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ORIGINAL ARTICLE

Correlations between intra and extraarticular factors measured by computed tomography in patients with recurrent patellar dislocation

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Abstract

Introduction: Lateral patellar dislocation (LPD) is a common injury of the knee, most frequent in young patients. It has a multifactorial etiology with several underlying risk factors. In most cases, patellar dislocation occurs on the lateral side, with the rupture of the medial patellofemoral ligament (MPFL), appearing in more than 80% of the cases. The tibial tuberosity-trochlear groove (TT-TG) distance of 20 mm or more in patients with lateral patellar dislocation is a gold standard for the surgical indication of tibial tubercle osteotomy (TTO).

Hypothesis: Our investigation aimed to establish whether there is a correlation between the TT-TG distance and other bony landmarks, like trochlear groove medialization, tibial tuberosity lateralization, and knee rotation angle, in the surgical algorithm for the patient with patellar dislocation.

Methods: We conducted a prospective study, analyzing and comparing data from two groups, 33 patients with a diagnosis of patellar dislocation, and a control group of 30 patients, with meniscal injury, but healthy contralateral limb. Using computed tomography, we measured the TT-TG distance, femoral anteversion, tibial torsion, knee rotation angle, tuberosity lateralization, and trochlear groove medialization of all the patients in our study. The measurements were conducted by two independent orthopedic surgeons in a randomized manner. Using an unpaired *t* test, we compared and analyzed each parameters value from the study and the control group.

Results: Comparing the two groups, we observed a significant difference for TT-TG distance, knee rotation angle and tibial tuberosity lateralization with higher values in the study group compared to the control group (CI 95% 6.44-9.72, CI 95% 8.64-10.39, CI 95% 3.77-5.46, respectively), with a p value < 0.0001 in all cases. Also, the TT-TG distance positively correlated with knee rotation angle (r=.97, p=0.01) and tibial tuberosity lateralization (r=.86, p=0.0001) in the study group.

Conclusions: The TT-TG distance measurement usually defines the lateralization of the tibial tuberosity; yet, in some cases, it can be caused by the trochlear groove medialization, or high rotation between the femur and tibia. Our study revealed that knee rotation and tuberosity lateralization were factors implicated in patellar dislocation and they should be taken into account when making the decision of tibial tubercle osteotomy.

Keywords: patellar dislocation, tibial tubercle osteotomy, tibial tuberosity-trochlear groove distance

Introduction

Patellar dislocation is a common and disabling knee pathology that most often leads to anterior knee pain in young adults and adolescents, especially women. According to recent studies, 69% of patellar dislocations occur between the ages of 10 and 19 years [**1**]. According to Stefancin et al., the recurrence rate in patients who received conservative treatment is 48% [**2**]. Although the etiology, diagnosis and management of recurrent patellar dislocation have been studied over the past fifteen years, there are still uncertainties regarding the influence of anatomical risk factors on the surgical treatment of the recurrent patellar dislocation. The etiology of patellar instability is multifactorial, including a wide variety of anatomical factors, of which the most important are intra-articular (involving the trochlea and the patella), such as trochlear dysplasia, increased distance between tibial tubercle (TT) and trochlear groove (TG), or a high riding patella (patella alta), or extra-articular (involving the anatomical orientation of the femur or tibia), such as increased femoral anteversion, tibial external rotational deformity, recurved and valgus knee [**3,4**]. Recurrent patellar dislocation can lead to persistent symptoms and long-term complications such us osteochondral fracture or patellofemoral arthritis, and consequently disturbances of knee anatomy and soft tissue integrity that create a predisposition to patellar instability. Despite the improvement in diagnosis and surgical techniques, the management of this pathology remains difficult and controversial, and a single treatment protocol that can be applied to all the patients is difficult to obtain, due to its particularities [**5**]. Therefore, it is necessary to know the functional anatomy and biomechanics of the knee joint, a detailed history and a complete clinical examination, in order to obtain an appropriate management plan.

