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Correlation between Patellar Tilt Angle, Femoral Anteversion and Tibial Tubercle Trochlear Groove Distance Measured by Computer Tomography in Patients with non-Traumatic Recurrent Patellar Dislocation

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ABSTRACT

Introduction: *Recurrent patellofemoral dislocation (RPD) is a disabling condition with a variety of anatomical risk factors. Its management remains difficult and controversial. Patients with RPD are known to have increased femoral anteversion (FA) and tibial tubercle trochlear groove (TT-TG) distance, but their effect on the patellar tilt angle (PTA) is less studied.*

Aims: *The aims of this study are to compare PTA, TT-TG distance and FA between RPD patients and healthy controls and to establish a relation between these parameters and the type of surgery indicated for this pathology.*

Materials and methods: *A total of 63 knees (57.1% females, 28.1±6.2 years), of which 33 from subjects with RPD and 30 from healthy controls, were assessed by computed tomography (CT) scan under supine position, with the measurement of TT-TG distance, FA and PTA.*

Results: *The values of PTA, FA and TT-TG distance were significantly higher in the RPD group compared to the control group (CI 95% 9.52-11.64, CI 95% 5.87-11.8, CI 95% 6.44-9.72, respectively, with p value <0.0001 in all cases). In the RPD group, PTA significantly correlated to the FA (r=.53, p=0.001) and TT-TG (r=.39, p=0.02), while TT-TG correlated to FA (r=.53, p=0.001) too. Further analysis in the RPD group showed a significant correlation of PTA, FA and TT-TG (r=.96, r=.89, respectively, p=0.0001) when FA >25 degrees, but no significant correlation between TT-TG and FA or PTA when FA<25 degrees.*

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Moreover, higher values of PTA and FA positively correlated with TT-TG distance (r=.44, r=.74, r=.20, p=0.03) when TT-TG was >20 mm, but no correlations were found between TT-TG and FA on less than 20 mm.

Conclusions: *In patients with RPD, FA, TT-TG and PTA have significantly higher values than controls. Higher PTA, TT-TG and FA are associated with an anteversion angle greater than 25 degrees and a TT-TG distance more than 20 mm, which might indicate a derotational femoral osteotomy to these patients in order to correct this pathology.*

Keywords: femoral anteversion, patellar tilt angle, patellar dislocation, osteotomy.

INTRODUCTION

Recurrent patellofemoral dislocation (RPD) is a disabling condition related to a variety of anatomical dysfunctions such us trochlear dysplasia, patella alta, increased tibial tubercle trochlear groove (TT-TG) distance greater than 20 mm (1) as well as soft tissue abnormalities that include ligamentous laxity or an insufficient function of the medial patellofemoral ligament (2). Secondary factors that alter the stability of the patellofemoral joint include exceeding femoral anteversion, tibial external rotational deformity, and genu valgum knee and genu recurvatum knee (3). Studies show that patellar instability is an important factor that affects athletic ability at a young age, 69% of dislocations being found between the ages of 10 to 19 years (4). Although the etiology, diagnosis and surgical treatment of RPD made great progression in the past years, there is still uncertainty regarding the anatomical risk factors that influence the treatment for RPD (4). In the past decade, more than 100 procedures have been described in the literature for the management of this condition, but generally no single procedure was suitable in all cases due to the combination of static and dynamic stabilizers of the knee joint. Therefore, it is difficult to find a single treatment protocol to be used for all patients (5).

