Assessing Femoral Anteversion in Patients With Bilateral Recurrent Patellar Dislocations

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Background: After first-time lateral patellar dislocation, 44% to 70% of patients sustain redislocations. Increased femoral anteversion (FA) is considered to result in increased lateralizing forces on the patella, which might predispose one to patellar instability. When recurrent patellar dislocations (RPDs) are bilateral, it is unclear if the FA is even more increased.

Hypothesis: Patients with bilateral RPD would have greater FA than patients with unilateral RPD.

Study Design: Case-control study; Level of evidence, 3.

Methods: A total of 52 skeletally mature patients with RPD and a clinical suspicion of rotational malalignment underwent rotational computed tomography or magnetic resonance imaging. The uni- or bilaterality of the RPD was determined. A control group comprising 54 adult patients with trauma underwent computed tomography of both lower extremities as part of a multitrauma protocol. The FA values of both lower extremities were evaluated separately.

Results: In total, 20 of 52 (38.5%) patients in the study group had a history of unilateral RPD and 32 of 52 (61.5%) patients had a bilateral RPD diagnosis. The mean FA of the asymptomatic limb in unilaterally symptomatic patients was 18.0° (SD, 11.2°; range, 0.5°-40.0°; median, 16.5°). In the symptomatic limb, the mean FA was 19.2° (SD, 9.1°; range, 2.0°-33.0°; median, 19.0°) (mean difference, 1.2°; 95% CI −1.3° to 3.8°). In bilaterally symptomatic patients, the mean FA on the right side was 23.2°, and 22.5° on the left. The mean differences between the symptomatic limbs in the unilateral RPD group and the right or left limbs in the bilateral RPD group were 4.0° (P = .263) and 3.3° (P = .326), respectively. In the control group without RPD, the mean FA was 12.5° (SD, 8.5°; range, 0.8°-33.0°; median, 10.9°). The mean difference between right limbs of the patients with bilateral RPD and right limbs of controls was 10.8° (P = .001).

Conclusion: Patients with bilateral RPD have bilaterally greater FA than patients without a history of RPD. Patients with unilateral RPD have greater FA on both sides compared with the control group without a history of lateral patellar dislocation. No statistically significant difference of FA can be seen between patients with bilateral or unilateral RPD.

Keywords: knee; knee, patella; biomechanics; lateral patellar dislocation; recurrent patellar dislocation; femoral anteversion; bilateral patellar dislocation

Lateral patellar dislocation (LPD) is a common injury in young adults.[17,20,24] While the primary episode of LPD is typically traumatic, resulting in hemarthrosis, 44% to 70% of patients sustain nontraumatic redislocations or experience recurrent patellar dislocation (RPD).[7,13,17] Well-known anatomic risk factors for recurrent patellar instability include patella alta, trochlear dysplasia, and increased tibial tubercle–trochlear groove (TT-TG) distance.[1-5,17] Furthermore, although often unrecognized, increased femoral anteversion (FA) is considered to be one of the main causes of lateralizing forces on the patella, which might predispose one to patellar instability, either independently or in combination with other risk factors.[6,8,12,21] Abnormal FA is reported to exist in 12% to 19% of patients with patellar maltracking.[6,8]

The imaging of torsional features can be performed with magnetic resonance imaging (MRI) or computed tomography (CT).[10,14,19,23] In the current literature, normal FA is reported to be between 10° and 16°.[4,6,15,22] Dejour et al[4] reported an FA of 15.6° in patients with recurrent patellar instability (RPI), whereas that of controls was 10.8°. In

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TABLE 1
Patient Characteristics[a]

Characteristic	Bilateral RPD (n = 32)	Unilateral RPD (n = 20)	Control (n = 54; 47 right limb, 36 left limb)
Sex, male/female, n (%)	5 (16)/27(84)	2 (10)/18 (90)	38 (70)/16 (30)
Age, y			
Mean	22.4	22.2	41.1
SD	7.1	6.9	20.3
Range	15.6-42.5	15-39.4	15.5-84.3
Median	19.9	19.9	40.0
Imaging modality, CT/MRI, n (%)	12 (38)/20 (63)	8 (40)/12 (60)	0 (0)/54 (100)

[a]CT, computed tomography; MRI, magnetic resonance imaging; RPD, recurrent patellar dislocation.

their study, Diederichs et al[6] found a 1.56-fold higher mean FA in patients with RPD. The findings of some studies reveal that ignoring apparent increased FA while reconstructing the medial patellofemoral ligament (MPFL) alone or combined with osteotomy of the tibial tubercle may lead to poor outcomes.[12,21] However, Nelitz et al[11] and Yang et al[25] reported good patient outcomes after femoral derotation osteotomy in combination with MPFL reconstruction in patients with increased FA.

