Evaluation of Patellar Dysplasia and Postoperative Pain After Mini-Open, Thin-Flap Trochleoplasty

A Retrospective Analysis of 75 Consecutive Cases

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Background: The association between inherent patellar anatomy and postoperative pain after trochleoplasty in patients with patellar instability is poorly understood.

Purpose/Hypothesis: The study purpose was to evaluate outcomes after mini-open, thin-flap trochleoplasty. The hypothesis was that more severe patellar dysplasia would be correlated with increased postoperative pain after trochleoplasty.

Study Design: Case series; Level of evidence 4.

Methods: Patients with patellar instability who underwent mini-open, thin-flap trochleoplasty in combination with other individualized procedures between 2013 and 2022 were included. Patellar dysplasia was evaluated by calculating the Wiberg index at the widest and most distal cartilaginous parts of the patella on preoperative magnetic resonance imaging. At the postoperative follow-up, participants completed the visual analog scale for usual pain (VAS-U), Banff Patellofemoral Instability Instrument 2.0 (BPII), global rating of change scale, and an evaluation of their current symptom state. Redislocations and complications were recorded. The correlation between the Wiberg index and the VAS-U was calculated with the Spearman rho. Between-group analyses based on demographic and pathoanatomic features were conducted using the Mann-Whitney *U* test, independent-samples *t* test, and chi-square test.

Results: Included were 75 knees in 63 patients (median age at surgery, 19.1 years; IQR, 16-22 years) with a median follow-up of 44 months (IQR, 23.8-83.2 months). The median BPII score was 78.2 (IQR, 54.8-92.5), with 88% reporting an improvement in knee function relative to before surgery, but 21.1% remained dissatisfied with their current knee symptom state. New episodes of patellar dislocation were seen in 3 knees (4%), and 14 knees (18.7%) underwent reoperation with either revision surgery (n = 7; 9.3%) or arthroscopic synovectomy (n = 7; 9.3%). A weak positive, nonsignificant correlation was found between increased postoperative pain and a higher Wiberg index, both at the widest (r_S = 0.16; P = .23) and most distal (r_S = 0.02; P = .89) parts of the patella. Significantly worse VAS-U scores were seen in female versus male patients (P = .013).

Conclusion: Good patient-reported results with a low risk of redislocation were seen in the study cohort, but reoperation rates were high, and 21% of the patients remained dissatisfied with their current symptom state. More pronounced patellar dysplasia (increased Wiberg index) had only a poor association with more severe postoperative pain in the current study.

Keywords: patellar instability; trochlear dysplasia; trochleoplasty; Bereiter; mini-open trochleoplasty; patellar dysplasia

Trochleoplasty is a valid surgical procedure for the treatment of patellar instability in patients with severe trochlear dysplasia. It is usually combined with reconstruction of the medial patellofemoral ligament (MPFL) and, when indicated, other bony procedures, such as tibial tubercle osteotomy (TTO) and rotational osteotomies of the tibia or femur.[38,39] Even if the outcomes are good with a low risk of redislocation,[15,28] concerns have been raised

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regarding whether trochleoplasty can lead to irreversible chondral damage, pain, and patellofemoral osteoarthritis (OA) development.[18,32,40] However, as a result of a further refinement of the technique, and a shift in which trochleoplasty serves as a part of the primary treatment and not as a salvage procedure after previously failed surgery, complication rates have appeared to improve.[6,26,28,29,38] Nevertheless, one should consider that the procedure might lead to an alteration of patellofemoral congruency, since only the trochlear side of the joint is changed.[14] This can be reinforced by the fact that patients with patellar instability have a higher prevalence of patellar dysplasia, in terms of a shorter medical facet, compared with healthy individuals.[3,16]

Although some studies have discussed whether trochleoplasty might lead to patellofemoral incongruency in patients with pronounced patellar dysplasia,[2,25] to the best of our knowledge, no studies have investigated the effect of severe patellar dysplasia on clinical outcomes after trochleoplasty or other patellar stabilization procedures. In comparison, recent studies on total knee arthroplasty without patellar resurfacing have demonstrated increased postoperative pain in patients with more pronounced patellar dysplasia, possibly due to altered joint congruency between the femoral component with an anatomic trochlear shape and the dysplastic patella.[1,7]

In this study, we aimed to investigate the medium- to long-term outcomes of trochleoplasty using a mini-open, thin-flap technique. We hypothesized that more pronounced preoperative patellar dysplasia would be associated with increased postoperative pain in patients who underwent trochleoplasty.

