 Acta Chir Orthop Traumatol Cech. 90, 2023, No. 3, p. 206–210
DOI: 10.55095/achot2023/024

ORIGINAL PAPER
PŮVODNÍ PRÁCE

High Femoral Antetorsion Is a Major Risk Factor for Anterior Knee Pain whereas Trochlea Dysplasia Predisposes for Patella Dislocation

Velká antetorze femuru představuje zvýšené riziko bolesti předního kolena, zatímco dysplazie trochley je predispozicí pro luxaci patelly

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ABSTRACT

PURPOSE OF THE STUDY
Patellofemoral stability and congruency are influenced by different parameters. Their contribution to anterior knee pain and instability is not fully understood. We investigated, if isolated femoral antetorsion of more than 25° leads to patellofemoral instability.

MATERIAL AND METHODS
We analyzed 90 knees in patients with patellofemoral complaints and correlated clinical and radiological characteristics. Patients presenting at our center between January 2018 and December 2020 because of patellofemoral pain or instability were included, provided that there was no previous surgical intervention done.

RESULTS
The severity of trochlea dysplasia classified using the Oswestry-Bristol classification significantly correlated with events of patellofemoral dislocations. (χ=8.152, p=0.043, φ=0.288). All males with a history of patella dislocation had at least a mild trochlea dysplasia. The majority of females complaining about patellofemoral symptoms in general had a dysplastic trochlea. Patella alta is more frequently found in patients with trochlea dysplasia than in patients with a normal femoral trochlea anatomy.

DISCUSSION
The majority of unstable patellofemoral joints showed a dysplastic trochlea. A high femoral antetorsion was found to be an additional minor factor contributing to instability. Isolated high femoral antetorsion without trochlea dysplasia rather leads to anterior knee pain without patella dislocation. Furthermore, no direct significant correlation between patella alta and patellofemoral instability was found. Patella alta can therefore rather be seen as a result of a dysplastic trochlea than a primary major risk factor for patellofemoral instability.

CONCLUSIONS
Trochlea dysplasia is the major risk factor for patellofemoral instability. Patella alta can rather be seen as a result of a dysplastic trochlea than as a primary risk factor for patella instability or pain. Isolated high femoral antetorsion often leads to patellofemoral pain syndrome but not to patella dislocations.

Key words: MPFL, patella instability, patellofemoral instability.

INTRODUCTION

Patellofemoral complaints include patellofemoral pain syndrome and/or patellofemoral instability. Patella instability mainly affects young and active adults with a point prevalence of 7.2% in a population of mixed sex adolescents (18). Women are more often affected than men (14). Walking the stairs induces anterior knee pain or instability feelings, while the patella shows a high lateralization tendency (14).

There are many risk factors influencing articular congruency and stability of the patella and trochlea. Hence, there are various parameters to be considered for finding the correct diagnosis and therapy. The variety of contributors and their interactions require a standardized diagnostic workup and an individual therapy plan. While active stabilizers like the quadriceps muscle play a secondary role in patella stability and stabilize the patellofemoral joint mainly in higher degrees of flexion, passive and static factors are in focus in the latest research on patellofemoral instability and pain. Between 0°–30° of knee flexion, the most important factor for stability is the medial patellofemoral ligament (MPFL) as a passive stabilizer. Then, between 20° and 60° of

flexion, the patella should be guided by a normally configured femoral trochlea as static stabilizer. Injuries, absent/dysplastic trochlea, and insufficient soft tissue (medial patellofemoral ligament –MPFL) can lead to patella instability. More than 90% of first-time patella dislocations show MPFL lesions on MRI (12). Operative therapy leads to significantly lower re-dislocation rates than conservative therapy.

Static factors include a variety of osseus parameters; for instance, long-leg axis, femoral antetorsion, trochlea form. They determine patellofemoral alignment and congruency. The trochlea can show a deep, shallow, or even convex configuration while the patella itself can be disformed or displaced. Dejour described that in 85% of all patella dislocations, the trochlea was dysplastic (2). After successful MPFL reconstruction or repair, patients with trochlea dysplasia still presented higher redislocation rates and worse clinical outcome scores than patients without trochlea dysplasia (1). This emphasizes the importance of considering all contributing factors of patellofemoral congruency and stability in order to fully understand the actual underlying pathomorphology.