An interesting question is, do patients with bilateral RPD have bilaterally increased FA compared with patients with unilateral or no history of patellar dislocations? This question has potential clinical relevance, as several studies reported that bilaterality of RPD is not rare.[7,13,17] In this study, we aimed to clarify the possible pronounced increase in FA, especially when the RPD is bilateral. We hypothesized that patients with unilateral FA would have bilaterally greater FA than patients without a history of RPD.

METHODS

This study was approved by our local ethics committee (ETL code 05024). Between 2005 and 2013, 52 skeletally mature (physes closed) patients with RPD and a clinical suspicion (see below) of rotational malalignment underwent rotational CT or MRI as a routine diagnostic procedure at Tampere University Hospital. Scanning was bilateral. The clinical examination of patients was conducted in an outpatient clinic. Among other clinical tests, range of motion, patellar tracking, patellar apprehension, and hip rotation were examined. Rotational abnormalities were investigated by observing the alignment of lower limbs. An inward position of the patella while the feet were directed neutrally was considered as clinical suspicion of increased FA. According to the protocol of the study hospital, rotational images were used only when rotational abnormalities were clinically suspected, but not for every patient with RPD. Patient characteristics including age, sex, and the uni- or bilaterality of the RPD were collected from patient records (Table 1). RDP was defined as >2 complete patellar dislocations, and the diagnosis was verified with 1.5- or 3-T MRI. MRI findings indicating patellar dislocation include MPFL injury and bone edema in the medial patellar facet and lateral femoral condyle.

Additionally, a control group consisted of 54 skeletally mature (physes closed) patients admitted to the emergency department with suspected multitrauma between March 2019 and September 2021. CT scans of both lower extremities were performed as part of the multitrauma protocol. As in the study group, patient characteristics, including age and sex, were collected from patient records. There was no history of patellar dislocations among patients in the control group. CT scans of the control group showed femoral fractures or a preexisting endoprosthesis in some patients. Therefore, of the 54 patients in the control group, 47 right and 36 left limbs were analyzed.

Imaging

CT imaging of the rotational alignment of the lower limbs of the study group was performed at Tampere University Hospital between 2005 and 2012. As the availability of MRI for study purposes improved in our hospital, MRI replaced CT as the imaging modality from 2012 onward.

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Ethical approval for this study was obtained from Pirkanmaa Hospital District (R05024).

