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ORIGINAL PAPER

Combined supracondylar femoral derotation osteotomy and patellofemoral ligament reconstruction for recurrent patellar dislocation and severe femoral anteversion syndrome: surgical technique and clinical outcome

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Abstract
Purpose Severly increased femoral anteversion is an important risk factor for patellofemoral instability. Recurrent dislocations cause a traumatic disruption of the medial patellofemoral ligament. Therefore a procedure that combines femoral derotation osteotomy and patellofemoral ligament reconstruction should be considered for patients with severely increased femoral anteversion. The aim of the study was to evaluate the subjective and objective outcomes after combined femoral derotation osteotomy and anatomical reconstruction of the MPFL.
Methods 12 consecutive patients (12 knees) with patellofemoral instability and severely increased femoral anteversion underwent combined femoral derotation osteotomy and anatomical reconstruction of the MPFL. Preoperative radiographic examination included AP and lateral views to assess patella alta. MRI was performed to evaluate trochlear dysplasia and tibial tubercle-trochlear groove (TT-TG) distance. Additionally, MRI assessment of the rotational profile was performed. Evaluation included evaluation of cartilage injuries, preoperative and postoperative physical examination, visual analog scale (VAS), Kujala score, International Knee Documentation Committee score (IKDC), Activity Rating Scale (ARS) and Tegner activity score.
Results The average age at the time of operation was 18.2 years (range, 15–26 years). The average follow-up after operation was 16.4 months postoperatively (range, 12–28 months). No recurrent dislocation occurred. The results showed a significant improvement of the Kujala score, IKDC score and VAS ($p<0.01$). The activity level according to the Tegner activity score and ARS did not show statistically significant changes ($p=0.75$; $p=1.0$).
Conclusion Combined anatomical reconstruction of the MPFL and femoral derotation osteotomy resulted in significant improvement of knee function and good patient satisfaction in young patients with severely increased femoral anteversion. No re-dislocation of the patella occured.

Keywords Increased femoral anteversion · Patellofemoral instability · MPFL · Knee · Patellar dislocation

Introduction

The contribution of femoral internal torsion to anterior knee pain and patellofemoral instability has long been underestimated [6]. Increased femoral anteversion leads to an internally rotated gait unless compensated by external torsion of the tibia, which rotates the leg outward to maintain a normal foot progression angle [28]. In the knee, increased femoral internal torsion results in abnormal patellofemoral loads and the tendency for lateral subluxation [9, 16, 17, 29]. Parikh et al. [24] demonstrated that in patients with normal foot progression, medial orientation of the knee results in increased tension of the medial patellofemoral ligament, increased forces on lateral patellar facet and decreased forces on medial facet. Rotational malalignment may therefore be a

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primary risk factor in patellar dislocation [7, 8, 11, 24, 29]. In a CT-study, H. Dejour et al. [7] found that femoral anteversion in controls was 10.8 and 15.6° in patients with objective patellar instability ($P=0.013$). Similarly in an MRI study, Diederichs et al. [8] found a 1.56-fold higher mean femoral anteversion in patients with a history of patellofemoral instability compared with controls.

As the MPFL is the main static restraint to lateral displacement of the patella, its reconstruction to prevent recurrent dislocations has become increasingly popular. In patients with severely increased femoral anteversion however, MPFL reconstruction as an isolated procedure might not be sufficient, as it does not address the underlying increased femoral torsion [22, 24]. Additionally there is concern over residual or ongoing patellofemoral pain because of increased forces in the patellofemoral joint.

A combined correction of femoral anteversion and reconstruction of the MPFL is therefore reasonable in this patient group with rotational abnormalities, when doing a primary stabilization procedure. This study describes the operative technique and the clinical outcome of 12 patients with a minimum follow-up of 12 months after combined femoral derotation osteotomy and patellofemoral ligament reconstruction for recurrent patellar dislocation.

We hypothesised that in patients with severely increased femoral anteversion, combined correction of femoral anteversion and reconstruction of the MPFL would prevent redislocation of the patella and lead to improved knee function.

