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Original Research Article

The Role of Magnetic Resonance Imaging in the Assessment of Patellar Instability in the Indian Population

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Abstract

Purpose: The purpose of this study was to determine the role of MRI in the assessment of anatomical abnormalities in case of patellar instability and to determine the sensitivity, specificity, and accuracy of each variable in detecting the concerning pathology.

Methodology: This study included a total of 115 keens in 65 patients who attended the OPD of Amrita institute of medical science hospital, Kochi, Kerala, India. MR examinations were carried on 15 knees in 15 patients suffering patellar instability and 100 knees in 50 volunteers with healthy knees. Out of 15 patients with patellar instability, 4 patients were males and 11 were females. The mean age of these patients was 16 years. The age range was between 10 years to 42 years. Out of 50 patients who volunteer with healthy knees, 40 patients were males and 10 were females. The mean age of these patients was 26.5 years. The age range was between 20 years to 42 years. The MR imaging studies of the 115 selected knees were performed in a 1.5-T imager (General Electric Medical Systems, Milwaukee, WI, USA). A dedicated knee coil was used. The knees were positioned in a minimal flexion (30 °). Axial and sagittal proton density fat-saturated spin-echo and coronal T1 fast spin-echo sequences were performed. The participant's data were collected over 3 years from 2009 to 2012

Results: This study included a total of 65 patients who attended the OPD of Amrita institute of medical science hospital, Kochi, Kerala, India. MR examinations were carried on 15 knees in 15 patients suffering patellar instability and 100 knees in 50 patients volunteer with healthy knees. In this study, Patella Alta and trochlear depth showed the highest sensitivity (87%) followed by lateral trochlear inclination (80%). Lateral patellar tilt had the highest specificity (100%) followed by patellar lateralization (95%).

Conclusion: Patellar dislocation is characterized by the complete loss of contact between the patella from the trochlear groove of the femur. The most common predisposing factors for patellar instability include trochlear dysplasia, patella Alta, and lateralization of the tibial tuberosity. Important secondary factors contributing to patellar instability are trauma-related tear of the medial patellofemoral ligament (MPFL) and ligamentous laxity (Ehlers-Danlos and Marfan syndromes). Characterization and quantification of these anatomic anomalies will reveal the individual mechanism of patellar instability and help the orthopedic surgeon choose the optimal treatment. These anomalies can be diagnosed and characterized with MR imaging. This study demonstrated that Individual characterization of medial patellar stabilizers (MPFL and medial retinaculum), trochlear depth, and the assessment of patella Alta with any lateral displacement of its attachment in tibial tuberosity would help physicians in accurate planning of the concerned anatomical abnormality to get better treatment and surgical outcome in cases of Patellar instability.

Keywords: Anatomical abnormalities, Ehlers-Danlos syndrome, Marfan syndromes, Medial patellofemoral ligament, Patellar dislocation.

Introduction

Patellar instability is a disease where the patella bone pathologically disarticulates out from the patellofemoral joint. Patellar dislocation is characterized by the complete loss of contact between the patella from the trochlear groove of the femur. Over a period of time, patellar instability can trigger debilitating pain, limitations in basic function, and long-term arthritis. The normal function of the patellofemoral joint is ensured by passive stabilizers (bones and ligaments) and active stabilizers (extensor muscles). The femoral sulcus must be deep enough and the lateral trochlea high enough to ensure safe tracking throughout the range of patellofemoral flexion. The medial ligamentous stabilizers prevent lateral displacement of the patella during movement. The most important ligamentous stabilizers are the medial patellar retinaculum and the medial patellofemoral ligament (MPFL)[1].