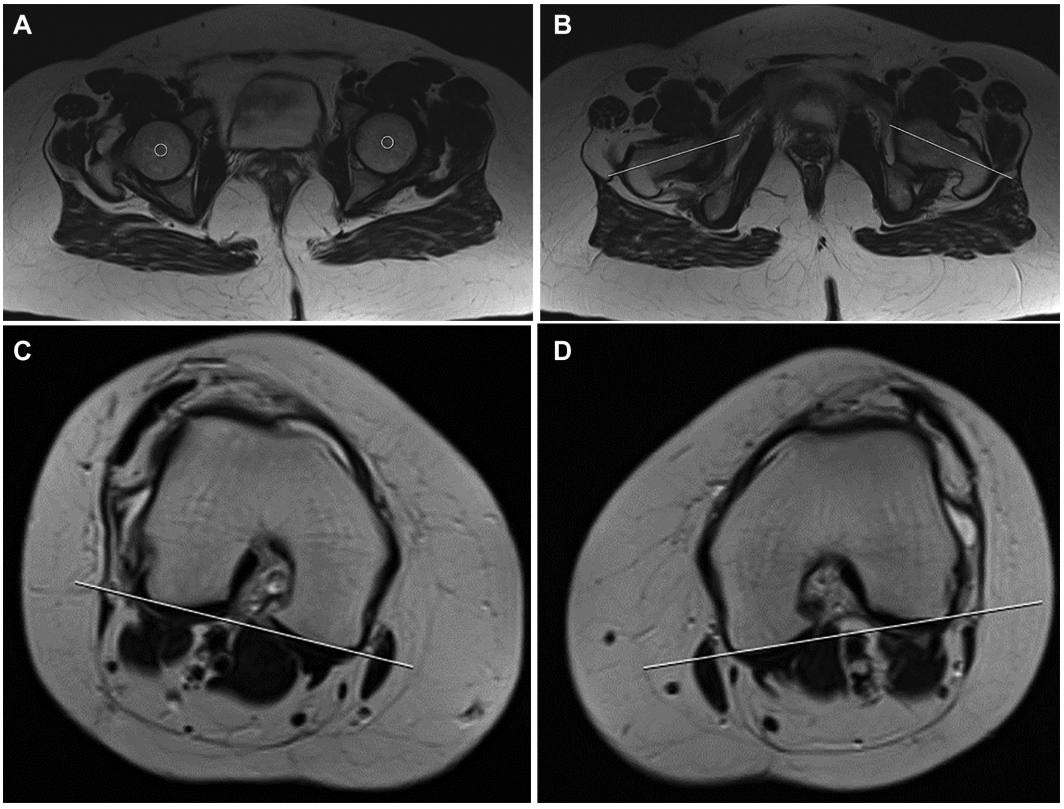


Figure 1. Method to measure the femoral anteversion in rotational magnetic resonance imaging. (A) The rotational center of the femoral head was determined (circle). (B) A line from the rotational center of the femoral head was drawn along the axis of the femoral neck. (C) At the level of the epicondyles, a line was drawn through the posterior cortexes of the femoral condyles. The femoral anteversion is the angle between the lines in panels B and C. (D) Femoral anteversion in rotational computed tomography was conducted using the same anatomic landmarks.

The imaging protocols for both modalities included 10-cm slabs from the level of both the hips, knees, and ankles of patients in the supine position. CT imaging was performed with 16-slice and 64-slice scanners (GE Lightspeed, GE Healthcare; and Philips Brilliance), with 5-mm axial reformates obtained as previously described elsewhere.[23]

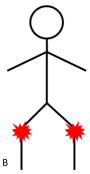
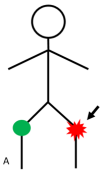
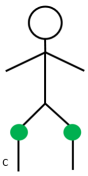
MRI was performed using a 1.5-T imager (MAGNETOM Avanto; Siemens Healthcare). T2-weighted axial turbo spin echo images (repetition time/echo time, 3500/90 milliseconds) with 5-mm slice thickness and 0.5-mm gap were obtained with the combined use of a body coil and a 24-channel peripheral angiography coil. The field of view was 396 mm for all joints, and the matrix size was 334 $\times$ 448 for the hips, 348 $\times$ 400 for the knees, and 292 $\times$ 448 for the ankles.

Imaging of the control group was performed as part of an imaging evaluation of patients with multitrauma at the emergency department of Tampere University Hospital. The patients in the control group had sustained severe lower limb injuries that indicated CT angiography imaging of the arteries. Typically, the CT angiography study was performed after trauma CT and the area from the pelvis to the knees or from the pelvis to the feet was imaged with a slice thickness of 0.5 mm. A Somatom Definition Flash 2 $\times$ 128-slice CT scanner was used to acquire the images (Siemens Healthcare).

Evaluation of Rotational Alignment

To assess FA, we measured the angle between the axis of the femoral neck and the line drawn along the posterior cortexes of the femoral condyles at the level of the epicondyles (Figure 1).[6,15] The acquired images were evaluated on a picture archiving and communication system (PACS) workstation. Carestream Vue PACS Version 11.14 software was used for the study group, and Sectra IDS7 PACS software was used for the control group, as the PACS system at Tampere University Hospital was changed in 2018. Two orthopaedic surgeons (E.E.H., P.S.) performed the measurements separately, and the mean values of the results were used in the analysis.Interobserver analysis was performed for patients in the study group using the intraclass correlation coefficient (0.943; 95% CI, 0.898-0.968). In the control group (multitrauma), some patients had femoral fractures or a preexisting endoprosthesis so FA was determined only in the intact limb. The mean value of available right and left limbs was assessed.