Materials and methods

Patients

This study was approved by the ethics committee of the institution. Between 2011 and 2013, 12 patients with severely increased femoral anteversion underwent combined femoral derotation osteotomy and reconstruction of the MPFL. Inclusion criteria were patients with severely increased femoral anteversion (anteversion angle >25°) (Fig. 1), who had experienced at least two recurrent dislocations of the patella despite a non-operative treatment program. Patients with high-grade trochlear dysplasia were excluded, as in these patients an additional trochleoplasty was performed. Only patients with a minimum follow-up of 12 months were included in this study.

Anatomical reconstruction of the MPFL was performed using a pedicled superficial quadriceps tendon graft. All operations were performed by the author.

Evaluation methods

Preoperative radiographic examination of the knee included AP (standing, weightbearing) and lateral views to assess patella alta, signs of malalignment and to exclude further skeletal abnormalities. Patellar height was measured on lateral radiographs utilizing the method described of Insall and Salvati [13].

Fig. 1 View from the front visualizing the squinting patellae on both sides with both femurs having greater than 30° anteversion

In all patients, tibial and femoral torsion were evaluated by magnetic resonance imaging as described by Tomczak at al. [31]. Femoral anteversion was defined as the angle formed between a line parallel to the femoral neck (femoral neck axis) and the distal femur (defined by a line running through the most posterior points of the medial and lateral femoral condyles). Severely increased femoral anteversion was defined when the measured anteversion angle exceeded 25°.

Tibial torsion was defined as the angle formed between a line parallel the posterior border of the tibial plateau and a line and a line drawn through the centers of the medial and lateral malleolus on an axial view [30].

In all patients, trochlear dysplasia and the TT-TG distance were evaluated by magnetic resonance imaging (MRI). To assess trochlear dysplasia, the most proximal cradiocaudal axial MRI slice (fat- saturated proton density–weighted fast spin echo imaging sequence; 1.5-T VA17A Symphony, A Tim System, Siemens, Munich, Germany), on which the cartilage along the entire width of the trochlea was visible, was analyzed. Only patients with no or mild trochlear dysplasia were included in the study. Severe trochlear dysplasia was defined as the presence of a dome-shaped chondral surface of the proximal trochlea. The distance between the tibial tuberosity

and the trochlear groove (TT-TG) was evaluated on superimposed axial slices. All measurements were performed by the same observer.

Pre- and postoperative knee assessment consisted of evaluation of symptoms and clinical examination, including, crepitus, range of motion, patellofemoral pain and patellar apprehension. Femoral anteversion was measured clinically according to the technique described by Ruwe et al. [26].

Knee function was assessed with the Kujala score [15], International Knee Documentation Committee score (IKDC) [14], Activity Rating Scale (ARS) [18], Tegner activity score [30] and visual analog scale (VAS). Patient satisfaction with the procedure was also recorded. The final clinical outcome was rated as very satisfied (knee function much exceeded their preoperative status), satisfied (knee function improved with no subluxation), partially satisfied (knee function improved but still apprehensive), not satisfied (knee function same as preoperative status with one or more episodes of patellar subluxation).

Surgical technique

All patients were examined under anaesthesia. An arthroscopy was then performed via a standard lateral portal to rule out further intraarticular pathologies and to evaluate the trochlear and retropatellar cartilage. An additional superolateral portal was used to visualize the proximal part of the patellofemoral joint. Trochlear dysplasia and chondral defects were assessed. The degree of degenerative changes of the patellofemoral joint was recorded according to ICRS [3].

Femoral derotation osteotomy

A longitudinal incision was made beginning inferiorly at the superomedial border of the patella. The subcutaneous tissue was incised and the fascia of the vastus medialis muscle was dissected. The muscle was then elevated and dissected as far as necessary from the intermuscular septum.