Femur and tibia can show a pathological torsion and/or valgus malalignment and thereby disturb patellofemoral kinematics and joint reaction forces. Standard values for femoral torsion differ depending on the measurement method. The assessment of Waidelich et al., which connects the centre of the femoral head with the centre of the trochanter major on superimposed axial CT images and uses the posterior condyles as a reference line, is widely accepted. The mean value of femoral antetorsion for this assessment method is -20.4°+/-9° (20) and -22,4°+/- 6.8° in recent data (6, 17, 19). Kaiser et al. confirmed a high intra- and interobserver agreement for the technique by Waidelich (6).

The tibial tuberosity-trochlear groove distance (TT-TG) measured on CT or MRI represents the clinical Q-angle, defined as the angle between the two intersecting lines of the anterior superior iliac spine to the center of the patella and the center of the patella to the tibial tuberosity. As the TT-TG value increases, lateral patella translation increases due to the rising lateral force vector of the quadriceps muscle on the patella. The TT-TG value is considered pathologic, if it is greater than 20 mm (2).

All the factors mentioned above can alone or in combination contribute to patellofemoral complaints. To this date, there is no comprehensive study on clinical and radiological correlations of these osseus parameters in patients with patellofemoral complaints.

The present study correlates clinical and radiological findings to investigate, if symptoms of instability and/or pain show high correlations with specific osseus parameters. The following research questions shall be answered:

1. Does high femoral antetorsion induce patella instability only when in combination with trochlear dysplasia?
2. Does high femoral antetorsion alone induce patellofemoral pain syndrome in a stable patellofemoral joint without trochlear dysplasia?

MATERIAL AND METHODS

Patients

Patients presenting with patellofemoral pain or instability at our center between January 2018 and December 2020 were included, provided that there was no previous surgical intervention done. The study population had to fulfill the following inclusion criteria:

- symptoms of patellofemoral pain and/or instability,
- conventional two-plane radiograph and sunrise view of the knee available,
- long-leg weight-bearing radiograph (antero-posterior) available,
- torsion measurement by CT or MRI available,
- mentioned imaging accessable via digital PACS,
- medical records/history accessable.

The exclusion criteria were:

- previous knee surgery,
- osteotomy of the affected leg,
- insufficient imaging quality.

Diagnostic imaging and radiographic parameters

Femoral and tibial torsion was measured on axial CT slides, professionally obtained during a special torsion measurement ex or in domo. We measured the femoral torsion according to Waidelich as we did in many previous studies due to its high reliability and availability of comparable values (20). Measuring was done by a resident physician with the mediCAD 2D program and controlled by a certified knee specialist senior consultant orthopaedic surgeon. The above mentioned conventional X-rays had been obtained during regular diagnostic work-up of patellofemoral complaints. The lateral knee radiograph of the knee was done in approximately 45° of flexion.

Long-leg weight-bearing radiographs were obtained in accordance with Paley using a 1.3 m cassette (Global Imaging Baltimore, MD). Long-leg antero-posterior standing radiographs were obtained with the patient standing in a bipedal stance in front of the long film cassette. The X-ray tube was positioned 305 cm away. The selected film cassette was of sufficient length to capture the hips, knees, and ankles. The magnification with this setup was approximately 5%. A magnification device (25 mm steel ball) was used to calibrate the radiographs. The X-ray beam was centered at the level of the knee joints. Radiologic technical assistants were instructed to position both legs with the patella centered between the femoral condyles pointing forward. It was of ultimate importance to ensure a standardized radiography.