Femoral version is defined as the angular difference between the axis of the femoral neck and the transcondylar axis of the knee (6, 7). The mean value of the physiological femoral torsion varies from 7 to 24 degrees of internal torsion, depending on the technique used by practicians (2). More and more, the influence of femoral torsion on patellofemoral pressures have been studied and it is known that excessive femoral torsion, also known as increased femoral anteversion (FA), can lead to different clinical presentations, which include anterior knee pain, patellofemoral instability or an internally rotated gait. Recent studies have also proved that increased FA is a risk factor for patellofemoral instability and can result in pathological patellofemoral contact pressure, and some authors have proposed performing derotational osteotomy in patients with internal femoral torsion more than 25 degrees and recurrent patellar dislocation (2, 6, 8). In other studies, a combined procedure of correction of FA and reconstruction of the MPFL was proposed in patients with rotational abnormalities as a primary stabilization procedure (9). However, there are few studies that focused on the effect of FA on the patellar tilt and the results until now are controversial (10, 11). There are a few parameters used to quantify patellar rotation and mediolateral displacement of the patella relative to the femur, and the patellar tilt angle is one of these parameters (12). It has been proved that excessive stress on the lateral retinaculum can lead to increased lateral patellar tilt, abnormal contact of the lateral surface of patella against trochlea and pathological patellar tracking (10). Patellar tracking is defined as the movement of the patella relative to the femoral groove during the knee flexion and extension. Its mechanism is multifactorial and involves anatomical and morphological abnormalities of the femoral trochlea and parapatellar soft tissue (14). It has been suggested a value more than 20 degrees for lateral patellar tilt as a threshold established on CT images with the knee in extension without quadriceps contraction. After this value, a lateral retinacular release may be indicated to correct the lateral inclination (10, 13, 15). Computed tomography scan can provide a three dimensional view of the patellofemoral joint, at different degrees of knee flexion or in dynamic examination and it is proved that CT scan has more accuracy and sen-

sibility in detecting abnormal tracking, tilt or subluxation by measuring FA, lateralization of the tibial tubercle or the lower limb alignment (1, 16, 17).

In the same time, recent studies have shown that increased lateral patellar tilt was rather a consequence of an increased TT-TG distance, patella alta, trochlear dysplasia, insufficient MPFL and various flexion angles of the femorotibial compartments than an independent risk factor of patellofemoral instability (13, 18, 19). However, it is less clear whether there is a relationship between femoral anteversion, patellar tilt and TT-TG distance in patients with RPD.

The aims of our study are to compare the patellar tilt angle, tibial tubercle trochlear groove distance and FA between patients with RPD and healthy controls and to establish a relation between these parameters and the type of surgery indicated for this pathology. ❑

MATERIALS AND METHODS

We prospectively identified 33 patients (34 knees; 24 left and 10 right-group 1) with RPD, from January 2015 to December 2018, in the Department of Orthopedics and Traumatology, Emergency University Hospital of Bucharest, Romania. The mean age at surgery for group 1 was 27.06 years (+/- 5.7 years), with 63.6% of patients being females. The control group (group 2) consisted of 30 knees from 30 patients with meniscal injury but healthy contralateral limb scanned with CT, 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, and 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 patients who underwent previous surgeries on the same knee, those with other previous injuries of the knee, patients who underwent proximal realignment, direct traumatic dislocation, and age younger than 18 years. All patients signed the informed consent.

All subjects underwent a CT scan under 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 the supine position and TT-TG distance, patellar tilt angle and FA were assessed. In order to determine the interobserver and intraobserver reliability of measurements, two independent orthopedic surgeons reviewed all data. Measurements were repeated three times by each observer and a mean value was used in the end.

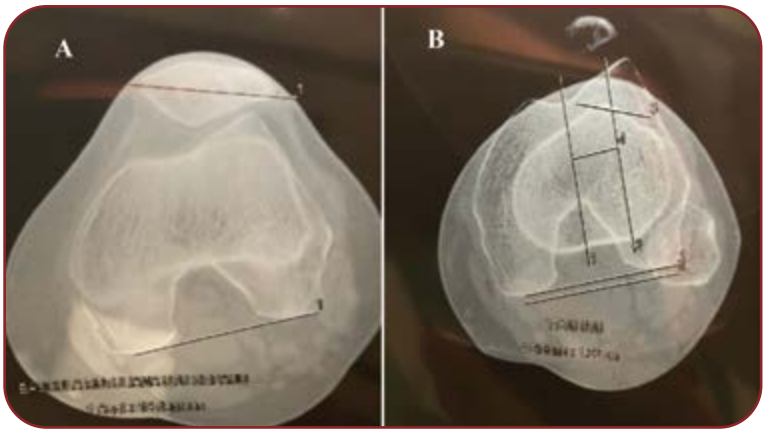


FIGURE 1. A) Measurement of the patellar tilt angle (PTA); B) Measurement of the tibial tubercle trochlear groove (TT-TG) distance

Femoral anteversion was measured as the angle between an imaginary transverse line passing medially to laterally through the knee joint and an imaginary transverse line through the center of the femoral head and neck. Positive degrees indicated FA, while negative values meant femoral retrotorsion. The patellar tilt angle (PTA) was measured as the angle between the patella and the posterior femoral condyles (Figure 1A). Larger values indicated increased external rotation of the patella relative to the femur. 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 trochlear groove (Figure 1B).