The distal insertion of the vastus medialis muscle was incised just proximal to the medial patellofermoral ligament at the distal end of the exposure. The intermuscular septum was then incised carefully, close to the bone and parallel to the femoral shaft. The soft tissues at the back of the knee were separated from the distal femur. A blunt Hohmann retractor was used to protect the neurovascular bundles behind the femoral shaft. The position of the osteotomy and plate were then determined on the anteromedial femur, with care taken to remain proximal to the site of MPFL graft fixation (Fig. 2). Two Schanz screws were then inserted parallel, proximal and distal to the planned osteotomy in order to facilitate derotation (Fig. 3a). It is important to place the Schanz screws in a position where they do not impede later positioning of the plate. Two parallel Kischner wires were placed under image intensifier perpendicular to the femoral shaft in order to guide the direction of the osteotomy. (Fig. 2). The osteotomy was performed with drill holes and with an oscillating saw, protecting the soft tissue with a Hohmann retractor. Derotation of the distal fragment was then performed to the desired amount of correction (Fig. 3b). Care was taken to avoid a sagittal or coronal plane deformity. Definitive fixation of the osteotomy was performed with a locking compression plate (TomoFix Medial Distal Femur Plate, Synthes, Umkirch, Switzerland) according to the manufacturer's recommendations (Fig. 3b).

Fig. 2 Intraoperative fluoroscopy demonstrating the level of the planned osteotomy (transverse K wire) and projected position of the locking plate proximal of the femoral insertion of the MPFL

Reconstruction of the MPFL was performed using a pedicled quadriceps graft.

Through the same incision, the subcutaneous tissues were divided to expose the quadriceps fascia and tendon. The initial superficial vertical incision of the tendon was made 2 to 3 cm proximal to the superior patellar pole because the superficial slip of the tendon is easiest to differentiate at this level [21]. In addition, this incision was made 2 to 4 mm lateral to the border of the vastus medialis, thus preserving a thin strip of the medial tendon (Fig. 4a). The second vertical incision was made into the tendon approximately 12 to 15 mm lateral to the first, thus determining the width of the graft [21].

The most superficial layer of the quadriceps tendon was elevated from the deeper tendon (Fig. 4b). Staying in the same plane, the graft was then carefully dissected superiorly, as far as the musculotendinous junction of the rectus femoris if possible.

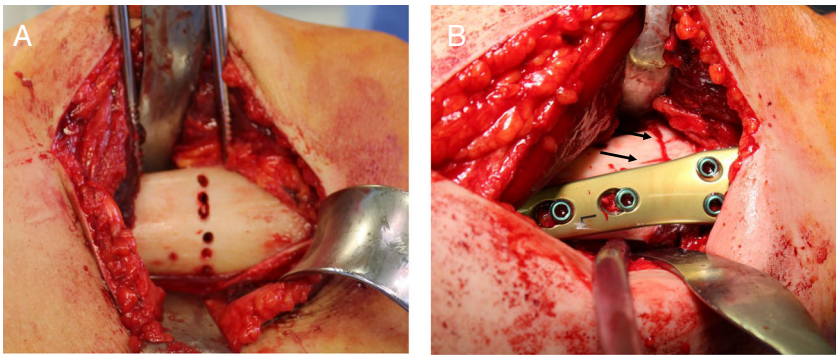

Fig. 3 Intraoperative photograph demonstrating the two Schanz screws inserted into the femur proximal and distal to the planned osteotomy in order to facilitate derotation. The osteotomy was performed with drill holes and with an oscillating saw (**a**). Fixation with a locking plate after a femoral derotation osteotomy. The degree of desired correction is visualized by the small vertical cuts (*black arrows*) (**b**)

The graft was divided at its superior end and reflected to expose the posterior surface. Harvesting of the graft then continued distally to a point over the proximal patellar third. The superficial slip of the quadriceps tendon inserts into the anterior portion of the base and the superior third of the anterior surface of the patella [21]. Care was taken not to accidentally divide the graft at its inferior attachment to the patella during dissection.

By blunt dissection the interval between the capsule and the vastus medialis obliquus was developed to the femoral insertion of the MPFL. Using the indirect radiographic method [27] the anatomical femoral insertion of the MPFL was identified under fluoroscopic control. A guide pin was placed at the femoral insertion. Fluoroscopy was used to confirm the correct placement of the guide-pin. After verification of the entry-point the guide-pin was drilled to the lateral condyle. The direction of the drill hole was determined under radiographic control in order to avoid collision with the screws of the locking plate (Fig. 5a). Then a medial blind tunnel was drilled along the guide pin to accommodate a single thickness of graft to an adequate depth to allow optimal graft tensioning. The graft was then passed between the second and third layers of the medial retinaculum to the femoral insertion point. A locking suture was passed through the transepicondylar axis pulling the graft into the medial tunnel (Fig. 5b). The knee was cycled several times from full flexion to full extension with the graft under tension. The graft was then secured within the medial condyle tunnel using a bioresorbable interference screw with the knee flexed to 30° avoiding excessive tightening of the graft. Finally, closure of subcutaneous tissues and skin was performed. Routine dressings and bandages were applied.