The following radiographic parameters were measured:

- Hip-Knee-Ankle angle (HKA) in degrees,
- femoral torsion in degrees,
- tibial torsion in degrees,
- Caton-Dechamps-Index (CDI) of patella height (8, 9),
- Dejour-Classification of trochlea dysplasia (2),

- Oswestry-Bristol-Classification (OBC) of trochlea dysplasia (10, 16),
- TT-TG-distance (tibial tuberosity-trochlear groove distance) (7).

The Caton-Deschamps-Index (CDI) was used to measure patella height and to identify patella alta. It was measured on a lateral radiograph of the knee joint. A CDI >1.3 was classified as patella alta.

Trochlea dysplasia (TD) was present, if the trochlea angle was greater than 145°. This complies with the Dejour classification of TD (2). As a more reliable classification system firstly reported by Sharma et al. in 2020, we also investigated the correlation between patella instability and the Oswestry-Bristol classification (OBC) (16). This is a classification system that marks a threshold for TD at < 11° between the lateral trochlea and the posterior femoral condylar line (10). This is defined as the lateral trochlea index (LTI).

Statistical analysis

To better categorize patients' patellofemoral characteristics, these were categorized in present or absent features. This results in a nominal distribution of values. We therefore used Pearson Chi-square Test to investigate the correlation between patellofemoral characteristics.

A p value of < 0.05 was considered statistically significant. The Coefficient of Contingency φ showed the strength of the correlation between two nominal values. SPSS version 24 (IBM, Armonk, NY, USA) was used.

RESULTS

In this study, 77 patients were included: 47 males (61.0%) and 30 females (39.0%). The mean patient age was 27.3 (min. 18, max. 44) years. 13 patients had complaints on both knees. In total, 90 knees were analyzed. In this cohort of patients, age and gender had no significant influence on patella instability.

Qualitatively, the correlation between TD and patella dislocation rate is significant (Table 1). Also quantitatively, the correlation between the OBC and dislocation rate is significant. Most cases of TD in the analyzed patient cohort were a Dejour A type. As the OBC, the LTI does also correlate significantly with patellofemoral instability; and also, the trochlea angle showed a significant impact on patellofemoral instability per se. In female patients, the relative number of cases with trochlea dysplasia was significantly higher than in males (Table 2).

Table 1. Correlation of trochlea dysplasia with patellofemoral dislocations

Trochlea form	Patellofemoral pain	Patellofemoral instability
normal	64.3 %	9.7 %
dysplastic	35.7 %	90.3 %

The results in table 1 demonstrate a significant correlation between OBC and dislocation events: $\chi^2(1)=8.152$, p=0.043, $\varphi=0.288$.

Table 2. Correlation of gender with trochlea dysplasia

Gender	Normal Trochlea	Trochlea Dysplasia
male	79.2 %	54.5 %
female	20.8 %	45.5 %

Table 3. Correlation of patella height and dislocation events

Patella norma or alta	Patella dislocation: no	Patella dislocation: yes	Significance
CDI < 1.3	31	17	n. s.
CDI > 1.3	25	8	n. s.

CDI: Caton-Deschamps index

The femoral antetorsion angle (FAA) per se does not correlate with patella dislocation. In cases with high FAA of more than 25° in combination with TD, the dislocation rate increased nearly sixfold compared to FAA > 25° alone (without TD). In 35% of patients with patellofemoral pain and no event of patella dislocation, we found a high FAA > 25° without TD. 46% of the female patients had a TD whereas 55% of the male patients had a dysplastic trochlea. The correlation between gender and trochlea dysplasia was significant.

The influence of an increased patella height on patella instability: as shown in table 3, there was no significant correlation found between patella alta and patella instability. There was also no correlation between HKA (valgus or varus alignment) and the patella dislocation rate.

DISCUSSION

This study presents a clinical-radiological characterization of patients complaining about patellofemoral pain syndrome and/or instability. Static stabilizers of the patellofemoral joint were analyzed. In this cohort of patients, a high femoral antetorsion defined over 25° had no significant influence on patellofemoral dislocations per se. A high FAA did not lead to a greater dislocation rate, if trochlea dysplasia was absent.