In order to obtain a normal patellofemoral kinematics, surgical treatment of recurrent patellar dislocation is based on the anatomical disorder [**6**]. Over 100 procedures have been described in literature over the past fifteen years, leading to the conclusion that a single surgical procedure cannot be applied to all the patients [**7**]. Analyzing the cause of the anatomical disorder, distal or proximal surgical realignment techniques can be applied, single or combined, and are based on the recovery of the medial stability, involving the medial patellofemoral ligament reconstruction (MPFL) or lateral release in proximal procedures or tibial tubercle osteotomy in distal ones [**8,9**].

Tibial tubercle osteotomy (TTO) is a frequent surgical technique applied for correcting abnormal patellar tracking caused by a lateral force vector, described in literature as the main cause of the lateralization of the tibial tubercle and other rotational deformities [**10,11**]. The surgical indication for TTO has been established by a computed tomography study of Dejour et al., in 1994, at a tibial tubercle-trochlear groove (TT-TG) distance of 20 mm or more and it has been considered a standard surgery indication since then [**12**]. In his study, Goutallier et al. described the tibial tuberosity-trochlear groove (TT-TG) distance as an indication of lateralization of the tibial tuberosity [**13**]. However, studies have shown that the TT-TG distance may not be the only factor that contributes to the tuberosity lateralization, but in a certain degree the trochlear groove medialization or high rotation of the femur and the proximal tibia [**14,15**]. In a retrospective computed tomography study, Tensho et al. found that the TT-TG distance was more influenced by the degree of knee rotation compared to the tubercle misalignment in patients with patellar instability, therefore its use as an indicator for tibial tubercle transfer may not be as precise as thought [**5,16**].

Therefore, the aims of our study were (1) to identify other factors associated with high TT-TG distance in patients with recurrent patellar dislocation, (2) to establish their correlation with the TT-TG distance and (3) to determine an indication for surgical treatment of patellar dislocation based on these factors.

Materials and Methods

We prospectively identified 33 patients (34 knees; 24 left and 10 right-Group 1), with recurrent patellar dislocation (RPD), from January 2015 to January 2019, in the Department of Orthopaedics and Traumatology of University Emergency Hospital, Bucharest, Romania. The mean age at surgery for Group 1 was 27.06 years (+/ - 5.7 years), and 63.6% of the patients were females. The control group (Group 2) consisted of 30 knees of 30 patients with meniscal injury, but healthy contralateral limb, evaluated by CT scan, with an average age of 29.4 years (+/ - 6.7 years).

The inclusion criteria for patients in group 1 were a history of at least two episodes of patellar dislocation, one or more typical symptoms, at least one physical sign (dislocation of patella, injury of the medial stabilizers, fracture of medial patellar or lateral femoral condyle). The exclusion criteria were: (1) patients who underwent previous surgeries on the same knee, (2) patients who had other injuries of the knee (3) patients who underwent proximal realignment, (4) direct traumatic dislocation and (5) age younger than 18 years. All patients signed the informed consent and the study was approved by the Local Committee of Ethics.

All the patients were scanned with the CT scan in supine position, using a standard imaging technique, with knee in full or almost full extension, position maintained using straps fixed at the middle thigh and middle leg. The axial images were taken at the levels of femoral neck, patella and femoral condyles in supine position and TT-TG distance, trochlear groove medialization, tibial tuberosity lateralization, tibial torsion and knee rotation angle were assessed.

In order to determine the interobserver and interobserver reliability, two independent orthopedic surgeons reviewed the data and made the measurements. The measurements were taken two times by each investigator and a mean value was used in the end.