Rehabilitation

Postoperatively, partial weight-bearing using crutches was allowed. Daily physiotherapy with active and passive flexion and extension exercises of the knee, strengthening of the vastus medialis muscle and straight leg-raise exercises was recommended. Full weight-bearing was allowed at 6 weeks and return to sport earliest at the third postoperative month depending on radiological evidence of healing.

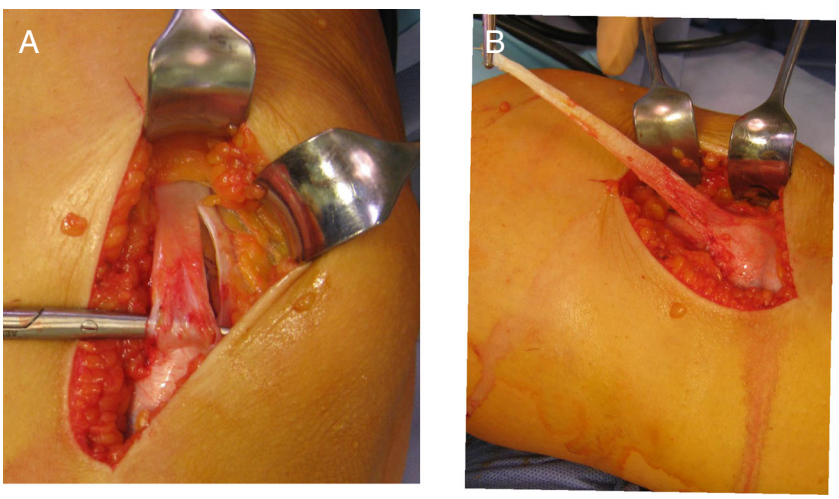

Fig. 4 Intraoperative photograph demonstrating incision of the quadriceps tendon lateral to the border of the vastus medialis (**a**). The superficial slip of the quadriceps tendon is elevated from the deeper tendon. Staying in the same plane, the graft is then carefully dissected superiorly, keeping the middle and deep laminae intact (**b**)

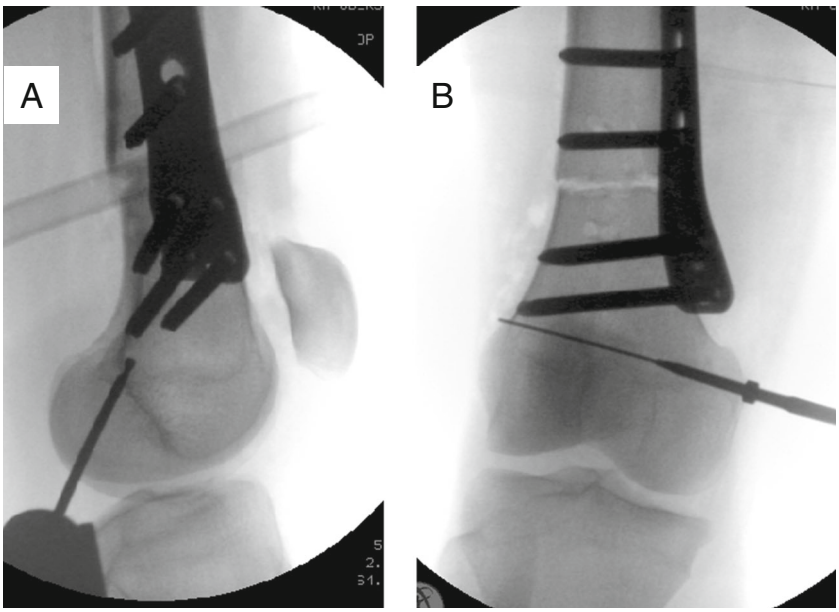

Fig. 5 Intraoperative fluoroscopy demonstrating the relation of the femoral insertion of the MPFL graft in relation to the locking plate and screws (**a**). A horizontal direction of the drill hole prevents collision with the screws (**b**)

