Original Article
Computed tomography-based pathogenic investigation of patellar dislocation

Pengkai Cao[1], Yingzhen Niu[1], Fei Wang[1], Xintong Luo[2], Yao Li[1], Jiangfeng Lu[1], Gang Ji[1], Xu Yang[3]

[1]Third Hospital of Hebei Medical University, Hebei, China; [2]Second Hospital of Hebei Medical University, Hebei, China; [3]Hospital for Special Surgery, New York, USA

Abstract: Purpose: To compare various values in computed tomography (CT) scanning between patella dislocation patients and health controls, to define the difference between the two groups, and to determine the rate of patellofemoral anatomical deformities in patients, providing relevant evidence for the appropriate treatment. Method: 100 health controls and 100 patients with patella dislocation from 2005 to 2014 were retrospectively analyzed through CT scanning. 6 values, including lateral patellofemoral angle, patella inclination angle, congruence angle, sulcus angle, trochlear groove depth, and tibial tuberosity-trochlear groove distance, were measured to identify the differences between controls and patients. Result: All of the six values were found to be significantly different between the 2 groups (P<0.05), lateral patellofemoral angle (-12.73±17.77 vs. 7.82±5.34), patella inclination angle (22.93±11.34 vs. 8.67±3.56), congruence angle (40.24±26.24 vs. 5.25±20.68), sulcus angle (155.85±11.39 vs. 140.22±5.49), trochlear groove depth, and TT-TG (19.84±6.27 vs. 14.12±4.00). And there were 88.75% patients with trochlear dysplasia, 52.04% patients' TT-TG distance was greater than or equal to 20 mm. Conclusion: Majority of patella dislocation patients were affected by patellofemoral anatomical deformities, so for patients, especially for children and young adolescent patients, conservative treatment could not remove the causation of dislocation and prevent redislocation obviously, early detection and diagnosis should to be advocated, and more aggressive etiotropic treatments based on patients' pathogenetic condition should be performed to prevent redislocation and sequelae.

Keywords: Patellar dislocation, computed tomography, measurement, treatment

Introduction

Patellar dislocation is a common patellofemoral injury at sports medicine clinics, most frequently occurring in young and active patients with a slight female majority [1, 2]. And it may result in multifactorial causes including trochlear dysplasia, abnormal extensor mechanism alignment, patella alta, hypermobility syndrome, a tight lateral retinaculum, hypoplasia of the vastus medialis obliquus (VMO) and abnormal lower extremity biomechanics such as excessive femoral anteversion and tibial external rotation [1-5]. The incidence of primary patella dislocation was approximately 6 per 100,000 [6], in the 10 to 17-year-old age group, it climbed to 29 per 100,000 [2], and the corresponding figures in female were 104 per 100,000 persons per year [7].