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 sex, age at surgery and body mass index, as shown in Table 1. In the RPD group, 63% of patients had a first episode of

TABLE 1. Demographic characteristics in the RPD and control groups

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/cm^2	25.6±1.34	25.04±1.27	t=1.940	0.057

RPD=recurrent patellar dislocation, BMI=body mass index

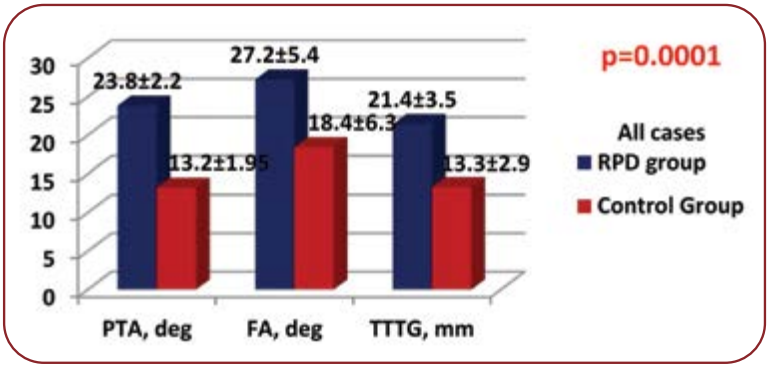


FIGURE 2. Mean values of patellar tilt angle (PTA), femoral anteversion (FA) and tibial tubercle trochlear groove (TTTG) in all cases. RPD=recurrent patellar dislocation

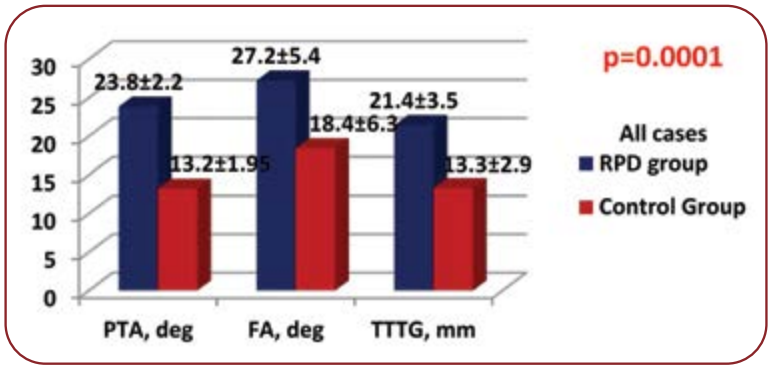


FIGURE 3. Mean values of patellar tilt angle (PTA), femoral anteversion (FA) and tibial tubercle trochlear groove (TTTG) in cases with FA>25 degrees. RPD=recurrent patellar dislocation

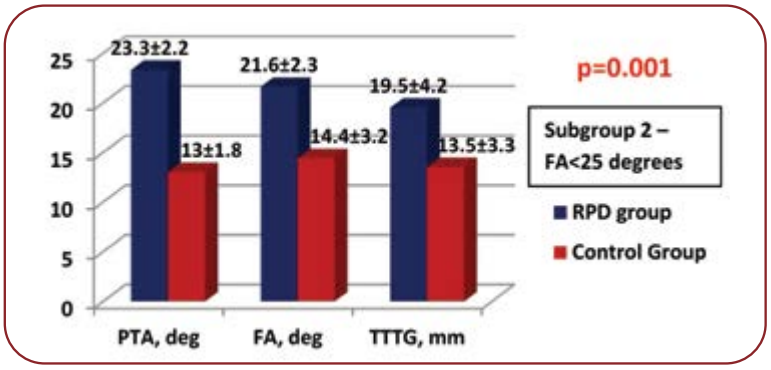


FIGURE 4. Mean values of patellar tilt angle (PTA), femoral anteversion (FA) and tibial tubercle trochlear groove (TTTG) in cases with FA<25 degrees. RPD=recurrent patellar dislocation

dislocation between 19 and 20 years old, while 37% of patients between 18 and 19 years old.