Statistical analysis

Continuous variables were summarized as median, minimum and maximum. Nominal and ordinal variables were analyzed using frequencies. The values of preoperative and postoperative scores were compared using the Wilcoxon signed-rank test. The interrelation between patellar height, TT-TG, femoral anteversion and tibial torsion and outcome scores was investigated using the Spearman's rank correlation coefficient. Statistical analysis was carried out using SAS 9.2 (SAS Institute, Cary, NC, USA). Due to the explorative nature of this study, no adjustment for multiple testing was made. A p-value less than 0.05 was considered significant. The results of all statistical tests are interpreted in an exploratory sense.

Results

There were 12 combined femoral derotation osteotomies and reconstruction of the MPFL performed with no loss to followup. The mean age of the patients at the time of operation was 18.2 years (range, 15–26 years). The average postoperative follow-up was 16.4 months (range, 12–28 months). 2 patients had undergone previous surgery (medial reefing) prior to the index surgery. All patients were female.

Preoperative AP and lateral radiographs and MRI were available for all patients. Patient characteristics are described in Table 1.

Preoperative physical examination showed a positive apprehension-sign in all patients. The J-sign was positive in 7/12 patients.

At arthroscopy, chondral lesions of the retropatellar cartilage ICRS grade 1 were observed in 7 knees and grade 2 in one knee. In four knees, no degenerative changes were detected. Chondral lesions of the trochlear cartilage grade 1 were observed in three knees, grade 2 in one knee. In 8 out of 12 patients, no degenerative changes were detected.

Clinical outcome

There have been no recurrent dislocations. All patients had healing of their osteotomy. A mild flexion deficit of 10° was measured in 2 knees at follow up, without subjective impairment. No extension deficit was measured. All other knees regained full extension and flexion.

Eight patients were rated as "very satisfied" with the surgical procedure, 3 patients were "satisfied" and one was "partially satisfied". No patient was not satisfied with the procedure.

The median Kujala-score improved significantly from 69 preoperatively (range, 46–77) to 92.5 at follow-up (range, 73–100, $p<0.01$). The median IKDC-score improved

Table 1 Patient characteristics

Variable	Value
Age at time of primary surgery y, median (range)	18.2 (15–26)
Follow-up (range), mo	16.4 (12–28)
Male patients, n	0
Female patients, n	12
Patients with previous operations, n	2
Insall-Salvati index, median (range)	1.2 (1.05–1.3)
Tibial tuberosity–trochlear groove distance, cm, median (range)	1.7 (1.5–2.0)
Femoral anteversion, median (degree)	33.8 (28–40)
Tibial torsion, median (degree)	31.7 (26–38)

significantly from 60 preoperatively (range, 32–80) to 85 at follow-up (range, 75–95, $p<0.01$). The patients were additionally asked to compare their function pre- and postoperatively on a scale from zero (cannot perform daily activities) to ten (no limitation in daily activities). The median knee function improved significantly from 5 (range, 3–7) preoperatively to 8 (range, 6–10) at follow-up ($p<0.01$). The median VAS illustrated significant preoperative to postoperative improvement from 4 (range, 1–6) to 1.5 (range, 0–3) ($p<0.01$). Additionally 8 patients emphasized the better cosmetic alignment of the patella with reduced squinting of the patella and improved squatting of the knee.

The Spearman's rank correlation coefficient did not reveal a significant relation between extent of femoral anteversion, tibial torsion, patella alta and Kujala and IKDC scores.

The activity level according to the Tegner activity score increased from 4.0 preoperatively (range, 2–8) to 4.5 postoperatively (range, 3–8), which was not statistically significant ($p=0.75$), (Table 2). The median ARS did not show statistically significant changes from 5 preoperatively (range, 2–16) to 5 at follow-up (range, 2–16) ($p=1.0$) (Table 2).