Generally primary patella dislocation patients have been traditionally treated conservatively as those without displaced associated patellar or lateral femoral condylar osteochondral fracture [2, 3, 7-9]. The outcome of conservative treatment, however, resulted unsatisfactory [10], the redislocation rate of acute patella dislocation patients who undertaken non-operative treatment ranked 15% to 44% [11], and more than half of those patients experience recurrent patellar dislocation and subluxation [12]. So some authors have advocated operative management should be performed, and some related literatures have also suggested that the long-term outcomes of operative treatment were better than non-operative treatment [6, 13-15]. Proper treatment makes difference in minimizing sequelae like recurrent dislocation, painful subluxation, and osteoarthritis [16]. According to related research, patellar dislocation or subluxation may result in trochlear dysplasia in the process of bone development; what's more, early reduction could reduce the
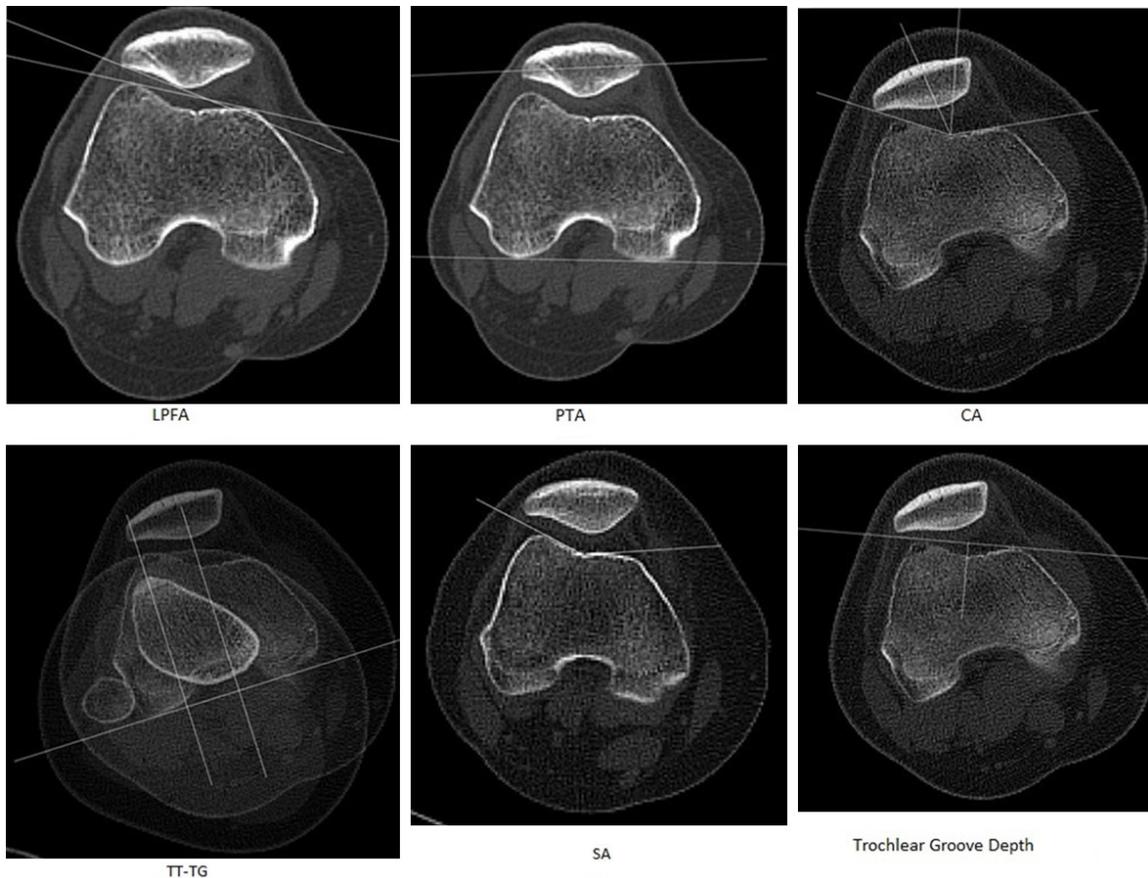
Figure 1. Picture showed measurement of 6 values.

incidence of trochlear dysplasia [17]. While it mainly affects adolescents and young adults who are in rapid process of bone development, so proper treatment is of great importance. The main purpose of this investigation is to analyze the CT-based measurements of patellar dislocation patients, to determine its pathogenic features, to provide a basis for the selection of treatments.

Materials and method

We retrospectively analyzed the patients with patellar dislocation in Third Hospital of Hebei Medical University from 2005 to 2014. Patient selection was based on the following inclusion criteria: 1. Patients with clinical diagnosed had a history of recurrent episodes of pain in the knee and often had swelling and giving-way etc, which lasted more than a year; 2. Physical findings, like a lateral position of the patella, passive subluxation of the patella, a positive apprehension sign in response to a lateral thrust to the patella etc, were objective; 3. There were or

not radiologic evidence that confirm the dislocation or subluxation, including X-ray, CT, MRI etc. 4. Without a history of knee surgery, trauma or tumor; 5. Without periarticular scar tissues which may impact patellar location. 100 patients were selected according to above criteria, containing 34 males and 66 females.

100 volunteers, comprising of 49 males and 51 females, were selected without symptoms such as pain, swelling, dislocation etc, without joint hypermobility syndrome and joint hyperextension, without a history of knee surgery or trauma.