TABLE 2
Between-Patient Comparison of Mean FA and Mean Difference[a]

	Bilateral RPD (n = 32)		Unilateral RPD (n = 20)		Control (n = 54)	
						
	Right	Left	Asymptomatic (reference 1 for comparisons)	Symptomatic Side (reference 2 for comparisons)	Right (n = 47)	Left (n = 36)
FA, deg						
Mean	23.2	22.5	18.0	19.2	12.4	13.1
SD	14.1	12.9	11.2	9.1	8.9	9.3
Range	0.5 to 63.0	2.5 to 53.0	0.5 to 40.0	2.0 to 33.0	–1.0 to 38.0	0 to 39.0
Median	20.3	20.5	16.5	19.0	12.0	11.0
FA compared with reference 2, deg						
Mean difference	4.0	3.3	1.22	NA	6.8	6.1
95% CI	–11.1 to 3.0	–0.9 to 3.4	–1.3 to 3.8	NA	2.0 to 11.6	1.0 to 11.3
P	.263	.326	.329	NA	.006	.021
FA compared with reference 1, deg	NA	NA	NA	NA		
Mean difference	NA	NA	NA	NA	5.6	4.9
95% CI	NA	NA	NA	NA	0.4 to 10.7	0.7 to 10.5
P	NA	NA	NA	NA	.035	.0085

[a]FA, femoral anteversion; NA, not applicable; RPD, recurrent patellar dislocation. A, patients with unilateral RPD; B, patients with bilateral RPD; C, controls.

Evaluation of the Anatomic Risk Factors for Patellar Dislocation

The MRI or CT scans of all patients were evaluated to assess anatomic risk factors for LPD. The anatomic features determined were the TT-TG, sulcus angle, lateral inclination angle, and sulcus depth for each knee.[1,16] All patients in the control group and 20 of 52 patients in the study group underwent CT. Therefore, the evaluation was conducted using bony structures instead of cartilage to ensure that all values were comparable throughout the data. Otherwise, measurements were done using accurately documented and illustrated methods described by Arendt et al.[1]

Statistical Analysis

Within-patient comparison of the study parameters was performed using a paired-samples *t* test. Between-patient comparison was performed using the Welch *t* test. As a sensitivity analysis, we also performed adjusted comparisons. Linear regression was used including the mean FA of the groups, and anatomic risk factors were determined in separate analyses (TT-TG distance, trochlear sulcus angle, sulcus depth, and lateral inclination angle) (Supplemental Table S1). A *P* value of <.05 was considered statistically significant. All analyses were conducted using SPSS Version 27 (IBM Corp).

RESULTS

A total of 32 of 52 (61.5%) patients in the study group had a bilateral RPD diagnosis, and 20 of 52 (38.5%) patients had a history of unilateral RPD (Table 1). Most of the patients in the study group were female (45/52; 86.5%). In the control group (without a history of RPD), 16 of 54 (29.6%) patients were female. Patients in the control group were somewhat older (mean age, 41.1 years; range, 15.5-84.3 years) than patients in the study group (mean age, 22.3 years; range, 15-42.5 years).

Within-Patient Comparison

Patients With Unilateral RPD. The mean FA of the asymptomatic limb in unilaterally symptomatic patients was 18.0° (SD, 11.2°; range, 0.5°-40.0°; median, 16.5°) and 19.2° (SD, 9.1°; range, 2.0°-33.0°; median, 19.0°) in the symptomatic limb (mean difference, 1.2°; 95% CI, –1.3° to 3.8°; *P* = .329) (Table 2).

Patients With Bilateral RPD. Patients with bilateral RPD had a combined (left and right) mean FA of 22.8° (SD, 13.1°; range, 0.5°-63.0°; median, 19.8°). When both right and left limbs with bilateral RPD were analyzed separately, the mean FA on the right side was 23.2°, and 22.5° on the left.

Patients Without a History of RPD. In the control group without a history of RPD, the mean FA was 12.5° (SD, 8.5°; range, 1.0°-39.0°; median, 10.9°) (Table 2).