Tomographic findings

On tomographic evaluation, PTA, FA and TTTG distance were significantly higher in the RPD group than the control group (CI 95% 9.52-11.64, CI 95% 5.87-11.8, CI 95% 6.44-9.72, respectively, with p value <0.0001 in all cases.

In a further analysis, considering cut off values of 25 degrees for FA and 20 mm for TTTG, recommended for femoral osteotomy in the literature, we found that 19 cases with FA >25 degrees and 23 cases with TTTG >20 mm in the RPD group, and 10 cases with FA>25 degrees and only two patients with TTTG >20 mm in the control group.

Regarding the subgroup analysis, the mean values for PTA, FA and TTTG were significantly higher in the RDG group than the control group, in both FA >25 or <25 degrees subgroups, as shown in Figures 2-4 and Table 2. No significant difference was found in cases with TTTG >20 mm regarding the mean value of TTTG in RPD *vs* controls.

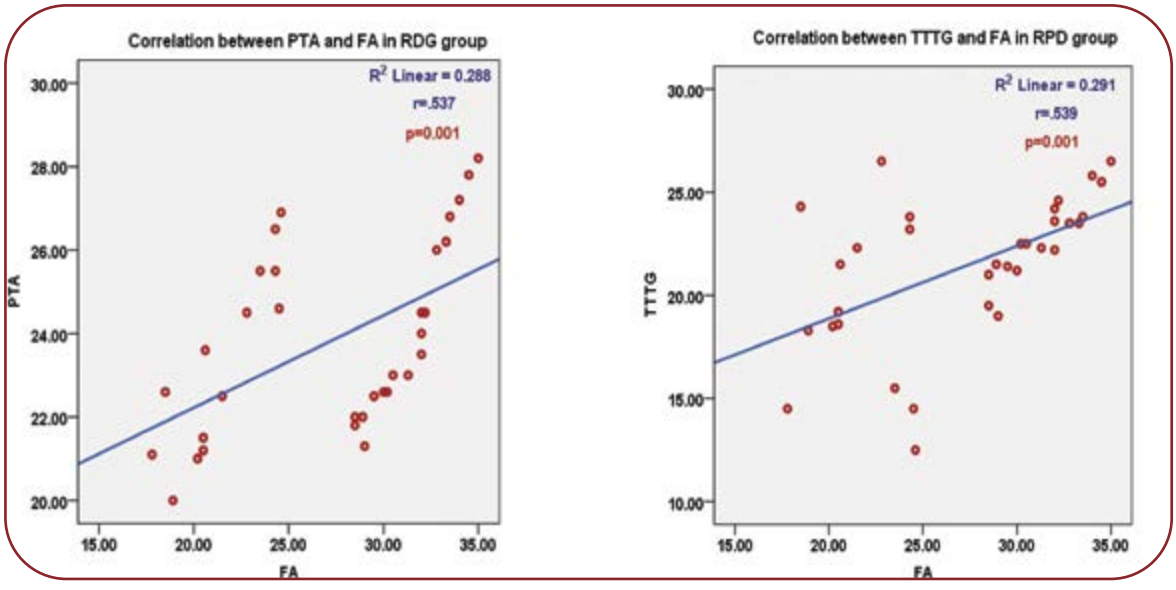
Correlations analysis

In the RPD group, we found a significant positive correlation between PTA and FA (r=.53, p=0.001), PTA and TTTG (r=.39, p=0.02), as well as TTTG distance and FA (r=.53, p=0.001), while in the control group no significant correlation was noted (Figures 5-6). Furthermore, in the subgroup analysis with FA>25 degrees, PTA positively correlated with FA and TTTG distance (r=.96, r=.89, respectively, p=0.0001), and TTTG correlated also with FA (r=.91, p=0.0001). When FA was less than 25 degrees, PTA significantly correlated with FA (r=.88, p=0.0001), but no significant correlation was found between TT-TG and FA or PTA, in the RPD group. Moreover, we analyzed the relationship between the