Patella Alta is considered the main factor in patellofemoral misalignment because, with patella Alta, the degree of flexion needs to be higher for the patella to engage in the trochlea, compared with a normal knee. [1] This problem leads to the reduced patellar contact area and decreased bone stability in shallow degrees of flexion. The position of the tibial tubercle is crucial for the inferolateral force vector of the patella. In a normal joint, the tibial tuberosity lies vertically under the femoral sulcus, directing the force vector inferiorly during knee bending. However, if there is excessive lateralization of the tibial tuberosity, the patella is pulled laterally during flexion. Therefore, excessive lateral displacement is considered a risk factor for instability. Trochlear dysplasia has been identified as one of the main factors contributing to chronic patellofemoral instability[2]. In individuals with trochlear dysplasia, the trochlear joint surface is flattened proximally, and the concavity is less pronounced distally. This combination results in considerable loss of lateral patellar tracking and in lateral dislocation of the patella at the initiation of flexion. In the more severe expressions of trochlear dysplasia, the trochlear surface may even become convex with increasing hypoplasia of the medial joint surface. Because of its high frequency of occurrence bilaterally, trochlear dysplasia is believed to be a developmental anomaly. Recurrent patellar dislocation/subluxation leads to Disruption of medial ligamentous stabilizers, such as the MPFL and the medial patellar retinaculum

Proper diagnosis is decisive for selecting the most promising treatment.[3] Diagnostic evaluation includes the identification and characterization of underlying anomalies. Nonsurgical treatment alone may not fully restore the patella to its normal position if there is severe damage to these structures. MR imaging findings are therefore important for both therapeutic decision-making and planning of the surgical procedure. The most common surgical procedures after patellar dislocation involve the medial and lateral stabilizers (MPFL reconstruction, medial capsular plication, and lateral release). Bone procedures include reconstruction of a dysplastic trochlea (trochleoplasty) and tibial tuberosity transfer in patients with an abnormal distance between the tibial tubercle and the trochlear groove. The optimal time of surgery depends on the individual constellation of findings. The most common predisposing factors for patellar instability include trochlear dysplasia, patella Alta, and lateralization of the tibial

tuberosity. Important secondary factors contributing to patellofemoral instability are femorotibial malrotation, genu recurvatum (back-knee), and ligamentous laxity (Ehlers-Danlos and Marfan syndromes). Characterization and quantification of these anatomic anomalies will reveal the individual mechanism of patellar instability and help the orthopedic surgeon choose the optimal treatment.

Studies on the role of MRI in diagnosing patellar instability focusing on the Indian subcontinent were lacking. This study assessed the role of MRI in the assessment of patellar instability in the Indian population and attempted to find out the diagnostic relevance of several MRI parameters used to assess patellar instability.

Aim and Objectives:

The purpose of this study was to determine the role of MRI in the assessment of anatomical abnormalities in case of patellar instability and to determine the sensitivity, specificity, and accuracy of each variable in detecting the concerning pathology.

Methodology

This study included a total of 115 keens in 65 patients who attended the OPD of Amrita institute of medical science hospital, Kochi, Kerala, India. MR examinations were carried on 15 knees in 15 patients (4 male patients, 11 female patients; mean age, 16 years; age range, 10-42 years) suffering patellar instability (Group 1) and 100 knees in 50 patients (40 male patients, 10 female patients; mean age, 26.5 years; age range, 20–42 years) volunteer with healthy knees (Group 2) were included in this study. The participant's data were collected over a period of 3 years from 2009 to 2012.

In this study following subjects were included:

(1) Patient's referred to AIMS Radiology department for Knee imaging, with or without patellar instability based on clinical assessment.

(2) Study would incorporate individuals of Indian ethnic origin.

The following subjects were excluded:

(1) Those patients who are sent with a history of trauma to the Knee joint.

(2)Foreign nationals, as the study is confined to come up with diagnostic criteria for Indians.

The MR imaging was performed in a 1.5-T imager (General Electric Medical Systems, Milwaukee, WI, USA). A dedicated knee coil was used. The knees were positioned in a minimal flexion (30 °). Axial and sagittal proton density fat-saturated spin-echo (repetition time millisecond/echo time millisecond, 3000/42 ms; field of view,160.160 mm, two signal acquired; matrix, 204·256; section thickness, 4.0 mm; intersection gap, 1 mm for axial and 0.5mm for sagittal sections) and coronal T1 fast spin-echo (repetition time millisecond/echo time millisecond, 640/16v ms; field of view,180.180 mm, two signal acquired; matrix, 204·256; section thickness, 4.0 mm; intersection gap, 0.5 mm sections) sequences were performed.