TABLE 3
Anatomic Risk Factors[a]

Result	Unilateral RPD, Symptomatic Limb (n = 20)	Unilateral RPD, Asymptomatic Limb (n = 20)	Bilateral RPD (n = 32)	Asymptomatic Control (n = 54)
TT-TG, mm				
Mean	18.4	18.1	22.5	13.3
SD	6.5	6.2	5.0	4.6
Range	7.4-32.4	7.5-27.3	11.2-34.45	4.8-24.1
Median	18.4	17.6	22.3	13.0
Sulcus angle, deg				
Mean	155.7	154.3	159.5	132.1
SD	12.2	13.4	9.8	7.6
Range	129.6-177.9	128.9-178.6	142.4-178.5	116.9-154.5
Median	157.3	150.5	158.7	131.8
Sulcus depth, mm				
Mean	2.8	3.1	2.5	6.5
SD	1.9	2.0	1.7	1.3
Range	0.5-8.2	0.4-8.0	0.2-6.5	3.2-9.3
Median	2.7	2.9	2.3	6.6
Lateral trochlear inclination angle, deg				
Mean	11.2	12.6	12.4	24.7
SD	6.5	6.4	6.7	3.8
Range	0.3-25.4	0.4-23.4	1.2-24.5	14.4-31.2
Median	10.9	12.8	13.3	24.9

[a]RPD, recurrent patellar dislocation; TT-TG, tibial tubercle–trochlear groove.

Between-Patient Comparison

Comparison Between Patients With Unilateral RPD and Patients with Bilateral RPD and Controls. Patients with unilateral RPD were compared with patients with bilateral symptoms and patients without a history of RPD (controls). Both limbs in each group were analyzed separately. All comparisons were adjusted with anatomic covariates (TT-TG distance, sulcus angle, sulcus depth, and lateral trochlear inclination angle) (Supplemental Table S1). No significant change of outcomes between patient comparisons was detected (Table 2).

Comparison Between Patients With Bilateral RPD and Patients Without a History of RPD. When comparing the right limb of patients with bilateral RPD and the right limb of controls, the mean difference was 10.8° (95% CI, 5.6°-16.0°; $P < .001$). When comparing the left limb of patients with bilateral RPD and that of controls, the mean difference was 9.4° (95% CI, 4.0°-14.7°; $P < .001$) (Table 2).

A comparison was made between the affected and unaffected knees of unilaterally symptomatic patients. The right and left limbs were compared separately between the symptomatic limbs of patients with unilateral RPD. The left and right limbs of the control group were compared with both the unaffected and affected limbs of unilaterally symptomatic patients. The comparison between the control group and patients with bilateral RPD is seen in Table 2.

Anatomic Risk Factors

All determined known anatomic risk factors for RPD are presented in Table 3.

DISCUSSION

In the present study, FA of the patients with bilateral RPD was greater than that of patients without a history of RPD (mean FA, 22.8° vs 12.5°). FA of the patients with bilateral RPD was also greater than FA of the patients with unilateral RPD. The difference was detected in symptomatic (mean FA, 22.8° vs 19.2°) and asymptomatic (mean FA, 22.8° vs 18.0°) limbs. Patients with unilateral RPD had no significant difference between FA of symptomatic and asymptomatic limbs (mean FA, 19.2° vs 18.0°). Statistically significant differences between the RPD groups were not detected. However, a clear tendency can be seen in increasing FA when looking at the outcomes of the controls, the asymptomatic or symptomatic limbs of unilaterally symptomatic patients, and especially in those patients with a history of bilateral RPD.

In previous studies, normal FA values have been reported to be 10° to 16°,[4,6,15,22] which is comparable to values of the control group without a history of RPD. The previously reported FA value of patients with RPD was 15.6°, or 1.56-fold greater than values of patients without RPD.[4,6] FA of the study patients was even greater. To our

knowledge, the correlation of bilateral RPD and increased FA has not been previously reported.