CT measurement

All subjects were examined with axial CT on bilaterally knees at 0° of flexion in supine position. The CT images were analyzed through Adobe Illustrator CS5, and 6 values (**Figure 1**), including lateral patellofemoral angle (LPFA), patella inclination angle, congruence angle (CA), sulcus angle (SA), trochlear groove depth,

Table 1. Comparison of patients and controls' measurements

	LFPA	PIA	SA	CA	Trochlear Groove Depth	TT-TG
Patients	-12.73±17.77	22.93±11.34	155.85±11.39	40.24±26.24	2.82±1.26	19.84±6.27
Controls	7.82±5.34	8.67±3.56	140.22±5.49	5.25±20.68	5.66±1.21	14.12±4.00
P Value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 2. Abnormal rate of 6 values

Abnormal Rate	LFPA	PIA	SA	CA	Trochlear Groove Depth	TT-TG
Patients	74.75%	74.24%	88.75%	91.92%	81.31%	52.04%
Controls	6.50%	9.00%	14.50%	52.50%	9.00%	7.00%

and tibialtuberosity-trochlear groove (TT-TG) distance, were measured both in patient and control group.

Statistical analysis

Data was analyzed through SPSS 22.0 software. Significance was defined a *P* value of <.05.

Results

All of measurements were expressed as mean ± SD. For the limitation in CT imaging quality, 2 controls' and 1 patient's TT-TG distance were unobtainable. A patient suffered from patellofomoral malformation in one knee, and another patient only had one side of knee CT image, all measurement of those two patients could not be obtained. Eventually, this allowed us to collect TT-TG distance data of 196 controls knees and 198 patient's knees, and the other five measurements data of all controls and 198 patient's knees. All measurements are listed in **Table 1**. Abnormal rates of these values are listed in **Table 2**.

The result of lateral patellofomoral angle (LPFA), patella inclination angle, congruence angle (CA) could be seen in **Table 1**. LPFA and patella inclination angle were analyzed using independent Student t tests and CA was analyzed using rank sum test, which were found to be significantly different between the controls and the patients. The abnormality rate of those three measurements in patents are 74.75%, 74.24%, 91.92%, respectively, and the control's rate are 6.5%, 9%, 52.5%. The abnormality rates of CA are high in both 2 group, we consider that the

boundary of CA in X-ray image doesn't apply to CT images; more details will be written in discussion.

There is a significantly difference between 2 groups in sulcus angle (SA) and trochlear groove depth, which were analyzed using independent Student t tests. The abnormality rates of those two measurements are highly reached to 88.75% and 81.31%, and in controls they are only 14.50% and 9.00%. This means that most of patellar dislocation suffered from devious degrees of trochlear dysplasia, and what's more, that conservative treatment has a fairly limited role in preventing redislocation and subluxation.

Tibialtuberosity-trochlear groove (TT-TG) measurement proved to significantly different between 2 groups, analyzed using independent Student t tests. 52.04% of the patients' TT-TG measurements were found to be greater than or equal to 20 mm, only 7% in controls.

After above procedure two groups were identified in affected knees of patients based on Patellofemoral anatomical deformities (trochlear dysplasia or increased TT-TG), and it should be specially explained that if either SA or trochlear groove depth was within normal range, we identified this knee without trochlear dysplasia. Then there were 153 knees (89 patients) suffered from trochlear dysplasia, 101 knees (71 patients) suffered from increased TT-TG, so 174 knees (94 patients) were found with Patellofemoral anatomical deformities, 24 knees (19 patients) without Patellofemoral anatomical deformities, which listed in **Table 3** combined with demographic information. What's more, according to their out-patients case history or in-patients case history, clinic feature of patients in these two groups were analyzed using chi-square tests and listed in **Table 4**. Eventually comparisons of two groups'

Table 3. Demographic information of two groups of patients' knees based on Patellofemoral anatomical deformities

	knees with Patellofemoral anatomical deformities	knees without Patellofemoral anatomical deformities	P Value
Gender (male/female)	54/120	14/10	P=0.016
Side (lift/right)	86/88	12/12	P=1.000
Age (mean ± SD)	19.71±13.33	29.07±14.76	P<0.001
Number of cases	174	24	-

