to depict data distribution in graphical format. For interobserver agreements, the results of each reviewer were compared using intraclass correlation coefficient (ICC) analysis. Accordingly, ICC values between 0 and 0.20 indicate "no" agreement, between 0.21 and 0.39 indicate "minimal" agreement, and between 0.40 and 0.59 indicate "weak" agreement. Furthermore, ICC values between 0.60 and 0.79 indicate "moderate" agreement," between 0.80 and 0.90 indicate "strong" agreement, and >0.90 indicate "almost perfect" agreement. Receiver operating characteristics (ROCs) were used to specify a possible cutoff value of TSA and TSD to determine the presence of CIP, and area under the curve (AUC) values were calculated for both measurements. Independent samples t-test was used to determine differences in TSA and TSD values based on the presence or absence of CIP. Statistical differences between the subgroups (no CIP, mild CIP, and severe CIP) were analyzed using analysis of variance and Tukey test; $p<0.05$ were accepted as significant.

Results

In total, 325 right and 184 left knee MR images were included in the study; age and sex distributions are presented in Table 3.

There was almost perfect agreement between the reviewers regarding TSA (ICC value: 0.984) and TSD (ICC value: 0.985) measurements. There was homogenous data distribution for TSA and TSD values, as shown by the histograms in Figure 2.

The mean TSA value was 143.66°±7.01° in the patient group and 137.83°±5.92° in the control group for reviewer 1 and 143.62°±6.75° in the patient group and 137.79°±5.65° in the control group for reviewer 2. TSD values were 4.10°±1.62° (patient group) and 5.05°±1.05° (control group) for reviewer 1 and 4.10°±1.61° (patient group) and 5.03°±1.04° (control group) for reviewer 2.

Table 3. The age and sex distribution of patients

	Knee MRI's with CIP	Knee MRI's without CIP	Total
Age (mean±SD)	39.40±8.10	33.82±9.00	34.96±9.10
Sex	-	-	-
Males, n (%)	33 (6.5)	238 (46.7)	271 (53.2)
Females, n (%)	71(14.0)	167 (32.8)	238 (46.8)
Side	-	-	-
Right knees, n (%)	61 (12.0)	264 (51.8)	325 (63.8)
Left knees, n (%)	43 (8.5)	141 (27.7)	184 (36.2)

CIP: Chondral injury of patellofemoral joint; SD: Standard deviation.

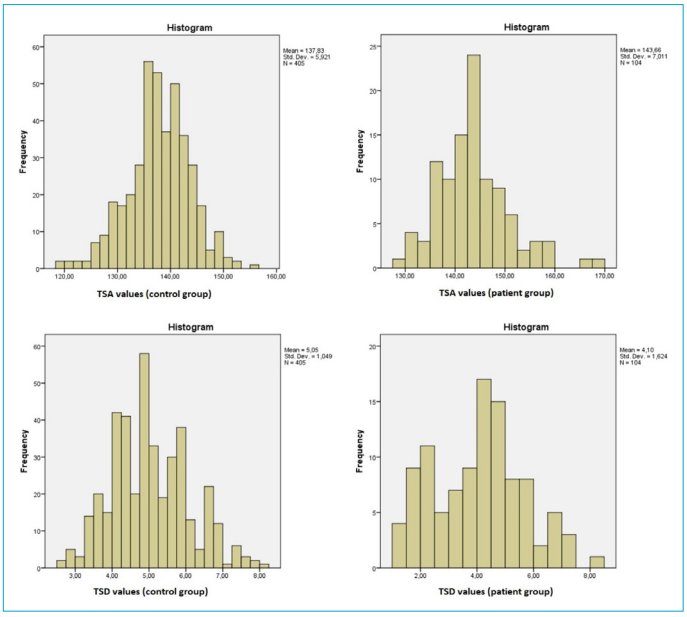

Figure 2. The histograms showing the data distribution of patient and control groups with regard to TSA and TSD values.

Significant differences were found in both TSA and TSD values between patients with and without CIP (Table 4). In addition, significant differences were found in TSA and TSD values for both male and female group (p<0.001) between patients with and without CIP.

ROC analysis revealed that a TSA of 141.83° had 61.5% sensitivity and 76.8% specificity (with AUC value of 0.737) in detecting CIP, whereas a TSD of 5.18 mm had 26% sensitivity and 57.3% specificity (with AUC value of 0.321) in detecting CIP in patients (Fig. 3).