Tibial tubercle trochlear groove (TT-TG) distance measurement was made on the axial image from the most anterior point of the tibial tuberosity to the deepest point of trochlear groove (**Fig. 1**). Trochlear groove medialization (TGM) measurement was made from the deepest point of the groove to the medial perpendicular line and was presented as a percentage of the femoral width. Tibial tuberosity lateralization (TTL) was measured on the axial image of the proximal tibia where the tuberosity was in closest contact to the patellar tendon, at the most cephalic section and it was represented by the distance between the line of the most anterior part of the tuberosity perpendicular to the plateau of the tibial width and the medial perpendicular line (**Fig. 2**). Tibial torsion (TT) was measured as the angle of the tangent on posterior cruciate ligament and a tangent line through the bimalleolar axis. Knee rotation angle, as a relative rotation of the femur and tibia in relation to each other, was measured as the angle formed by the posterior cruciate ligament and the tangent on the posterior cruciate ligament (**Fig. 3**). Femoral anteversion (FA) was measured as the angle between an imaginary transverse line that passes medially to laterally through the knee joint and an imaginary transverse line through the center of the femoral head and neck. Positive degrees indicated femoral antetorsion while negative values meant femoral retrotorsion.

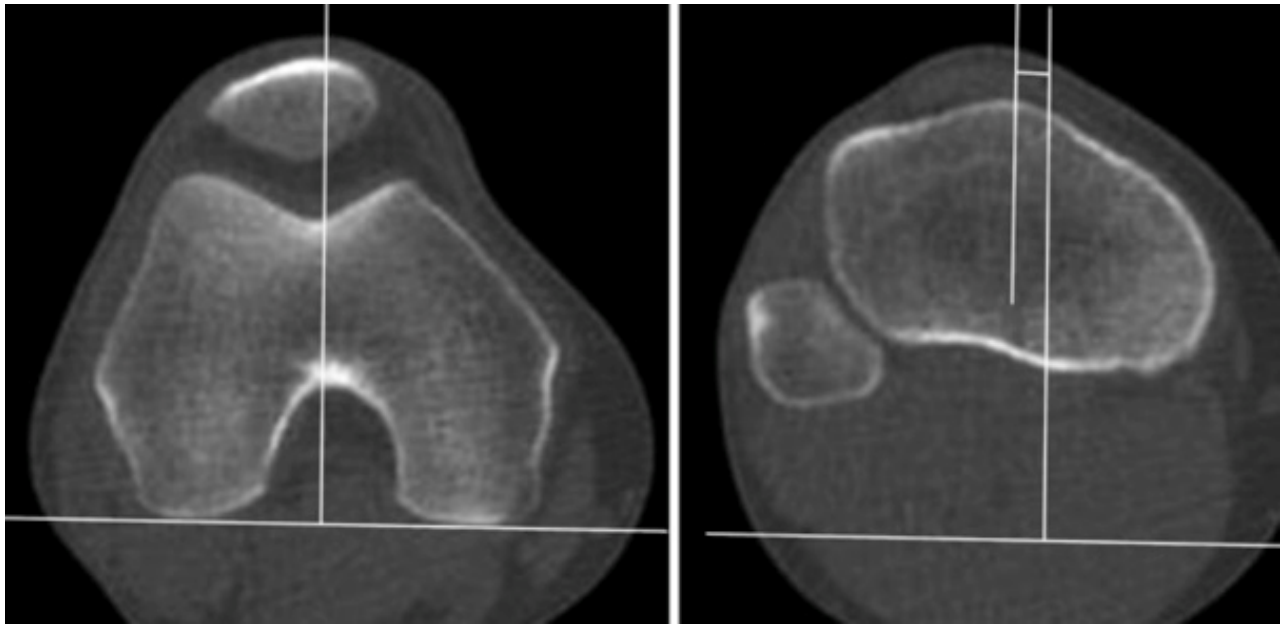

Fig. 1 Tibial tubercle trochlear groove (TT-TG) distance was measured on the axial image of the distal femur from the most anterior point of the tibial tuberosity and the deepest point of the trochlear groove