Table 4. Clinic feature of patients' knees in two groups

	Occurrence of disease over 3 years	Recurrent dislocation >5 times	Pain of knees	Apprehension test	Patella Grind Test
Patients with Patellofemoral anatomical deformities	147/174	126/174	169/174	141/174	52/174
Patients without Patellofemoral anatomical deformities	11/24	8/24	21/24	8/24	1/24
P value	P<0.001	P<0.001	P=0.058	P<0.001	P=0.015

Table 5. Comparison of two groups' measurements

	LFPA	PIA	CA	SA	Trochlear Groove Depth	TT-TG
Patients with Patellofemoral anatomical deformities	-12.93±17.74	23.50±11.42	40.31±26.14	157.96±10.06	2.56±1.12	20.65±6.06
Patients without Patellofemoral anatomical deformities	-11.24±18.28	18.88±10.06	39.70±27.50	140.47±8.33	4.60±0.73	14.04±4.48
P Value	0.664	0.062	0.915	<0.001	<0.001	<0.001

measurements were analyzed using independent Student t tests and listed in **Table 5**.

Discussion

Pathogenesis of each patellar dislocation or redislocation patient is different, so the treatments that patients need are also different, etiotropic treatments should be chosen based on patients' pathogenetic condition. The main purposes of this investigation were to define its pathogenic features, determine the rates of patellofemoral anatomical deformity in patellar dislocation or redislocation patients, provide relevant evidence for the appropriate treatment, and prevent redislocation and sequelae.

The reasons why we choose to measure through CT scans are that most patellofemoral measurements were defined in the radiographs [18, 19], and there is a good correlations between the measurements on the radiograph and CT scans [20]; and compared to traditional radiographs, CT scans could provide sharp cross-sectional images in a good repeatability with simple operations, which can easily measure and computed [2, 3]; eventually, although mag-

netic resonance imaging (MRI) has an advantage in visualizing the articular surface and soft tissue structure, MRI may underestimate the measurements of joint, especially TT-TG distance, when compared with CT [21].

Lateral patellofomoral angle (LPFA), patella inclination angle, congruence angle (CA) are classical measurements of patellar tilt and patellar congruence, which make a difference to the diagnosis of patellar dislocation. In this investigation, the relative lager standard deviation of those three measurements in patient group can be interpreted as that there was a big difference in the anatomical severity of abnormality among patellar dislocation patients, and some previous literatures had the same situations [18, 20, 22, 23]. The abnormal rates of LPFA and patellar inclination angle (74.75%, 74.24%) were somehow lower in patient group, which may result from different of race photographing, as well as measuring [19, 24]. If we followed the standard of Merchant et al [18] when radiographs were taken by knees full extension, the abnormal rate was highly reached 91.92% in patients group, while it is still highly reached to 52.50% in controls

group. We considered that it was caused by the degree of flexion of the knee, according to the study of Pmar et al, there was a gradual decrease in CAs with knee flexion, and that the quadriceps relaxed or contracted may have an influence on CAs [20, 25]. So the measurement of CA should be done with knee 30° flexion. On clinic, positive result of LPFA, patellar inclination angle, CA stands for that patella may in an instable position, for acute patellar dislocation patients it means that patella may not be reduced, and if we continue to perform non-operative treatment, patella may remain instable after treatment. If it occurs to recurrence patellar dislocation patients, it implies imbalance of soft tissues, hinting the necessity of operative treatment. There were some patients whose result of those three measurements were all negative in this investigation, which meant patients' patella had been reduced, and it might lead to misdiagnosis if imaging tests performed only. For those patients, the importance of physical examination need to be more emphasized to avoid misdiagnosis, based on the result of which evaluate soft tissues balance and decide further treatment. For acute patella dislocation patients suffering soft tissue imbalance, immobilization to promote tissue healing might be the better option, but for recurrence patellar dislocation or chronic phase patients, soft tissue reconstruction might be the best option.