METHODS

All patients who underwent trochleoplasty at a single tertiary-care university hospital between 2013 and 2022 were retrospectively identified through a selective search in the operation-planning system (Orbit Version 5.11; Evry Healthcare Systems). Their eligibility was assessed by screening relevant entries in the patient journal system. The study inclusion criteria were trochleoplasty procedures due to (1) recurrent patellar instability and (2) acute patellar dislocation with significant osteochondral injury. Excluded were patients aged <16 years as well as those with genetic syndromes, chronic fixed patellar dislocations, established patellofemoral OA, patellar pain without instability, and those having undergone revision surgery after the trochleoplasty. All surgeries were performed by experienced knee surgeons trained in treating patellofemoral conditions (including A.B.K., E.I.).

The study participants were asked to complete questionnaires and patient-reported outcome measures (PROMs). Preoperative magnetic resonance imaging (MRI) was used to assess patellar dysplasia and the pathoanatomic risk factors for patellar instability. Ethics approval was obtained for the study protocol, and written informed consent was obtained from all study participants before enrollment.

Preoperative Imaging Evaluation

The preoperative MRI scans were evaluated using Sectra software (Version 22.1; Sectra). As patellar dysplasia is characterized by a shorter medial facet, the cartilaginous Wiberg index at the widest part (Wiberg-W) was measured as described by Fucentese et al[16]: (1) the axial image with the largest patellar diameter was identified; (2) the baseline (bl) was drawn from the most medial to the most lateral subchondral edge; (3) a perpendicular line between the bl and the most posterior part of the patellar cartilage (c) was established (blc); (4) the distance between the intersection of these lines at the baseline (bc) and the lateral subchondral edge was measured (lbc); and (5) Wiberg-W was calculated as lbc/bl (Figure 1).

In addition, the Wiberg index of the most distal cartilaginous part of the patella (Wiberg-D) was measured in the same manner, as this area is most prone to dysplastic changes and is the first to enter the proximal trochlea in early flexion.[3] A larger Wiberg index indicates a shorter medial facet, and a mean Wiberg-W of 0.57 is representative of a population without patellar instability.[16] Trochlear dysplasia was assessed with the lateral trochlear inclination (LTI) angle using the 2-image technique[21] (Figure 2A). The tibial tubercle–trochlear groove (TT-TG) distance was used to measure the lateralization of the tibial tubercle.[8] A previous study by our group found excellent inter- and intrarater reliability for the TT-TG distance and LTI.[41] Patella alta was evaluated as the overlap between the trochlear and patellar cartilage on sagittal MRI using the patellotrochlear index (PTI)[5] (Figure 2B).

Surgical Technique and Rehabilitation

Patients were treated using an individualized surgical approach based on their inherent deviant patellofemoral anatomy. In all cases, an initial diagnostic arthroscopy was undertaken. Patellofemoral cartilage status was graded according to the Outerbridge classification.[37]

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Ethical approval for this study was obtained from the Regional Committee for Medical and Health Research Ethics–West (ref No. 488689).

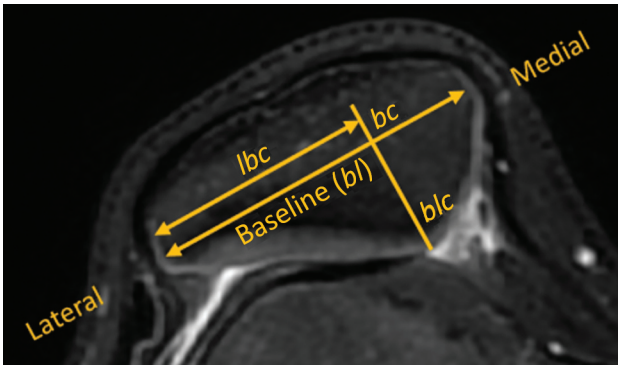

Figure 1. Patellar measurements. The baseline (*bl*) indicates the distance between the lateral and medial subchondral edge, *bc* indicates the intersection between *bl* and a perpendicular line (*blc)* drawn from the most posterior part of the patellar cartilage, and *lbc* indicates the distance from point *bc* to the lateral subchondral edge. The Wiberg index was calculated as *lbc/bl.*

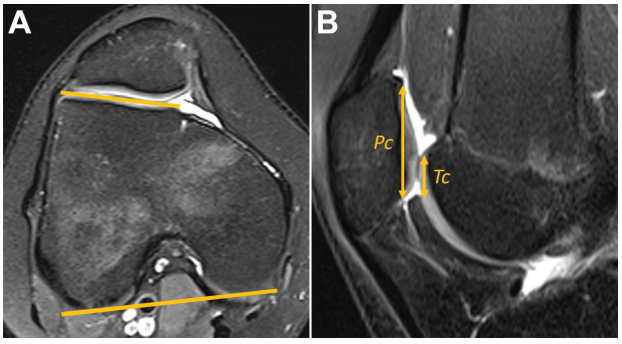

Figure 2. (A) The lateral trochlear inclination angle was defined as the angle between the posterior femoral condylar line (bottom line) and the tangent line of the most proximal trochlear cartilage (top line). A 2-image technique was used in the current study. (B) The patellotrochlear index was defined *Tc*/*Pc*, where *Pc* is the overall length of the patellar cartilage and *Tc* is the length of the overlapping trochlear cartilage.