(1) Insall-Salvati index (2) Lareral patellar tilt (3) Patellar nose length (4) Morphology ratio (5) Patellar lateralization (6) Lateral Trochlear Inclination (7) Trochlear tubercle distance (8) Trochlear Depth (9) Trochlear articular facet asymmetry (TAFA) (10) Ventral trochlear prominence (VTP) and (11) Wiberg angle were quantitatively assessed on the MR images of knee.

All the quantitative parameters assessed in all participants were evaluated and compared for their association with patellar instability. For descriptive analysis, the quantitative parameters were evaluated by calculating the mean value and standard deviation. The categorical parameters consisted of absolute and relative frequencies. The quantitative parameters of both groups were compared by using the

Mann-Whitney U test with statistical significance at 5%. Hence, the relevant parameters which had significant differences between the groups were determined. And the most suitable threshold values were calculated by using the ROC curve for these parameters. The sensitivity, specificity, positive and negative predictive values, and the area under the ROC curve for all the calculated threshold values were determined. Statistical analyses were performed using commercially available software (SPSS 11.0).

Result

It was found that there was a significant difference between the groups with a P-value of <0.05 for Trochlear depth, patellar lateralization, Lateral trochlear inclination, Trochlear articular facet asymmetry, Trochlear tubercle distance, Lateral patellar tilt Insall-Salvati index, and ventral trochlear prominence in the decreasing order of their area under ROC curve respectively. Hence, the MRI diagnosis of patellar instability would depend upon these parameters, and the parameters like Wiberg angle, Patellar nose length, and morphology ratio do not play a significant role in diagnosis.

The value of measurement that had maximum sensitivity and specificity was derived and compared with the published values. And it was found that LTI, PL, TD, ISI, TTD, and TAFA had a significant difference in threshold values and other parameters like LPT and VTP did not show much difference. This indicates that the established values had poor sensitivity and specificity for diagnosing patellar instability in the Indian population.

It was also found that Patella Alta and trochlear depth showed the highest sensitivity (86%) followed by lateral trochlear inclination (80%). And Lateral patellar tilt had the highest specificity (100%) followed by patellar lateralization (95%).

Table 1: Parameter Specificity

Parameters	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Area under ROC	Derived cut off values
TD	87	98	86.7	98	0.932	4.5 mm
ISI	86	60	24.5	96.8	0.765	1.17 mm
LPT	73	91	52.4	95.7	0.833	11°
LTI	80	89	52.2	96.7	0.859	19.3°
PL	73	95	68.8	96	0.859	3.5 mm *
TTD	67	90	50	94.7	0.818	14.5 mm
TAFA	60	88	42.9	93.6	0.855	64.5 %
VTP	60	62	19.1	91.2	0.678	3.5 mm
PNL	66	72	6.5	73.7	0.648	
MR	60	23	28	92	0.648	
WA	53	44	11.7	85.5	0.515	

For this parameter specificity was given higher importance because the parameter may or may not be positive in a case but it should not be abnormal in a normal subject. The rest of all the parameters were evaluated with a balance between sensitivity and specificity