Complications

Two patients required a prolonged rehabilitation for limited flexion 6 weeks after surgery. Full range of motion was achieved after an intensified physiotherapy program. No delayed unions of the osteotomy, no wound infections or deep infections occurred.

Discussion

In this prospective study, combined femoral derotation osteotomy and anatomical reconstruction of the MPFL led to significant improvement of knee function and good patient satisfaction in young patients with severely increased femoral anteversion and patellofemoral instability. There were no redislocations and an overall low complication rate.

Table 2 Comparison of pre- and post-operative Kujala Knee Function Score, International Knee Documentation Commitee Score (*IKDC*), visual analog scale (*VAS*), Tegner Activity Score and Activity Rating Scale (*ARS*)

Score	Pre-operative score	Post-operative score	*p*-value
Kujala score	69 (46 to 77)	92.5 (73 to 100)	<0.01
IKDC score	60 (32 to 80)	85 (75 to 95)	<0.01
VAS	4 (1 to 6)	1.5 (0 to 3)	<0.01
Tegner score	4 (2 to 8)	4.5 (3 to 8)	=0.75
ARS	5 (2 to 16)	5 (2 to 16)	=1.0

Values are expressed in median (range)

p significant at<0.05 (Wilcoxon signed-rank test)

Various authors have emphasized the role that rotational malalignment plays as a risk factor for patellofemoral instability [7, 11, 24]. Diederichs et al. [8] postulated that increased femoral torsion might be a primary risk factor in patellar dislocation that has so far been underestimated. The mechanical basis for the increased risk likely lies with an increased in the Q angle resulting from the femoral anteversion, which increases laterally directed forces on the patella [24]. It can even be speculated, that there may be long term benefits to derotating the femur in this patient population, because of the potential for decreasing cartilage overload.

Compared with frontal- and sagittal-plane deformities of the lower limb, which are apparent on clinical examination and conventional radiographs, rotational deformities are often missed or ignored because of difficulties in their assessment [6]. Moreover, a higher index of suspicion for rotational malaligment is required when assessing patients with recurrent patellofemoral instability.

Reconstruction of the MPFL as an isolated procedure has shown good results [2, 4, 5, 12]. However in the presence of increased femoral anteversion, reconstruction of the MPFL without concomitant correction of the torsional deformity may be at increased risk of failure since the laterally-directed patellofemoral joint forces are unaddressed and lead to increased tension across the MPFL reconstruction [22, 24].

When a patient remains symptomatic with patellofemoral pain or instability in presence of an increased Q angle, a frequently recommended surgical procedure is a medialization osteotomy of tibial tubercle. However, this osteotomy increases the external tibial torsion and, in the presence of underlying rotational malalignment, may exacerbate symptoms [24].

Although there are numerous studies emphasizing the importance of increased femoral anteversion as risk a factor for patellofemoral instability [7, 8, 11, 29], there are no studies evaluating the operative treatment in this group of patients. Femoral derotational osteotomy for persistent femoral anteversion is performed most commonly in adolescents and young adults, as remodelling after this age is minimal [19, 25].

Whereas there are several studies that evaluated the combined reconstruction of the MPFL with a tibial tuberosity transfer or trochleoplasty [1, 10, 20, 23], to our knowledge this is the first study that describes the technique and clinical outcome of a combined femoral derotation osteotomy and anatomical reconstruction of the MPFL in patients with patellofemoral instability and increased femoral anteversion.

Interestingly, in our study group there were no patients with increased external tibial torsion, which may typically be found in patients with miserable malalignment. This however concurs with two previous studies, which also found increased femoral anteversion without increased external tibial torsion

in patients with patella dislocations [7, 8]. Using CT, Dejour et al. [7] found a significant difference in femoral anteversion between patients with dislocations and controls (15.6° vs. 10.8°) but no significant difference for external tibial torsion (33° vs. 35°).

In the study by Diederichs et al. [8] no significant differences in tibial torsion were found in patients with patellofemoral instability compared to the control group. Consequently, no tibial derotation osteotomies had to be performed in our study group. In patients with clinically increased anteversion, magnetic resonance imaging (MRI) to assess abnormal rotational alignment of the lower limb is recommended. When an increased anteversion is present, a concomitant derotational osteotomy should be considered.