Sulcus angle (SA) and trochlear groove depth are two measurements to evaluate the growth of femoral trochlear, and it is considered to be an indication of trochlear dysplasia that SA measuring more than 145 degrees and trochlear groove depth measuring less than 4 mm generally [2-5, 18]. In this investigation, the abnormal rate of SA and trolchear groove depth were highly reached up to 88.75% (155.85±11.39) and 81.31% (2.82±1.26) in patients group, and considering the above two measured values, it means 153 affected knees (77.27% of all affected knees) suffer from trochlear dysplasia. It supported the result found by Dejour et al [4], which indicated that vast majority of instance suffered from trochlear dysplasia. If the positive results of SA and trochlear groove depth were found on clinic, it meant that the dislocations were not only caused by trauma for acute patella dislocation patients, and it might most likely induced redis-

location if the non-operative treatment was performed; for recurrence patellar dislocation patients, it connoted trochlear dysplasia in patients and futility of non-operative treatment. What's more, patellar dislocation or subluxation may result in trochlear dysplasia in the process of bone development [17], which means early and effective treatment for reduction might minimize trochlear dysplasia in children and young adolescents, and then reduce the morbidity. The negative result indicated that femoral trochlear grown at a normal lever, the causes may be abnormal lower extremity biomechanics, medial and lateral soft tissue imbalance or trauma etc, more examination were needed for those patients.

For tibial tuberosity located in the lateral of femoral trochlear groove, tibial tuberosity-trochlear groove distance (TT-TG) could reflect genicular eversion vector [26], and has been defined as an isolated predisposing factor of patellofemoral instability, and one of the gold standards of diagnostic measurements [2-4, 27, 28]. Our abnormal rate 52.04% (19.84±6.27) in patients group is somehow bigger than the results of some recent literature [4, 20, 29, 30], which may result from the discrepancy of races, radiography techniques and measurements. The mean of patients group 19.84 mm<20 mm is an indication that some patients with TT-TG <20 mm may also have patellofemoral misalignment, corresponding with the result of Diederichs et al [30] that there was an increased likelihood of instability in those with 15 to 20 mm, and research of Michael et al had the same situation [29]. This may be caused by that the incidence of the main crowd are children and young adolescents whose body size differences are significant, so cutoff of 20 mm for all patients is obviously inappropriate, personal factors should be certainly taken into consideration as measuring TT-TG distance. When positive results of TT-TG were found in patellar dislocation patients, it indicated that patellar dislocation was not simply induced by trauma or soft tissues issues, and if non-operative treatments continue to be received, redislocation would be inevitable for patellofemoral misalignment remaining existed.

87.77% patients' knees (174/198) were suffered from patellofemoral anatomical deformities, and 12.12% patients' knees (24/198)

were without patellofemoral anatomical deformities according to **Table 3**, and listed in **Table 5**, it wasn't surprisingly found that there is no significant difference between the two groups in term of LPFA, PIA and CA, but significant difference were proved between the two groups in SA, trochlear groove depth and TT-TG.

Furthermore we could discover in **Tables 3**, **4** that patients with patellofemoral anatomical deformities whose mean age was 19.71 had longer histories, 84.88% of these patients (147/174) had prior histories more than 3 years, and they tended to have more redislocation-72.41% of them (126/174) suffered from repeated dislocation more than 5 times until they came to our department. While the histories of patients without patellofemoral anatomical deformities were relatively short, only 45.83% (11/24) patients having prior histories more than 3 years, and tendencies to redislocation after reduction were less obvious, only 33.33% patients (8/24) had repeated dislocation more than 5 times. Because of trochlear dysplasia or patellofemoral misalignment, most of the former group suffered first patella dislocation at their early ages, a lot of them had their first patellar dislocation under 10, usually during light activities like going up and down or jogging on PE class, and had redislocation frequently since then. Recurrent dislocation might not have only exacerbated the damage of patellar soft tissues but also influenced the development of trochlear [17], whose interaction formed a vicious circle. Nevertheless the latter group suffered patella dislocation often resulting from abnormal lower extremity biomechanics, or medial and lateral soft tissue imbalance, and may be induced by strenuous exercise or external impact directly, so their onset age were older, usually over 15. For no patellofemoral anatomical deformity existed, patellar soft tissues would achieve scar healing after reduction and the patella would remain stable relatively. Redislocation rarely happened without intense stimulation.