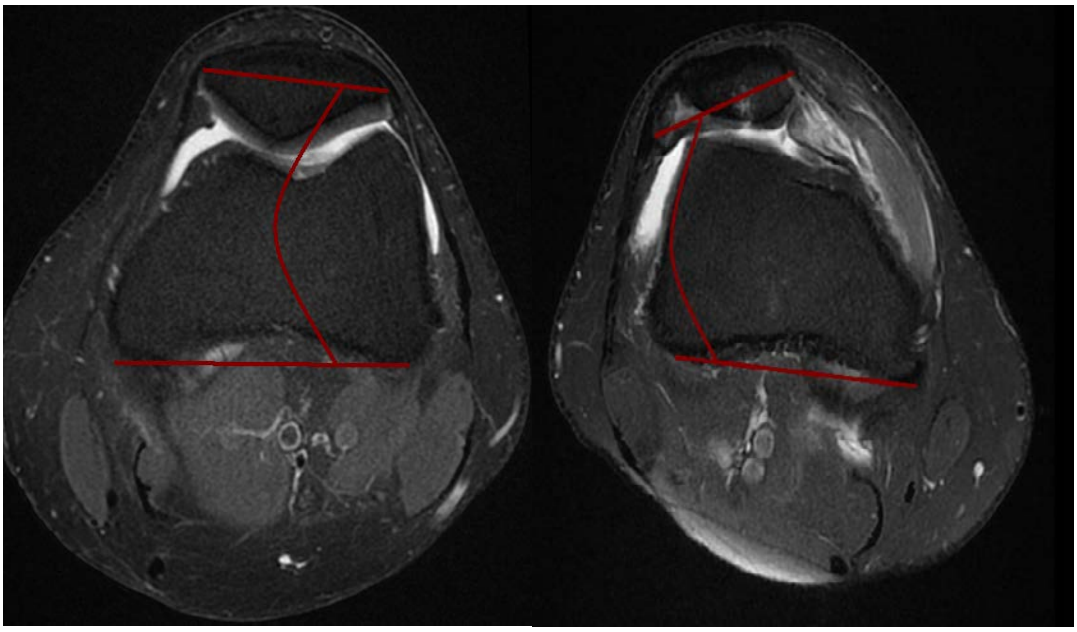

Figure 1: Lateral patellar tilt assessed on an axial PD weighted fat-saturated MR images shows a normal angle of 4° in a normal individual and an abnormal angle of 18° in a patient with bipartite patella, MPFL injury and history of recurrent patellar dislocation.