Significant differences in TSA values were found between group 1 (control) and group 2 (mild CIP) as well as between group 1 (control) and group 3 (severe CIP) (p<0.001); however, no significant difference was found between group 2 (mild CIP) and group 3 (severe CIP) (p=0.921). Similarly, significant differences in TSD values were found between control and mild CIP groups as well as between control and severe CIP groups (p<0.001); however, no significant difference was found between mild and severe CIP groups (p=0.44; Table 5)

Table 4. The TSA and TSD measurements for male and female groups

	Knee MRI's with CIP	Knee MRI's without CIP	p
Total (n=509)			
TSA (mean±SD)	143.66±7.01	137.83±5.92	<0.001
TSD (mean±SD)	4.10±1.62	5.05±1.05	<0.001
Male (n=271)			
TSA (mean±SD)	142.32±5.41	137.77±5.79	<0.001
TSD (mean±SD)	4.34±1.78	5.28±1.07	<0.001
Female (n=238)			
TSA (mean±SD)	144.27±7.59	137.91±6.11	<0.001
TSD (mean±SD)	3.98±1.56	4.71±0.91	<0.001

CIP: Chondral injury of patellofemoral joint; MRI: Magnetic resonance imaging; TSA: Trochlear sulcus angle; TSD: Trochlear sulcus depth.

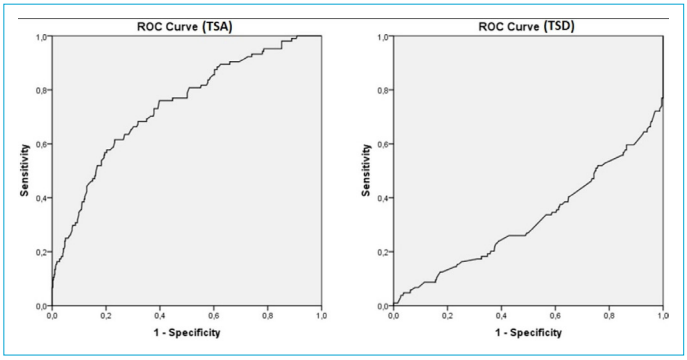

Figure 3. The ROC analysis for TSA and TSD values.

Discussion

This study confirms the results of previous studies and emphasizes the association of two important parameters of trochlear anatomy with patellar chondral injuries in a large sample of MR images. In addition, the reliability of measurements of TSA and TSD was also tested.

Studies have reported on the different aspects of the trochlear groove geometry and the effects of these anatomic alterations on PFJ. For instance, increased TSA was found to be associated with increased lateral and medial patellar cartilage.[12] In another study, no significant difference in TSA and TSD measurements was detected between patients with early stage patellar chondromalacia and those with advanced stage patellar chondromalacia.[13] Furthermore, Türkmen et al.[14] found no significant difference in TSA values obtained from MR images between patients with anterior knee pain and control group with knee complaints other than anterior knee pain. We focused on the effect of TSA and TSD on the presence of CIP rather than on cartilage volume or the clinical symptoms of PFJ disorders.

Reliability of TSA and TSD measurements is an important point of consideration. Reviewers need to be very careful while studying small numbers of MR images. In the study by Huysteen et al.,[15] the mean interobserver repeatability was 0.76 and intraobserver repeatability was 0.87 for TSA (measured by drawing an angle using the bony contours of the femoral trochlear surface). In our study, interobserver reliability as measured using ICC values was 0.984 for TSA and 0.985 for TSD.

Studies have investigated TSA as a possible risk factor for CIP, although this relationship remains debatable. Yang et al.[16] included 111 patients with anterior knee pain who had chronic cartilage lesions of PFJ and underwent arthroscopy. In their study, the patients with dominant lateral articular surface had more frequent patellofemoral cartilage lesions that were significantly associated with TSD. They

Table 5. The TSA and TD measurements of the 3 subgroups

	Group 1 (n=405)	Group 2 (n=49)	p (1-2)	Group 3 (n=55)	p (1-3)
Total					
TSA (mean±SD)	137.83±5.92	143.41±6.77	<0.001	143.88±7.28	<0.001
TSD (mean±SD)	5.05±1.05	4.25±1.51	<0.001	3.96±1.72	<0.001

CIP: Chondral injury of patellofemoral joint; MRI: Magnetic resonance imaging; TSA: Trochlear sulcus angle; TSD: Trochlear sulcus depth.

suggested that less sulcus depth of femoral trochlea is associated with a higher risk for patellofemoral cartilage injury. Furthermore, Tuna et al.[17] have reported that patients with patellar chondromalacia have a significantly increased TSA and decreased TSD. Similarly, Yeniçeri et al.[18] (n=220) have demonstrated significant differences in TSA and TSD values between patients with chondromalacia and the control group. Similar to our study, Ali et al.[5] followed the International Cartilage Repair Society Classification System to group their subjects as "no cartilage defect," "mild cartilage defect," and "severe cartilage defect." In addition, the subjects were further classified as "<40 years old" and "≥40 years old." They reported no significant differences in TSA and TSD values between "mild cartilage defect" group and control group; however, significant differences were reported between the "severe cartilage defect" group and control group in patients aged <40 years. In the current study, significant differences were found between knee MR images of the control and mild CIP groups. Moreover, there were significant differences between TSA and TSD values of the control and severe CIP groups. In addition, the TSA cutoff value calculated using ROC analysis demonstrated a relatively high sensitivity and specificity for detecting the presence of CIP.