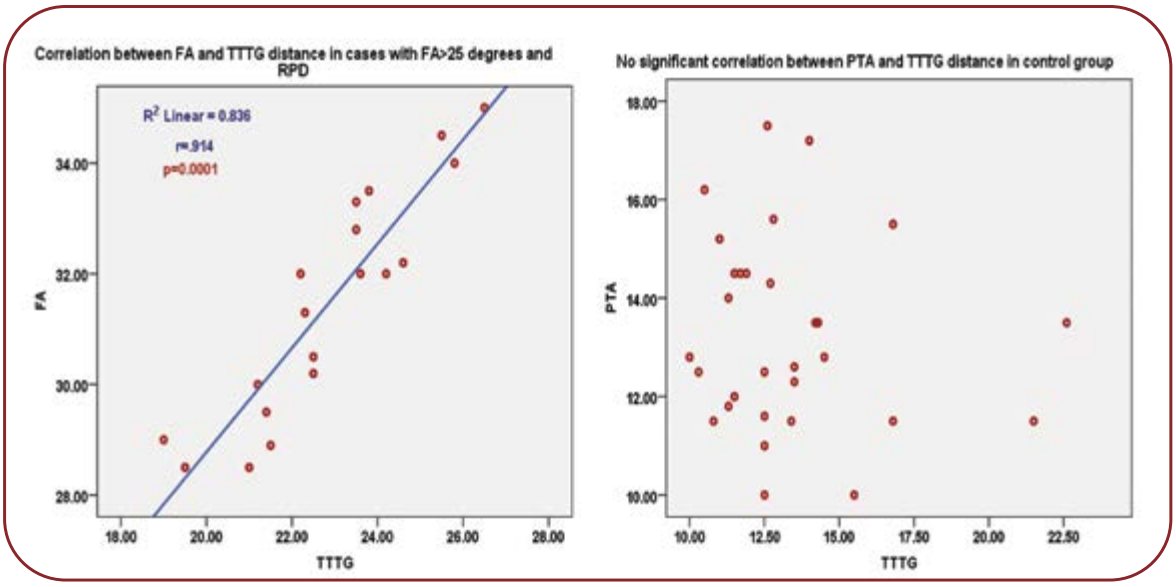
Parameter	RPD group	Control group	Statistic value	P value
All cases	33	30	-	-
PTA, deg	23.8±2.2	13.2±1.95	t=19.9	0.0001
FA, deg	27.2±5.4	18.4±6.3	t=5.96	0.0001
TTTG, mm	21.4±3.5	13.3±2.9	t=9.84	0.0001
Subgroup 1 (FA>25 deg)	19	10	-	-
PTA, deg	24.1±2.2	13.6±2.2	t=12.119	0.001
FA, deg	31.4±2.07	26.4±0.74	t=7.283	0.001
TTTG, mm	22.8±2.01	12.8±1.9	t=12.870	0.001
Subgroup 2 (FA<25 deg)	14	20	-	-
PTA, deg	23.3±2.2	13.0±1.8	t=14.790	0.001
FA, deg	21.6±2.3	14.4±3.2	t=7.112	0.001
TTTG, mm	19.5±4.2	13.5±3.3	t=4.554	0.001
Subgroup 3 (TTTG >20 mm)	23	2	-	-
PTA, deg	24.4±1.9	12.5±1.4	t=8.310	0.001
FA, deg	29.2±4.8	14.9±4.8	t=4.034	0.000
TTTG, mm	23.3±1.6	22±0.7	t=1.092	0.286
Subgroup 4 (TTTG <20 mm)	10	28	-	-
PTA, deg	22.4±2.3	13.3±1.9	t=11.998	0.001
FA, deg	22.8±3.8	18.6±6.4	t=1.889	0.06
TTTG, mm	17±2.5	12.7±1.7	t=5.840	0.001