The indications for trochleoplasty were typically a flat or convex proximal trochlea with an LTI of <11° and clinically reduced lateral trochlear support of the patella. The mini-open version of the Bereiter thin-flap technique[4,33] was used. A 4- to 5-cm lateral parapatellar incision was made before the retinaculum was split in a fashion that allowed lateral lengthening/Z-plasty at closure. The proximal and central parts of the trochlea were identified, and if present, the trochlear bump was removed using an osteotome. Then, a 3.2-mm bur was applied to undermine the cartilage in the proximal and central trochlea until plastic deformation of the cartilage was possible using manual pressure with a finger (Figure 3). The new trochlear sulcus was secured with 1 or 2 bioabsorbable SmartNail implants (CONMED). Patients with patella alta (PTI <18%) and/or a lateralized tibial tubercle (TT-TG distance >15-20 mm) with corresponding clinical findings were considered for TTO (medialization, distalization, or both). MPFL reconstruction (MPFLR) was performed in all cases, either by using a medial quadriceps tendon autograft attached to the Schöttle point[36] with a SuperQuick suture-anchor (Depuy-Mitek) or by using a gracilis autograft that was passed through an osseous channel in the proximal and medial aspects of the patella and attached to the Schöttle point with a PEEK (polyetheretherketone) interference screw (Arthrex) with the knee at 70° of flexion. Before closure, the knee was cycled through full range of motion to ensure adequate patellar tracking.

After surgery, the patients were immediately allowed full range of motion and partial weightbearing (foot touch) supported by crutches. From 4 to 6 weeks postoperatively, patients gradually increased to full weightbearing. After 6 weeks, all postoperative restrictions were lifted.

Outcome Measures

Questionnaires were administered either by mail or digitally. The incidence of postoperative recurrent patellar dislocation, reoperations, and other complications, such as infection and thromboembolism, were documented based on patient journal entries and responses to the questionnaires. Major reoperation was defined as patellofemoral revision surgery, except for screw removal or arthroscopic synovectomy.

Based on the previous 3 months, patients were asked to complete a visual analog scale for usual pain (VAS-U), with 0 indicating no pain and 100 indicating the worst imaginable pain. The VAS-U is a valid tool for assessing patellofemoral pain.[12] Patients also completed the Banff Patellofemoral Instability Instrument 2.0 (BPII), a disease-specific, quality-of-life measure ranging from 0 to 100, where a higher score indicates a higher quality of life.[23] The Norwegian version has been validated and demonstrated good psychometric properties.[19] A 5-point global rating of change (GRC) scale (1 = much worse; 2 = a little worse; 3 = no change; 4 = a little better; 5 = much better) was used to evaluate changes in knee function relative to the preoperative state. Finally, the patients were asked whether they found their present symptom state to be satisfactory (yes/no response). Suboptimal outcomes were defined as postoperative patellar dislocation, major reoperation, or deterioration/no improvement in knee status from pre- to postoperative (GRC scores 1-3).

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows (Version 26.0; IBM). The a priori significance level was set to .05. Normality was assessed using the Kolmogorov-Smirnov test. Because of the retrospective nature of this study, no formal a priori power analysis was performed. Sample size was determined based on eligible patients who underwent trochleoplasty within the given time period and were available for follow-up.

Scale variables were reported as means with standard deviations for normally distributed data or medians with

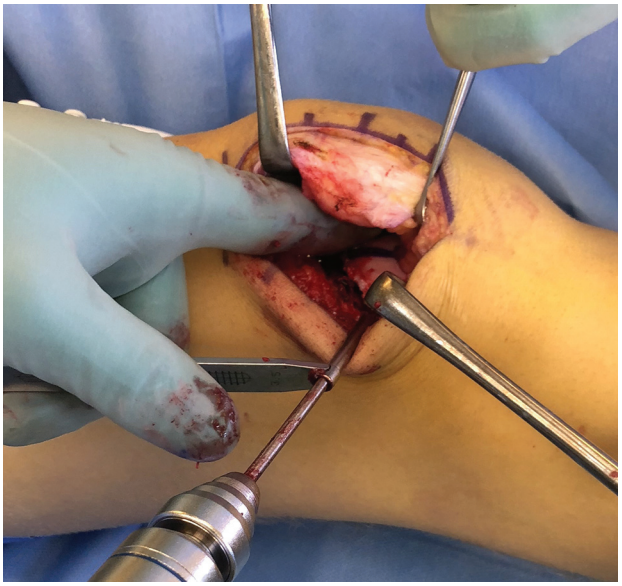

Figure 3. Mini-open, thin-flap trochleoplasty. A 3.2-mm bur was used to undermine the cartilage until deformation of the trochlear sulcus was possible.