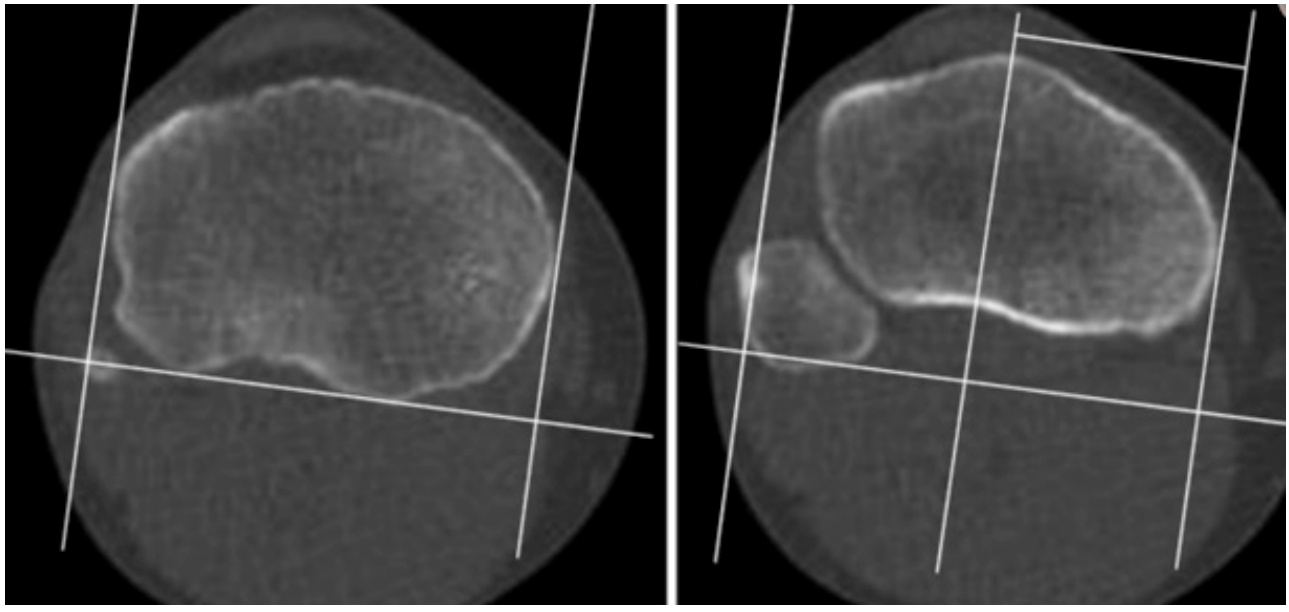

Fig. 2 Tibial tuberosity lateralization (TTL) was represented by the distance between the line of the most anterior part of the tuberosity perpendicular to the plateau of the tibial width and the medial perpendicular line