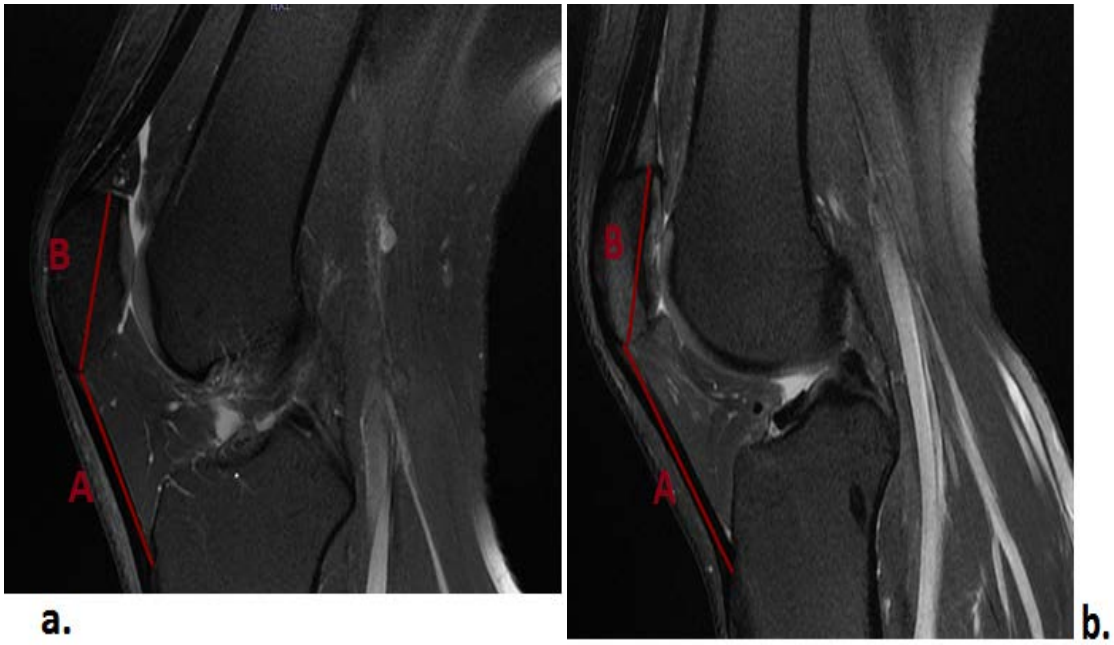

Figure 2: Patellar height ratio assessed on sagittal intermediate-weighted MR images. The length of the patellar tendon (line A) is measured posteriorly from the patellar apex to its attachment to the tibial tuberosity and is divided by the longest superoinferior diameter of the patella (line B) to obtain the patellar height ratio (PHR), as follows: PHR = A/B. A patellar height ratio of more than 1.3 indicates a high-riding patella (patella alta). (a) Image shows a knee with a patellar height ratio of 1, which is in the normal range. (b) Image shows a high-riding patella, with a patellar height ratio of 1.4.

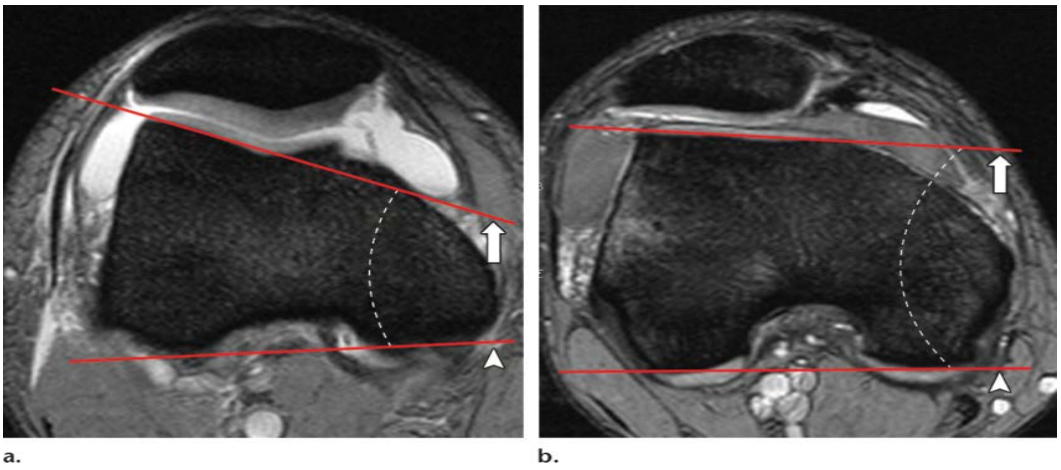

Figure 3: Lateral trochlear inclination assessed on axial fat-saturated T2-weighted MR images (11). A line (arrow) is drawn along the subchondral bone of the lateral trochlear facet, and a second line (arrowhead) is drawn along the posterior aspect of the femoral condyles. The angle between the two lines is the inclination angle (dashed line). An inclination angle of less than 11° indicates trochlear dysplasia. (a) Image shows a normal trochlea, with an inclination angle of 24°. (b) Image shows type B trochlear dysplasia, with an inclination angle of only 7°

Discussion

Patellar dislocation is characterized by the complete loss of contact between the patella from the trochlear groove of the femur. Over a period of time patellar instability can trigger debilitating pain, limitations in basic function, and long-term arthritis. The prevalence of acute patellar dislocation is 6–77 per 100,000 population [4,5]. It is attributed to the abnormal course of the patella during knee flexion. In these cases, imaging techniques play a major role, since they may demonstrate findings that could be related to abnormal tracking of the patella. MR imaging has been shown to be a highly sensitive cross-sectional imaging modality for detecting capsular, ligamentous, cartilaginous, and bone injuries associated with patellar dislocation [6]. Moreover, MR images can be used to assess anatomic variants that may contribute to chronic patellar instability [7].