The results of this study demonstrate that a high FAA with a regular trochlea form rather leads to anterior knee pain. This can be explained by the increased lateral patellofemoral pressure during knee flexion and quadriceps muscle contraction, while the normal femoral trochlea prevents lateral dislocation of the patella.

This can result in cartilage damage and osteoarthritis of the lateral patellofemoral joint (4). The described biomechanics of this pathomorphology also lead to increasing strain in the medial patellofemoral ligament (MPFL) and thereby to a higher risk of failure and instability over time.

On the other hand, we demonstrated that TD has a significant influence on patellofemoral instability - also in the absence of high femoral antetorsion. Remarkably, the combination of TD and a high FAA lead to over 60% of all patella dislocations in the whole study group. A positive correlation between TD and high femoral antetorsion was also described earlier (4).

With respect to the above mentioned findings, TD however seems to be the major factor for patellofemoral

instability. Dejour et al. showed that up to 85% of patients with symptoms of patella instability had a dysplastic trochlea (2). In the patient cohort analyzed in the present study, 90% of all unstable patellofemoral joints had a TD. This anatomic situation increases the lateralization of the patella and the probability of dislocation events.

Additional factors that are accepted as contributors to patellofemoral instability like genua valga or a high TT-TG-distance were not found to be of significant influence but can be seen as contributing factors on patellofemoral malalignment. Patella alta, patella tilt or shift as well as an increased TT-TG can therefore rather be seen as the results of TD than as independent risk factors.

TD as the major risk factor for patella instability can be inherited and could explain high familiar accumulation of patella dislocation rates (5). In this context, it can be questioned, if an isolated MPFL reconstruction in a case with present severe TD is effective. Liu et al. published that in the setting of a dysplastic trochlea, the clinical outcome measured using the Kujala score was very good, and the re-dislocation rate was low (11). Erickson et al. also revealed isolated MPFL reconstructions as an effective treatment of patellofemoral instability regardless of bony pathologies (3).

As already mentioned, the MPFL is the most important passive stabilizer of the patellofemoral joint. It stabilizes the patella in especially lower but also in higher degrees of knee flexion against lateral force vectors. In the setting of a dysplastic trochlea, this ligament can be developed insufficiently. After surgical anatomic reconstruction, the MPFL can operate effectively again (15).

It is important to mention that the above cited publications were short-term studies of one to two years of follow-up. It is possible that on the long-term, the MPFL-reconstruction loosens due to high strain by remaining bony malalignment. Ntagiopoulos et al. published good mid-term clinical outcomes (7 years) for a combined sulcus-deepening trochleoplasty and additional bony and/or soft tissue corrections like MPFL-reconstruction or tibial tuberosity distalization (16).

While some earlier studies demonstrated a correlation between female patients and a high femoral antetorsion, there was no significant correlation found in our cohort of patients.

In orthopaedic surgery, a comprehensive preoperative workup and analysis of the pathomorphology is essential in order to develop an individualized treatment strategy. This seems to be especially true for patellofemoral disorders.

This work has several limitations. Some bony anatomic factors that might additionally contribute to the tracking and the stability of the patellofemoral joint like the tibial external rotation as part of the overall torsional limb alignment were not analyzed in this study. The active stabilizers of the patella could not objectively be included in the assessment. A direct comparison with a healthy, symptom-free population was not possible.

CONCLUSIONS

The majority of unstable patellofemoral joints showed a dysplastic trochlea. A high femoral antetorsion was found to be an additional minor factor contributing to instability. Isolated high femoral antetorsion without trochlea dysplasia rather leads to anterior knee pain without patella dislocation. Furthermore, no direct significant correlation between patella alta and patellofemoral instability was found. This information is important and should be considered in each individual conservative and operative therapy plan.

Abbreviations:
FAA: femoral antetorsion angle
LTI: lateral trochela index
MPFL: medial patellofemoral ligament
OBC: Oswestry Bristol Classification
TD: trochlea dysplasia
TT-TG: tibial tuberosity-trochlear groove distance

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