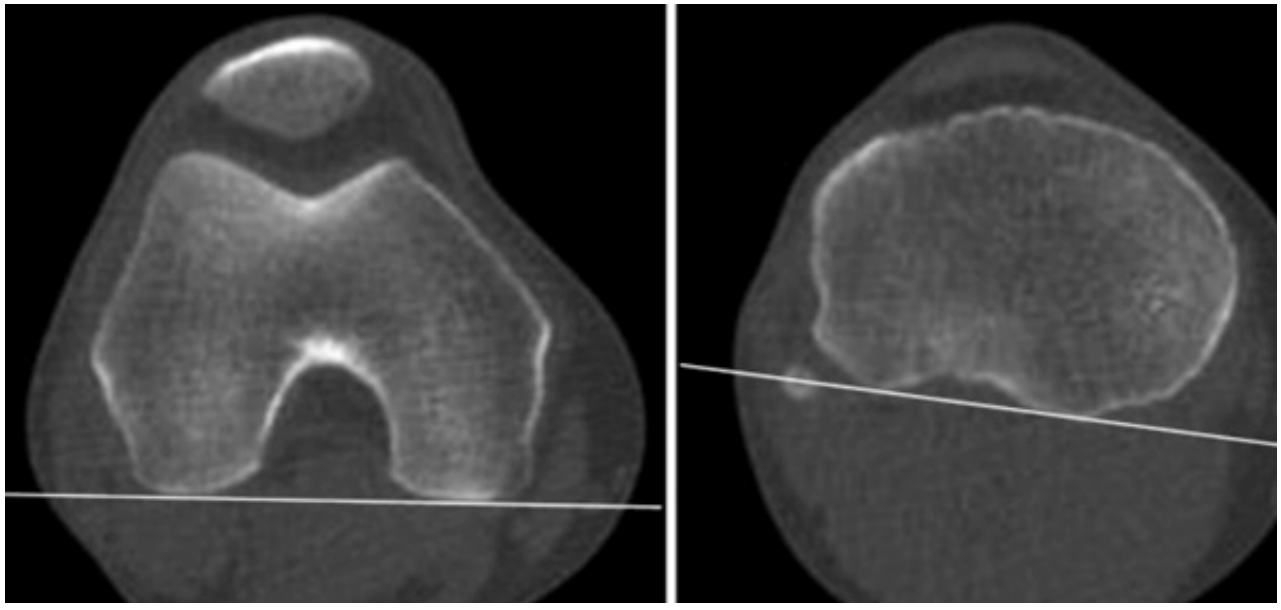

Fig. 3 Knee rotation angle was measured as the angle formed by the posterior cruciate ligament and the tangent on the posterior cruciate ligament

Comparative statistical analysis was performed using IBM SPSS Statistics v20, using independent t-test, one-way Anova test, Pearson correlation. Statistical significance was defined as a p value of < 0.05.

Results

Demographic assessment

The demographic data showed no statistically significant differences between the control and the RPD group regarding the sex, age at the surgery and the body mass index, as shown in **table 1**.

Table 1. Demographic characteristics in RPD group and control group

Parameter	RPD group	Control group	Statistic value	P value
Sex, male/ female, n	**12/ 21**	**15/ 15**	**-**	**0.282**
Age, y	**27.06 ± 5.7**	**29.4 ± 6.7**	**t=-1.482**	**0.14**
BMI, kg/ cm2	**25.6 ± 1.34**	**25.04 ± 1.27**	**t=1.940**	**0.057**

RPD = recurrent patellar dislocation, BMI = body mass index

Tomographic findings

On tomographic evaluation, the tibial tubercle trochlear groove (TT-TG) distance, the knee rotation angle and the tibial tuberosity lateralization (TTL) were significantly higher in the recurrent patellar dislocation group compared to the control group (CI 95% 6.44-9.72, CI 95% 8.64-10.39, CI 95% 3.77-5.46, respectively), with a p value < 0.0001 in all cases. Interestingly, the knee rotation angle had a mean value of -0.19 ± 0.62˚ in the control group, which means that these patients had the proximal tibia in slight internal rotation to the femur, while in group 1, the mean value of knee rotation angle was of 9.32 ± 2.31˚, meaning that the proximal tibia was in extreme rotation to the femur. Moreover, in the recurrent patellar dislocation group, the tibial tubercle lateralization was significantly higher compared to the control group (63.1% vs. 58.3%, p < 0.0001). No statistically significant differences were noticed between the two groups regarding femoral anteversion, tibial torsion or trochlear medialization (**Table 2**).

Furthermore, on Pearson correlation analysis, in group 1, TT-TG distance positively correlated with the knee rotation angle (r=.97, p=0.01), and the tuberosity lateralization (r=.86, p=0.0001), while in group 2, TT-TG distance positively correlated with the tuberosity lateralization (r=.64, p=0.0001). No significant correlations were found with the other analyzed parameters (**Table 3, Fig. 1,2**).