There was no significant difference between these two groups of patients in anterior knee pain (P=0.058), yet significant differences were found in apprehension tests (P<0.001) as well as patella grind tests (P=0.015), and higher positive rate would be found in patients with patellofemoral anatomical deformity. Although almost all patients had the anterior knee pain, situation of two groups differed from each other. Patients with patellofemoral anatomical deformity usually were affected by anterior knee pain after going up and down or long-distance walking, and might suffer arthrocele even hydrarthrosis after strenuous exercise. Whereas the pain of patients without patellofemoral anatomical deformity was relatively light, often in form of discomfort, which had a smaller effect on life, and patients generally went to hospital for aggravation after strenuous exercise or external impact. For patella apprehension tests, as patients with patella patellofemoral anatomical deformity, majority of who were females, used to suffer from redislocation repeatedly, they were more susceptible and the distances patella pushed outward were larger than the other group of patients. Positive rate of patellar grind tests weren't high in both groups of patients (29.89% vs. 4.2%), most of the positive results were found in elder patients with patellofemoral anatomical deformity. It wasn't hard to explain that patients in this group had a longer history as well as more redislocation, so if they didn't receive proper treatment early, sequelae like patellofemoral osteoarthritis would appear when they got elder.

In conclusion, we could find that 77.27% (153/198) patients suffered from trochlear dysplasia, 52.04% (101/198) patients suffered from increased TT-TG from this investigation, therefore receiving simple conservative treatment could not solve the fundamental problems to prevent redislocation for most of the patients. Recurrence patellar dislocations could not only bring too much pain to patients, but may also load to sequelae such as osteoarthritis etc. So when faced with patellar dislocation patients, especially children and young adolescents who are in period of developing, they should receive more than simple conservative treatments. Early detection and diagnosis should to be made, find out the pathogenic factors, and then more aggressive etiotropic treatments based on patients' pathogenetic condition should be performed to reduce the patella and prevent redislocation, which may make a difference to reduce the morbidity of trochlear dysplasia among children and young adolescents.

Address correspondence to: Dr. Fei Wang, Third Hospital of Hebei Medical University, 139 Ziqiang Road, Shijiazhuang 050051, Hebei, China. Tel: +86-311-88602013; E-mail: 407444072@qq.com

References

[1] Hughston JC. Subluxation of the patella. J Bone Joint Surg Am 1968; 50: 1003-26.

[2] Colvin AC and West RV. Patellar instability. J Bone Joint Surg Am 2008; 90: 2751-62.

[3] Koh JL and Stewart C. Patellar Instability. Clin Sports Med 2014; 33: 461-476.

[4] Dejour H, Walch G, Nove-Josserand L and Guier C. Factors of patellar instability: an anatomic radiographic study. Knee Surg Sports Traumatol Arthrosc 1994; 2: 19-26.

[5] Bollier M and Fulkerson JP. The role of trochlear dysplasia in patellofemoral instability. J Am Acad Orthop Surg 2011; 19: 8-16.

[6] Smith TO, Song F, Donell ST and Hing CB. Operative versus non-operative management of patellar dislocation. A meta-analysis. Knee Surg Sports Traumatol Arthrosc 2011; 19: 988-998.

[7] Sillanpää P, Mattila VM, Iivonen T, Visuri T and Pihlajamäki H. Incidence and Risk Factors of Acute Traumatic Primary Patellar Dislocation. Med Sci Sports Exerc 2008; 40: 606-611.

[8] Stefancin JJ and Parker RD. First-time Traumatic Patellar Dislocation. Clin Orthop Relat Res 2007; 455: 93-101.

[9] Panni AS, Vasso M and Cerciello S. Acute patellar dislocation. What to do? Knee Surg Sports Traumatol Arthrosc 2013; 21: 275-278.

[10] Cofield RH and Bryan RS. Acute dislocation of the patella: results of conservative treatment. J Trauma 1977; 17: 526-31.

[11] Hawkins RJ, Bell RH and Anisette G. Acute patellar dislocations. The natural history. Am J Sports Med 1986; 14: 117-20.

[12] Fithian DC, Paxton EW, Stone ML, Silva P, Davis DK, Elias DA and White LM. Epidemiology and natural history of acute patellar dislocation. Am J Sports Med 2004; 32: 1114-21.