Several surgical technique issues need to be considered when performing a femoral derotation osteotomy in combination with a MPFL reconstruction.

1. Violation of the MPFL graft can be avoided by carefully planning the level of the osteotomy so that the distal tip of the plate is placed proximal to the MPFL femoral tunnel.
2. The direction of the femoral tunnel for MPFL graft placement has to be confirmed by fluoroscopy in order to avoid collision with the screws of the locking plate.

The significant improvement in IKDC and Kujala scores and the decrease in VAS pain levels demonstrate the ability of the combined femoral derotation osteotomy and anatomical reconstruction of the MPFL to improve function and relieve clinical symptoms of patients with patellofemoral instability. Additionally, some patients in our series described increased comfort when walking and squatting, which we hypothesize is probably due to the corrected intoeing.

Although in our cohort no major complications occurred, there are different downsides of the procedure, which have to be discussed with the patient: The risk non-union or malunion, over or under correction. Need for plate removal and possibly the need to do a derotation osteotomy on the other leg so they are symmetric.

In our patient cohort, physical activity as measured with the Tegner activity score and the activity rating scale did not increase significantly in the postoperative period. This was despite there being no redislocations and 92 % of the patients reporting being satisfied or very satisfied with their knee function. Most patients were concerned about the risk of redislocation during vigorous sports and therefore personally chose to limit their activities.

A major strength of this case series is the fact that all operations were performed by a single surgeon and that a standardised operative technique without additional procedures was evaluated. There are obvious limitations of this study. The numbers are relatively small and only short-term results are reported. Although the combined procedure was found to be successful, the long-term outcome is not yet known. Another limitation of the study is the lack of a control group. Because the combined procedure has become the standard procedure in our institution in patients with severe rotational abnormalities and patellofemoral instability a control group is not available at our center.

Conclusion

Combined anatomical reconstruction of the MPFL and distal femoral derotational osteotomy resulted in significant improvement in knee function, good patient satisfaction and no recurrent dislocations with acceptable morbidity in young patients with increased femoral anteversion and patella instability.

References

1. Banke IJ, Kohn LM, Meidinger G, Otto A, Hensler D, Beitzel K, Imhoff AB, Schöttle PB (2014) Combined trochleoplasty and MPFL reconstruction for treatment of chronic patellofemoral instability: a prospective minimum 2-year follow-up study. Knee Surg Sports Traumatol Arthrosc 22:2591–2598
2. Bicos J, Fulkerson JP, Amis A (2007) Current concepts review: the medial patellofemoral ligament. Am J Sports Med 35:484–492
3. Brittberg M, Winalski CS (2003) Evaluation of cartilage injuries and repair. J Bone Joint Surg Am 85-A(Suppl 2):58–69
4. Buckens CF, Saris DB (2010) Reconstruction of the medial patellofemoral ligament for treatment of patellofemoral instability: a systematic review. Am J Sports Med 38:181–188
5. Camp CL, Krych AJ, Dahm DL, Levy BA, Stuart MJ (2010) Medial patellofemoral ligament repair for recurrent patellar dislocation. Am J Sports Med 38:2248–2254
6. Cooke TD, Price N, Fisher B, Hedden D (1990) The inwardly pointing knee: an unrecognized problem of external rotational malalignment. Clin Orthop Relat Res 260:56–60
7. Dejour H, Walch G, Nove-Josserand L, Guier CH (1994) Factors of patellar instability: an anatomic radiographic study. Knee Surg Sports Traumatol Arthrosc 2:19–26
8. Diederichs G, Köhlitz T, Kornaropoulos E, Heller MO, Vollnberg B, Scheffler S (2013) Magnetic resonance imaging analysis of rotational alignment in patients with patellar dislocations. Am J Sports Med 41:51–57
9. Eckhoff DG, Montgomery WK, Kilcoyne RF, Stamm ER (1994) Femoral morphometry and anterior knee pain. Clin Orthop Relat Res 302:64–68
10. Feller JA, Richmond AK, Wasiak J (2014) Medial patellofemoral ligament reconstruction as an isolated or combined procedure for recurrent patellar instability. Knee Surg Sports Traumatol Arthrosc 22:2470–2476
11. Hawkins RJ, Bell RH, Anisette G (1986) Acute patellar dislocations: the natural history. Am J Sports Med 14:117–120
12. Howells NR, Barnett AJ, Ahearn N, Ansari A, Eldridge JD (2012) Medial patellofemoral ligament reconstruction: a prospective outcome assessment of a large single centre series. J Bone Joint Surg (Br) 94:1202–1208