This study included a total of 115 keens in 65 patients who attended the OPD of Amrita institute of medical science hospital, Kochi, Kerala, India. MR examinations were carried on 15 knees in 15 patients (4 male patients, 11 female patients; mean age, 16 years; age range, 10-42 years) suffering patellar instability (Group 1) and 100 knees in 50 patients (40 male patients, 10 female patients; mean age, 26.5 years; age range, 20–42 years) without anterior knee pain (Group 2) were included in this study. The participant's data were collected over a period of 3 years from 2017 to 2020

Statistical evaluation was done after tabulating 115 data using SPSS. Sensitivity, specificity, accuracy, and area of ROC curve calculated. Mann-Whitney U test was applied for all the parameters (Trochlear depth, Trochlear articular facet asymmetry, Lateral trochlear inclination, Trochlear Tubercle distance, Patellar nose length, morphology ratio, Wiberg angle, Insall-Salvati index, Lateral patellar tilt, patellar lateralization, and morphology ratio). It was found that there was a significant difference between the case and control with a P-value of <0.05 for Trochlear depth, patellar lateralization, Lateral trochlear inclination, Trochlear articular facet asymmetry, Trochlear tubercle distance, Lateral patellar tilt Insall-Salvati index, and ventral trochlear prominence in the decreasing order of their area under ROC curve

respectively. Hence, the MRI diagnosis of patellar instability would depend upon these parameters, and the parameters like Wiberg angle, Patellar nose length, and morphology ratio do not play a significant role in diagnosis.

The value of measurement that had maximum sensitivity and specificity was derived and compared with the published values. And it was found that LTI, PL, TD, ISI, TTD, and TAFA had a significant difference in threshold values and other parameters like LPT and VTP did not show much difference. This indicates that the established values had poor sensitivity and specificity for diagnosing patellar instability in an Indian population. It was also found that Patella Alta and trochlear depth showed the highest sensitivity (86%) followed by lateral trochlear inclination (80%). And Lateral patellar tilt had the highest specificity (100%) followed by patellar lateralization (95%).

A study conducted by H. Dejour, G. Walch et al[8] and Gerd Diederichs et al[9], showed that the sensitivity and specificity of ISI with cut off > 1.2 was 78 %and 67 % respectively. [7] The same cut-off (>1.2) in the Indian population had sensitivity and specificity of 47% and 83% respectively. The lower sensitivities in an Indian population with cut-off values of >1.2mm is probably because most of the participated patients had ISI values nearing 1.2mm. In this study population, the ISI value with the highest sensitivity (86%), specificity (60%) and, accuracy (63%) was 1.17. It states that even the smallest change in the value was significant.

In another study conducted by H.Dejour et al[8] and Gerd Diederichs et al[9], the sensitivity and specificity of LPT with cut-off> 11 degrees was 92 % and 63 % respectively. When the same cut-off (>11) was applied to the Indian population the sensitivity and specificity were 73% and 90%. The value with the highest sensitivity (73), specificity (100%), and accuracy (89%) in the Indian population was 11.3 degrees. There was no significant difference in the derived value and that followed internationally and both the values had similar sensitivity and specificity for the Indian population. The relative decrease in the sensitivity is probably because most of the patients had recent onset of dislocation and did not have quadriceps dysplasia. LPT represents a more dynamic process that has to be assessed in a kinematic fashion. In this study, we imaged in the static position of 30-degree flexion, which might not have been sufficient for a positive result. According to the previous study trochlear depth of < 3mm had a reported sensitivity, specificity, and accuracy of 100%, 96%, and 97% respectively. [3,7,4,5] When the cut-off value of <3mm was applied on the participated patients the sensitivity and specificity were 47% and 100% respectively. This was because in this study group more number of diseased had a borderline value when compared to the controls who had a significantly deeper trochlear groove.

Trochlear depth of < 4.5mm had the highest sensitivity (87%), specificity (98%), and accuracy of 97% in the Indian population. And It was similar to the study conducted by Joan. S Escala et.al [10] which had the highest sensitivity and specificity of 77% and 61% respectively for a Trochlear depth value of <4. In a study by Christian W.A Pfirrmann et al[11] and Mc NallyEG et al[12], TAFA of <40% had sensitivity, specificity, and accuracy of 100%, 96 %, and 97%.[9] This value of <40%, when applied to our study group, the sensitivity and specificity was 20% and 100% respectively. We also found that a TAFA of <64.5 % had the highest sensitivity, specificity, and accuracy of 60%, 88%, and 90% respectively for the Indian population. This states that most of the controls had a higher TAFA value when compared to those with an unstable patella and that by increasing the threshold we could increase the sensitivity. A minor decrease in

specificity could be ignored owing to a high sample size of controls in this study.