[13] Regalado G, Lintula H, Kokki H, Kröger H, Väätäinen U, Eskelinen M. Six-year outcome after non-surgical versus surgical treatment of acute primary patellar dislocation in adolescents: a prospective randomized trial. Knee Surg Sports Traumatol Arthrosc 2016; 24: 6-11

[14] Cheng B, Wu X, Ge H, Qing Sun Y and Zhang Q. Operative versus conservative treatment for patellar dislocation: a meta-analysis of 7 randomized controlled trials. Diagn Pathol 2014; 9: 60.

[15] Camanho GL, Viegas Ade C, Bitar AC, Demange MK and Hernandez AJ. Conservative Versus Surgical Treatment for Repair of the Medial Patellofemoral Ligament in Acute Dislocations of the Patella. Arthroscopy 2009; 25: 620-625.

[16] Sillanpää PJ, Mattila VM, Mäenpää H, Kiuru M, Visuri T and Pihlajamäki H. Treatment with and without initial stabilizing surgery for primary traumatic patellar dislocation. A prospective randomized study. J Bone Joint Surg Am 2009; 91: 263-73.

[17] Wang S, Ji G, Yang X, Wang X, Wang R, Li M, Wang F, Dai C and Li X. Femoral trochlear groove development after patellar subluxation and early reduction in growing rabbits. Knee Surg Sports Traumatol Arthrosc 2016; 24: 247-53.

[18] Merchant AC, Mercer RL, Jacobsen RH and Cool CR. Roentgenographic analysis of patellofemoral congruence. J Bone Joint Surg Am 1974; 56: 1391-6.

[19] Laurin CA, Lévesque HP, Dussault R, Labelle H and Peides JP. The abnormal lateral patellofemoral angle: a diagnostic roentgenographic sign of recurrent patellar subluxation. J BoneJoint Surg Am 1978; 60: 55.

[20] Alemparte J, Ekdahl M, Burnier L, Hernández R, Cardemil A, Cielo R and Danilla S. Patellofemoral Evaluation With Radiographs and Computed Tomography Scans in 60 Knees of Asymptomatic Subjects. Arthroscopy 2007; 23: 170-177.

[21] Camp CL, Stuart MJ, Krych AJ, Levy BA, Bond JR, Collins MS and Dahm DL. CT and MRI measurements of tibial tubercle-trochlear groove distances are not equivalent in patients with patellar instability. Am J Sports Med 2013; 41: 1835-40.

[22] Pinar H, Akseki D, Genç I and Karaoğlan O. Kinematic and dynamic axial computerized tomography of the normal patellofemoral joint. Knee Surg Sports Traumatol Arthrosc 1994; 2: 27-30.

[23] Reikeras O andHoiseth A. Patellofemoral relationships in normal subjects determined by computed tomography. Skeletal Radiol 1990; 19: 591-2.

[24] MD FMT, et al. CT Patellar Cortex Tilt Angle A Radiological Method toMeasure Patellar Tilt. Musculoskeletal 2005.

[25] Delgado-Martínez AD, Estrada C, Rodríguez-Merchán EC, Atienza M and Ordóñez JM. CT scanning of the patellofemoral joint. The quadriceps relaxed or contracted? Int Orthop 1996; 20: 159-62.

[26] Wagenaar FC, Koëter S, Anderson PG and Wymenga AB. Conventional radiography cannot replace CT scanning in detecting tibial tubercle lateralisation. Knee 2007; 14: 51-4.

[27] Smith TO, Davies L, Toms AP, Hing CB and Donell ST. The reliability and validity of radiological assessment for patellar instability. A systematic review and meta-analysis. Skeletal Radiol 2011; 40: 399-414.

[28] Jones RB, Barlett EC, Vainright JR and Carroll RG. CT determination of tibial tubercle lateralization in patients presenting with anterior knee pain. Skeletal Radiol 1995; 24: 505-9.

[29] Charles MD, Haloman S, Chen L, Ward SR, Fithian D and Afra R. Magnetic resonance imaging-based topographical differences between control and recurrent patellofemoral instability patients. Am J Sports Med 2013; 41: 374-84.

[30] Diederichs G, Issever AS and Scheffler S. MR imaging of patellar instability: injury patterns and assessment of risk factors. Radiographics 2010; 30: 961-81.