13. Insall J, Salvati E (1971) Patella position in the normal knee joint. Radiology 101:101–104
14. Irrgang JJ, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P, Richmond JC, Shelborne KD (2001) Development and validation of the international knee documentation committee subjective knee form. Am J Sports Med 29:600–613
15. Kujala UM, Jaakkola LH, Koskinen SK, Taimela S, Hurme M, Nelimarkka O (1993) Scoring of patellofemoral disorders. Arthroscopy 9:159–163
16. Lee TQ, Morris G, Csintalan RP (2003) The influence of tibial and femoral rotation on patellofemoral contact pressure. J Orthop Sports Phys Ther 33:686–693
17. Lee TQ, Anzel SH, Bennett KA, Pang D, Kim WC (1994) The influence of fixed rotational deformities of the femur on the patellofemoral contact pressures in human cadaver knees. Clin Orthop Relat Res 302:69–74
18. Marx RG, Stump TJ, Jones EC, Wickiewicz TL, Warren RF (2001) Development and evaluation of an activity rating scale for disorders of the knee. Am J Sports Med 29:213–218
19. Mooney JF (2014) Lower extremity rotational and angular issues in children. Pediatr Clin North Am 61:175–1183
20. Nelitz M, Dreyhaupt J, Lippacher S (2013) Combined trochleoplasty and patellofemoral ligament reconstruction for recurrent patellar dislocation in severe trochlear dysplasia. A minimum two years follow-up study. Am J Sports Med 41:1005–1012
21. Nelitz M, Williams SR (2014) Anatomical reconstruction of the medial patellofemoral ligament in children and adolescents using a pedicled quadriceps tendon graft. Arthrosc Tech 28(3):e303-8
22. Nelitz M, Williams SRM, Lippacher S, Reichel H, Dornacher D (2014) Analysis of failure and clinical outcome after unsuccessful medial patellofemoral ligament reconstruction in young patients. Int Orthopaedics 38:2265–2272
23. Ntagiopoulos PG, Byn P, Dejour D (2013) Midterm results of comprehensive surgical reconstruction including sulcus-deepening trochleoplasty in recurrent patellar dislocations with high-grade trochlear dysplasia. Am J Sports Med 41:998–1004
24. Parikh S, Noyes FR (2011) Patellofemoral disorders: role of comput- ed tomography and magnetic resonance imaging in defining abnormal rotational lower limb alignment. Sports Health 3: 158–169
25. Payne LZ, DeLuca PA (1994) Intertrochanteric versus supracondylar osteotomy for severe femoral anteversion. J Pediatr Orthop 14:39–44
26. Ruwe PA, Gage JR, Ozonoff MB, DeLuca PA (1992) Clinical determination of femoral anteversion: a comparison with established techniques. J Bone Joint Surg Am 74:820–830
27. Schoettle PB, Schmeling A, Rosenstiel N, Weiler A (2007) Radiographic landmarks for femoral tunnel placement in medial patellofemoral ligament reconstruction. Am J Sports Med 35: 801–804
28. Staheli LT, Corbett M, Wyss C (1985) Lower extremity rotational problems in children: normal values to guide management. J Bone Joint Surg Am 67:39
29. Steensen RN, Bentley JC, Trinh TQ, Backes JR, Wiltfong RE (2015) The prevalence and combined prevalences of anatomic factors associated with recurrent patellar dislocation: a magnetic resonance imaging study. Am J Sports Med 43:921–927
30. Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. Clin Orthop 198:43–49
31. Tomczak RJ, Guenther KP, Rieber A, Mergo P, Ros PR, Brambs HJ (1997) MR imaging measurement of the femoral antetorsional angle as a new technique: comparison with CT in children and adults. Am J Roentgenol 168:791–794