Table 2. Computed tomography measurements of TT, FA, TT-TG distance, knee rotation angle, TTL and TGM and comparisons in recurrent patellar dislocation and control group

Parameter	RPD group	Control Group	Statistic value	p value
All cases	33	30	-	-
TT, deg	30.6 ± 2.9	29.6 ± 2.6	t=1.352	0.181
FA, deg	18.4 ± 2.7	17.4 ± 1.5	t=1.737	0.087
TT-TG, mm	21.4 ± 3.5	13.3 ± 2.9	t=9.846	0.0001
Knee rotation angle, deg	9.3 ± 2.3	-.19 ± .62	t=21.813	0.0001
TTL, deg	63.1 ± 1.4	58.5 ± 1.9	t=10.901	0.0001
TGM, mm	51.4 ± .70	51.3 ± .70	t=0.399	0.07

TT = tibial torsion, FA = femoral anteversion, TT-TG = tibial tubercle trochlear groove, TTL = Tibial tuberosity lateralization, TGM = Trochlear groove medialization, RPD = recurrent patellar dislocation

Table 3. Pearson Correlation analysis between TT-TG distance and the other parameters in recurrent patellar dislocation and control group

Parameter	RPD group		Control group	
	Correlation coefficient	p value	Correlation coefficient	p value
TT, deg	r=-.301	0.089	r=-.054	0.778
FA, deg	r=-.319	0.07	r=.011	0.953
Knee rotation angle, deg	r=.970	0.0001	r=.426	0.019
TTL, deg	r=.862	0.0001	r=.649	0.0001
TGM, deg	r=.162	0.367	r=.115	0.546

TT = tibial torsion, FA = femoral anteversion, TT-TG = tibial tubercle trochlear groove, TTL = Tibial tuberosity lateralization, TGM = Trochlear groove medialization, RPD = recurrent patellar dislocation

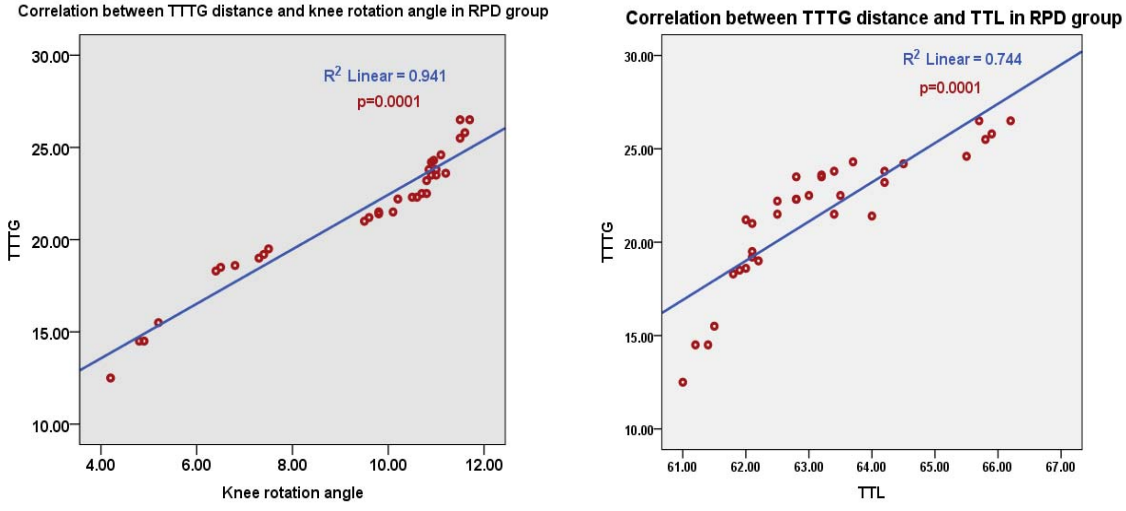

Fig. 4, 5 Scatter plots show the correlations between tibial tubercle trochlear groove (TT-TG) distance and knee rotation angle and tibial tuberosity lateralization (TTL) in recurrent patellar dislocation (RPD)

Discussion

Surgical management for non-traumatic patellar dislocation represents a challenge for any orthopaedic surgeon. The multifactorial etiology of patellofemoral instability has determined many authors to perform radiological and CT studies in order to identify the anatomical basis of the disease and formulate appropriate treatment algorithms [**16**]. But the various surgical techniques reviewed in literature and also the lack of a definite protocol make the treatment decision very difficult [**17**].