This study does have some limitations. First, MRI results were accepted as the gold standard instead of arthroscopy results. Arthroscopically operated patients may show more accurate results than the results observed on MR images. In addition, the significant difference in the age of patients and controls should also be taken into account before generalizing the results of this study to the entire population. In this retrospective study, data were collected from PACS of our hospital, and all MRIs were performed on patients in the supine position. MRI performed during weight bearing could be a better way of understanding the anatomical relationship between the patella and trochlear surface, potentially affecting the results of this study. Last, although two well-experienced reviewers measured the TSA and TSD values and interobserver reliabilities were calculated, human error should also be taken into account while analyzing the results of this investigation.

Conclusion

In conclusion, high TSA and low TSD values showed a significant relationship with the presence of CIP. Further investigations with more number of patients and arthroscopically confirmed results are needed to better understand this relationship. Studies comprising larger number of patients will be useful in identifying TSA cutoff values for MR images where presence of CIP may be ambiguous.

Disclosures

Ethics Committee Approval: The study was approved by the Local Ethics Committee.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – V.K., G.R.U.; Design – V.K., G.R.U.; Supervision – V.K.; Materials – V.K., G.R.U.; Data collection &/or processing – V.K., G.R.U.; Analysis and/or interpretation – V.K., G.R.U.; Literature search – V.K.; Writing – V.K.; Critical review – V.K., G.R.U.

References

1. Aglietti P, Insall JN, Cerulli G. Patellar pain and incongruence: measurements of incongruence. Clin Orthop Relat Res 1983; 176: 217–224.
2. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: an anatomic radiographic study. Knee Surg Sports Traumatol Arthrosc 1994; 2: 19–26.
3. Sasaki T, Yagi T. Subluxation of the patella: investigation by computerized tomography. Int Orthop 1986; 10: 115–120.
4. Christoforakis JJ, Strachan RK. Internal derangements of the knee associated with patellofemoral joint degeneration. Knee Surg Sports Traumatol Arthrosc 2005; 13: 581–584.
5. Ali SA, Helmer R, Terk MR. Analysis of the patellofemoral region on MRI: association of abnormal trochlear morphology with severe carthilage defects. AJR 2010; 194: 721–727.
6. Nietosvaara Y: The femoral sulcus in children. An ultrasonographic study. J Bone Joint Surg Br 1994, 76: 807–809.
7. Davies AP, Costa ML, Shepstone L, Glasgow MM, Donell S: The sulcus angle and malalignment of the extensor mechanism of the knee J bone Joint Surg Br 2000, 82: 1162–1166.
8. Grelsamer RP, Tedder JL. The lateral trochlear sign: femoral trochlear dysplasia as seen on a lateral view roentgenograph. Clin Orthop Relat Res 1992; 281: 159–163.
9. Chan WP, Lang P, Stevens MP, Sack K, Majumdar S, Stoller DW, Basch C, Genant HK. Osteoarthritis of the knee: comparison of radiography, CT, and MRimaging to assess extent and severity. AJR Am J Roentgenol 1991; 157: 799–806.
10. Wright RW, Boyce RH, Michener T, Shyr Y, McCarty EC, Spindler KP. Radiographs are not useful in detecting arthroscopically confirmed mild chondral damage. Clin Orthop Relat Res 2006; 442: 245–251.
11. Brittberg M, Winalski CS. Evaluation of cartilage injuries and repair. J Bone Joint Surg Am 2003; 85[suppl 2]: 58–69.
12. Tanamas SK, Teichtahl AJ, Wluka AE, Wang Y, Davies-Tuck M, Urquhart DM, Jones G, Cicuttini FM. The associations between indices of patellofemoral geometry and knee pain and patella cartilage volume: a cross-sectional study. BMC Musculoskeletal Disorders 2010, 11:87.
13. Aysin IK, Askin A, Mete BD, Guvendi E, Aysin M, Kocyigit H. Investigation of the Relationship between Anterior Knee Pain and Chondromalacia Patellae and Patellofemoral Malalign-

ment. Eurasian J Med 2018; 50: 28–33.
14. Türkmen İ, Işık Y. Association between patellofemoral congruence and patellofemoral chondropathy in patients with anterior knee pain: A T2 mapping knee MRI study. Eklem Hastalik Cerrahisi 2018; 29: 93–99.
15. Huyssteen AL, Hendrix MR, Barnett AJ, Wakeley CJ, Eldridge JD. Cartilage-bone mismatch in the dysplastic trochlea. An MRI study. J Bone Joint Surg Br 2006; 88: 688–691.
16. Yang B, Tan H, Yang L, Dai G, Guo B. Correlating anatomy and congruence of the patellofemoral joint with cartilage lesions. Orthopedics 2009; 32: 20.
17. Tuna BK, Semiz-Oysu A, Pekar B, Bukte Y, Hayirlioglu A. The association of patellofemoral joint morphology with chondromalacia patella: a quantitative MRI analysis. Clin Imag 2014; 38: 495–498.
18. Yeniçeri Ö, Çullu N, Yeniçeri EN, Kılınç RM, Deveer M, Canbek U. The relationship between chondromalacia and patellofemoral alignment and patella type. Muğla Sıtkı Koçman Üniversitesi Tıp Dergisi 2015; 2: 44–40.