A study conducted by Christian W. A Pfirrmann et al[11] and Mc NallyEG et al[12], patellar lateralization of > 6mm had a sensitivity, specificity, and accuracy of 75%, 83%, and 79% respectively. [10] And the same cut-off of > 6 mm when applied in Indian population the sensitivity and specificity was 60% and 99% respectively. Patellar lateralization of > 3.5 mm had the maximum sensitivity (73%) specificity (95%) and accuracy (91%) in the Indian population. This indicates that even a small amount of patellar lateralization was of significance in this study group and that most of the controls had patellar lateralization of either 1 or nil. Therefore, a lower cut-off value would be more relevant in the Indian population to diagnose patellar instability. Another study by Gerd Diederichs et al[9] LTI < 11° had a sensitivity specificity and accuracy of 93%, 87%, and 90% respectively.In this study group the sensitivity and specificity for LPT of < 11 degree was 20% and 99% respectively. LTI angle of < 19.3 degrees had the maximum sensitivity (80%), specificity (89%), and accuracy (88%) in the Indian population. There is a significant difference between the LPT angle of previous studies and the derived value and that is probably because the controls in this study had a much higher LPT angle and that the participated patients with recurrent patellar instability required a higher cut-off angle to establish the diagnosis.

In a study by Mc NallyEG et al[12], trochlear tubercle distance of > 20 mm had sensitivity and specificity and accuracy of 49, 53 and 52 % respectively[10]. In an another study conducted by Mc NallyEG et al[12], the sensitivity and specificity of TD >20 was 56% and 94% respectively. In the Indian population, the sensitivity and specificity of TD >20 was 13% and 100% respectively. TD > 14.5 had the highest sensitivity and specificity and accuracy of 67%, 90%, and 87% respectively in this study. A significant rise in sensitivity explains that the diseased need not have a TTD of 20 to establish the diagnosis and that more number of diseased can be accurately diagnosed with a lower cut-off value of 14.5 in the Indian population. But this might lead to a slightly higher incidence of a false-positive result. Hence, most of the parameters relevant in the studies by Joan et al[10] and Nogah Shabshin, et al[13] and H.Dejour et al[8], G.Walch et al[9]. were relevant in the Indian population except for Wiberg angle, PNL, and morphology ratio which had a P-value of >0.05. We also derived an appropriate cut-off value for each relevant parameter (Trochlear depth, patellar lateralization, Lateral trochlear inclination, Trochlear articular facet asymmetry, Trochlear tubercle distance, and Insall-Salvati index) which had significantly higher sensitivity and specificity when compared to those values followed internationally. The only exception was for LPT and VTP which had similar low sensitivity and specificity for the derived range as was followed internationally [12,15]

Minimal reduction in specificity for all the above said parameters could be ignored owing to the disproportion in the sample size with 15 cases and 100 controls. International standards have poor sensitivity in the study population. And with our derived cut-off; we could diagnose more positive cases with a minimal rise in false-positive cases which can be ignored.

Conclusion:

Patellar dislocation is characterized by the complete loss of contact between the patella from the trochlear groove of the femur. The most common predisposing factors for patellar instability include trochlear dysplasia, patella Alta, and lateralization of the tibial tuberosity. Important secondary factors contributing to patellar instability are trauma-related tear of the medial patellofemoral ligament (MPFL) and ligamentous laxity (Ehlers-Danlos and

Marfan syndromes). Characterization and quantification of these anatomic anomalies will reveal the individual mechanism of patellar instability and help the orthopedic surgeon choose the optimal treatment. These anomalies can be diagnosed and characterized with MR imaging. This study demonstrated that Individual characterization of medial patellar stabilizers (MPFL and medial retinaculum), trochlear depth, and the assessment of patella Alta with any lateral displacement of its attachment in tibial tuberosity would help physicians in accurate planning of the concerned anatomical abnormality to get better treatment and surgical outcome in cases of Patellar instability.

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