It is known from literature that values for the TT-TG distance over 20 mm recommend tibial osteotomy and medialization [**1,18**]. Many studies have shown good results using this only criterion but other disagreed because these results tend to deteriorate in time as Nakagawa et al. showed in their study [**19,20**]. The reason is not fully known at this moment, but our hypothesis is that the reason for a high TT-TG does not lie solely in the tubercle lateralization but also in the knee rotation angle, as the result of our study suggested. Moreover, increased lateralization of the tibial tuberosity can be evaluated throughout the measurement of the TT-TG distance. TT-TG value is independent of the patient's height and weight [**21**].

Our study showed that TT-TG distance, by comparison between the two groups, was the most specific and sensitive measurement for evaluating the risk of patellar dislocation.

Rotational malfunctions of the knee are a secondary cause of misalignment disorders of the extensor mechanism. We revealed in our study that values of tibial torsion and femoral anteversion were extremely similar compared to knee rotation angle values that were significantly different between the two groups. These findings are similar to those of Schueda et al. who also found the means of rotational parameters to be significantly different [**22**].

We concluded that this could represent an explanation of the fact that as a surgical procedure, tubercle osteotomy can have favorable results in some patients and no results in others. Patients who have a higher TT-TG value correlated with the tibial tuberosity lateralization, will probably have good outcomes with the tibial osteotomy [**23**]. In contrast, patients who have high knee rotation angle values that cause the rise of TT-TG distance are probably not better just with the tubercle osteotomy and could benefit from derotational osteotomies [**23,24**]. Also, studies revealed that the knee rotation angle may be changed by either femoral anteversion or tibial torsion [**5,25**]. But our data revealed no correlation between these two markers and the rotation angle in the group with dislocated patella, and this could lead to the conclusion that there might be another possible cause for the dislocation. Moreover, in these cases of increased knee rotation angle, derotational osteotomy might not be an adequate surgical technique, since the proximal tibia is not the source of malfunction.

Our suggestion is that more studies are needed in order to find the real cause of malrotation and apply the correct surgical method to resolve it. Elaborating a correct treatment algorithm for patients with recurrent patellar dislocation requires a good knowledge of all the above-mentioned measurements. An increased TT-TG distance usually dictates a distal-based procedure requiring the osteotomy of tuberosity and the medialization of it, but a high value in the measurement of knee rotation or femoral anteversion dictates the need of a rotational osteotomy.

Our investigation has some limitations. Firstly, the number of patients included in the study is small and this does not allow the extension of the results to the entire population. The second one is that we did not establish the precise anatomical localization of the rotational abnormality even if we noticed

that the femur and tibia had normal rotations. It is most likely that the knee rotation could represent a cause for the disrupted patellofemoral alignment. We believe that with efforts from the scientific community, more reliable and correlated data could be obtained. Nevertheless, we are confident that this represents a first step for a better comprehension of the aetiology and management of recurrent patellar dislocation.

Conclusions

Tubercle-trochlear groove distance represents a good indicator of the exact position of the tibial tubercle in patients confronted with patellar instability. Tibial tuberosity lateralization and knee rotation angle are also parameters present in patients with recurrent patellar dislocation, correlated with TT-TG distance. When choosing the surgical treatment represented by tibial tubercle osteotomy in patients with nontraumatic patellar dislocation, apart from the TT-TG distance, it is very important to also take into consideration the impact of the tubercle lateralization and knee rotation angle.

Conflict of Interest statements

Authors state no conflict of interest.

Informed Consent and Human and Animal Rights statements

Informed consent has been obtained from all individuals included in this study.

Authorization for the use of human subjects

Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies, is in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent commitee.

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