PTA=patellar tilt angle, FA=femoral anteversion, TTTG=tibial tubercle trochlear groove, RPD=recurrent patellar dislocation

TABLE 2. Computed tomography measurements of PTA, FA and TTTG distance and subgroup analysis for cases with FA more or less than 25 degrees and TTTG more or less than 20 mm, respectively



FIGURES 5 and 6. Scatter plots show the correlations between patellar tilt angle (PTA), femoral anteversion (FA) and tibial tubercle trochlear groove (TTTG) distance in the RPD group



FIGURES 7 and 8. Scatter plots show the correlations between femoral anteversion (FA) and tibial tubercle trochlear groove (TTTG) distance in the RPD group with FA >25 degrees (left) and patellar tilt angle (PTA) and TTTG in the control group

three parameters in cases of TTTG >20 mm, and we found that higher values of PTA and FA positively correlated with TTTG distance (r=.44, r=.74, r=.20, p=0.03) in the RPD group. In cases of TTTG <20 mm, PTA correlated with TTTG distance (r=-.76, p=0.009), but no linear correlations were found between the other parameters. No significant correlations were found in the control group (Figures 7-8). ❑

DISCUSSIONS

Some published studies reported increased femoral anteversion angle in patients with femuropatellar instability. Thus, Dejour et al found a value of 15.6 ±9.0 degrees for the RPD group compared to 10.8±8.7 degrees in the control group, or Takai et al reported a value of 30.1±13.9 degrees in the RPD group compared to 21.7±11.6 degrees in the control group (10, 21, 22); also, a cut off of 25 degrees for the indication for femoral osteotomy has been established (20, 23). However, the treatment for non-traumatic patellar dislocation remains a challenge for surgeons, due to its multifactorial character as well as to the difficulty of determining the anatomically anomaly that is responsible for the malfunctioning of the patellofemoral kinematics (5, 24).

Our study also showed an increased PTA in patients with RPD compared to controls and a positive statistically significant correlation between the PTA and FA in all subjects as well as in patients with FA more than 25 degrees. Another important finding was that a higher TT-TG distance was found in patients with RPD, this parameter significantly correlating with both FA and PTA in all patients and also in patients with TT-TG distance more than 20 mm and RPD. When either FA was less than 25 degrees or TT-TG distance less than 20 mm, no significant correlations were found between the FA and TT-TG distance. Biomechanical results in the literature showed that the medial patellofemoral ligament reconstruction as an isolated therapy might be useful only for 10 degrees increased internal torsion, while beyond this value a lateralizing force vector remained that needed an additional femoral derotational osteotomy (10, 25). Therefore, the decision of performing derotational femoral osteotomy in patients with RPD should be taking into consideration not only the value of femoral anteversion angle but also other factors such as severity of patellar maltracking or other anatomical deformities.

An adequate treatment algorithm can be elaborated only by fully understanding all of the above described parameters. In case of a high patellar tilt, usually there is an abnormality in the quadriceps mechanism and consequently, the flexion of the knee cannot be fully restored despite of centering the patella over the trochlea. Therefore, the solution could be represented by the quadricepsplasty. Moreover, the TT-TG distance with a higher value indicates a distal procedure, represented by osteotomy of the tibial tuberosity with its medialization, while femoral anteversion requires a rotational osteotomy.

The present study has several limitations. One of them is the relatively small number of participants. Another would be that the patellar motion was measured only by patellar tilt, and it is commonly evaluated by patellar shift also, and finally there are other factors that can contribute to the recurrent dislocation of the patella that were not evaluated in the study such us soft tissue abnormalities or recurved or valgus knee. ❑

CONCLUSIONS

The present study showed that in patients with RPD, significantly higher FA, PTA and TT-TG distance were found compared to normal subjects.

Our study demonstrates the relationship between PTA, FA and TT-TG distance in patients with RPD and therefore, it emphasizes the fact that medial patellofemoral ligament reconstruction is a primary surgical option to correct patellar tilt when the FA and TT-TG are less than 25 degrees, so an additional femoral osteotomy might be indicated when FA and TT-TG are more than 25 degrees for the patellofemoral instability. ❑

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