After first-time patellar dislocation, development of recurring instability of the patellofemoral joint is multifactorial. Increased FA might reinforce patellar lateralizing forces, either independently or in combination with other risk factors, such as trochlear dysplasia, genu valgum, elevated TT-TG, or patella alta.[6,8,11,12,14,19,21] The injury site at femoral insertion of the MPFL might also increase the risk of patellar redislocation.[18] In previous studies, unsatisfactory results have been described after MPFL reconstruction alone or combined with osteotomy of the tibial tubercle when preexisting increased FA was ignored.[11,12,21] The reason for the failure has been considered to be an excessive tension over reconstructed MPFL, caused by patellar lateralizing forces of increased FA.[12,14] In contrast, Nelitz et al[11] and Yang et al[25] reported good outcomes after derotation osteotomy in patients with increased FA in combination with MPFL reconstruction. Included patients of both studies had an FA angle >25° and a history of at least 2 episodes of LPD.[11,25] FA >30° has been set as an indication for derotation osteotomy alone or with other reconstructive or corrective procedures needed.[25,26] A systematic review of 6 studies including 161 patients with RPD and increased FA revealed a mean FA decrease from 34° preoperatively to 12° postoperatively. The reports of pre- and postoperative outcomes showed significant improvement in several knee scores.[26]

Coronal or sagittal plane anatomic abnormalities, such as patella alta, trochlear dysplasia, and increased TT-TG distance, are well known and recognized risk factors for RPD.[1-5,17] They are also quite easily assessed by conventional radiography and MRI. On the other hand, rotational abnormalities demand clinical suspicion and therefore a special protocol for both lower limb MRI and CT for the measurement. In this study, we found that FA can further increase when RPDs are bilateral. As the increased FA has been considered a significant risk factor for RPD and might result in failure of the treatment when ignored, the possible existence of rotational abnormalities should be included in clinical decision-making.[11,12,14,21,25,26] Therefore, MRI or CT of both lower limbs might be a beneficial additional tool for the assessment of the underlying risk factors for RPD and, furthermore, choosing the method of treatment. We recommend running rotational CT or MRI when clinical suspicion of underlying rotational abnormality arises. In this study, both CT and MRI modalities were used. Previous studies have shown that measurement results are comparable when similar FA evaluation techniques are used.[9,23]

Limitations

A potential limitation of the study is that the female sex was overrepresented in the study group and the patients were younger than in the control group. Female sex and young age are known risk factors for patellar dislocations.[7,8,14] However, we included only skeletally mature patients who had physes closed so regeneration of femoral alignment came to an end, thereby defining the groups as comparable. Furthermore, fewer female patients in the control group might have a slight effect on the FA values, but the mean FA of the control group was comparable to the normal values presented in the literature.[4,6,15,22]

CONCLUSION

Patients with bilateral RPD have bilaterally greater FA than patients without a history of RPD. Furthermore, patients with unilateral RPD have greater FA on both sides compared with the control group without a history of LPD. We suggest using bilateral rotational MRI or CT whenever rotational malalignment is suspected, especially in those patients with a history of bilateral RPD.

REFERENCES

1. Arendt EA, England K, Agel J, Tompkins MA. An analysis of knee anatomic imaging factors associated with primary lateral patellar dislocations. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(10):3099-3107.
2. Biedert RM, Albrecht S. The patellotrochlear index: a new index for assessing patellar height. *Knee Surg Sports Traumatol Arthrosc*. 2006;14(8):707-712.
3. Caton J, Deschamps G, Chambat P, Lerat JL, Dejour H. Patella infera. Apropos of 128 cases. Article in French. *Rev Chir Orthop Reparatrice Appar Mot*. 1982;68(5):317-325.
4. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: an anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc*. 1994;2(1):19-26.
5. Diederichs G, Issever AS, Scheffler S. MR imaging of patellar instability: injury patterns and assessment of risk factors. *Radiographics*. 2010;30(4):961-981.
6. Diederichs G, Kohlitz T, Kornaropoulos E, Heller MO, Vollnberg B, Scheffler S. Magnetic resonance imaging analysis of rotational alignment in patients with patellar dislocations. *Am J Sports Med*. 2013;41(1):51-57.
7. Fitzpatrick CK, Steensen RN, Tumuluri A, Trinh T, Bentley J, Rullkoetter PJ. Computational analysis of factors contributing to patellar dislocation. *J Orthop Res*. 2016;34(3):444-453.
8. Franciozi CE, Ambra LF, Albertoni LJ, et al. Increased femoral anteversion influence over surgically treated recurrent patellar instability patients. *Arthroscopy*. 2017;33(3):633-640.
9. Guenther KP, Tomczak R, Kessler S, Pfeiffer T, Puhl W. Measurement of femoral anteversion by magnetic resonance imaging—evaluation of a new technique in children and adolescents. *Eur J Radiol*. 1995;21(1):47-52.
10. Jarrett DY, Oliveira AM, Zou KH, Snyder BD, Kleinman PK. Axial oblique CT to assess femoral anteversion. *AJR Am J Roentgenol*. 2010;194(5):1230-1233.
11. Nelitz M, Dreyhaupt J, Williams SR, Dornacher D. Combined supracondylar femoral derotation osteotomy and patellofemoral ligament reconstruction for recurrent patellar dislocation and severe femoral anteversion syndrome: surgical technique and clinical outcome. *Int Orthop*. 2015;39(12):2355-2362.
12. Nelitz M, Williams RS, Lippacher S, Reichel H, Dornacher D. Analysis of failure and clinical outcome after unsuccessful medial patellofemoral ligament reconstruction in young patients. *Int Orthop*. 2014;38(11):2265-2272.
13. Nikku R, Nietosvaara Y, Kallio PE, Aalto K, Michelsson JE. Operative versus closed treatment of primary dislocation of the patella. Similar 2-year results in 125 randomized patients. *Acta Orthop Scand*. 1997;68(5):419-423.

14. Parikh S, Noyes FR. Patellofemoral disorders: role of computed tomography and magnetic resonance imaging in defining abnormal rotational lower limb alignment. *Sports Health*. 2011;3(2):158-169.
15. Schneider B, Laubenberger J, Jemlich S, Groene K, Weber HM, Langer M. Measurement of femoral antetorsion and tibial torsion by magnetic resonance imaging. *Br J Radiol*. 1997;70(834):575-579.
16. Seitlinger G, Scheurecker G, Hogler R, Labey L, Innocenti B, Hofmann S. Tibial tubercle-posterior cruciate ligament distance: a new measurement to define the position of the tibial tubercle in patients with patellar dislocation. *Am J Sports Med*. 2012;40(5):1119-1125.
17. Sillanpaa P, Mattila VM, Iivonen T, Visuri T, Pihlajamaki H. Incidence and risk factors of acute traumatic primary patellar dislocation. *Med Sci Sports Exerc*. 2008;40(4):606-611.
18. Sillanpaa PJ, Peltola E, Mattila VM, et al. Femoral avulsion of the medial patellofemoral ligament after primary traumatic patellar dislocation predicts subsequent instability in men: a mean 7-year nonoperative follow-up study. *Am J Sports Med*. 2009;37(8):1513-1521.
19. Steensen RN, Bentley JC, Trinh TQ, Backes JR, Wiltfong RE. The prevalence and combined prevalences of anatomic factors associated with recurrent patellar dislocation: a magnetic resonance imaging study. *Am J Sports Med*. 2015;43(4):921-927.
20. Stefancin JJ, Parker RD. First-time traumatic patellar dislocation: a systematic review. *Clin Orthop Relat Res*. 2007;455:93-101.
21. Stevens PM, Gililland JM, Anderson LA, Mickelson JB, Nielson J, Klatt JW. Success of torsional correction surgery after failed surgeries for patellofemoral pain and instability. *Strategies Trauma Limb Reconstr*. 2014;9(1):5-12.
22. Tamari K, Tinley P, Briffa K, Breidahl W. Validity and reliability of existing and modified clinical methods of measuring femoral and tibiofibular torsion in healthy subjects: use of different reference axes may improve reliability. *Clin Anat*. 2005;18(1):46-55.
23. Tomczak RJ, Guenther KP, Rieber A, Mergo P, Ros PR, Brambs HJ. MR imaging measurement of the femoral antetorsional angle as a new technique: comparison with CT in children and adults. *AJR Am J Roentgenol*. 1997;168(3):791-794.
24. Visuri T, Maenpaa H. Patellar dislocation in army conscripts. *Mil Med*. 2002;167(7):537-540.
25. Yang GM, Wang YY, Zuo LX, Li F, Dai Y, Wang F. Good outcomes of combined femoral derotation osteotomy and medial retinaculum plasty in patients with recurrent patellar dislocation. *Orthop Surg*. 2019;11(4):578-585.
26. Zhang Z, Cao Y, Song G, Li Y, Zheng T, Zhang H. Derotational femoral osteotomy for treating recurrent patellar dislocation in the presence of increased femoral anteversion: a systematic review. *Orthop J Sports Med*. 2021;9(11):23259671211057126.