interquartile ranges for nonnormally distributed data. The Spearman rho coefficient (r_S) was used to investigate the correlation between preoperative MRI measurements (Wiberg index, LTI, TT-TG distance, PTI) and postoperative VAS-U and BPII, and r_S values were categorized qualitatively according to Chan[10] (<0.3 indicated poor, 0.3-0.5 indicated fair, 0.6-0.8 indicated moderately strong, and >0.8 indicated very strong correlations). The Wilcoxon signed-rank test was used to evaluate changes in pre- and postoperative scores. Independent-samples *t* tests and chi-square tests were performed to analyze differences in demographic characteristics and anatomic risk factors between suboptimal and desired outcomes, and Mann-Whitney *U* tests were used to investigate whether selected patient-related and/or surgical factors influenced postoperative PROMs. The paired Student *t* test was used to evaluate the differences between Wiberg-W and Wiberg-D. The intraclass correlation coefficient (ICC) based on a single-measurement, absolute-agreement, 2-way mixed model was used to assess the inter- and intrarater reliability of Wiberg-W and Wiberg-D and was graded according to Cicchetti.[11] Two of the authors (P.A.S.W. and E.I.) independently measured both Wiberg-W and Wiberg-D, with measurements made again by one of the authors (P.A.S.W) after 8 weeks to measure intrarater reliability.

RESULTS

Included were 75 knees in 63 patients (median age at surgery, 19.1 years; IQR, 16-22 years; range, 13-35 years) and a median follow-up of 44 months (IQR, 23.8-83.2 months; range, 12-125 months). Of these, 72 knees of 61 patients were offered follow-up questionnaires, and responses

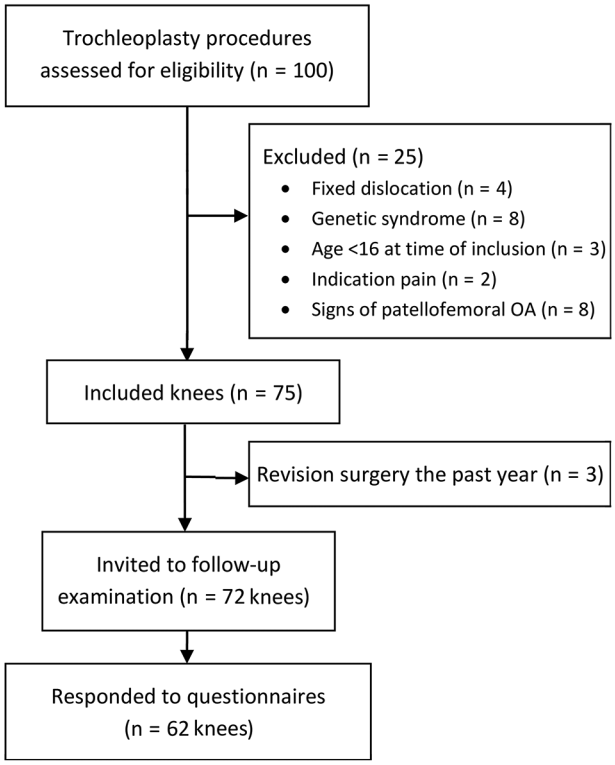

Figure 4. CONSORT (Consolidated Standards of Reporting Trials) flowchart of the patient inclusion process. OA, osteoarthritis.

were received for 62 knees of 51 patients, for an overall response rate of 86.1% (Figure 4). In those who responded, the VAS-U score was missing in 4 cases, and preoperative MRIs were not available for 2 knees.

The demographic and pathoanatomic features of the included knees are presented in Table 1. The mean difference between the Wiberg-W (mean, 0.63 ± 0.04; range, 0.50-0.73) and Wiberg-D (mean, 0.69 ± 0.06; range, 0.52-0.81) was 0.06 ± 0.06, indicating a significant increase in Wiberg index/patellar dysplasia from proximal to distal ($t = -7.1[62]$; $P = .008$). The intrarater reliability for both Wiberg-W (ICC = 0.75 [95% CI, 0.59-0.85]; $P < .001$) and Wiberg-D (ICC = 0.76 [95% CI, 0.60-0.86]; $P < .001$) was excellent, and the interrater reliability for Wiberg-W (ICC = 0.63 [95% CI, 0.39-0.78]; $P < .001$) and Wiberg-D (ICC = 0.67 [95% CI, 0.38-0.82]; $P < .001$) was good. Concomitant procedures were performed for all 75 trochleoplasties and are listed in Table 2.

Outcomes

Postoperative redislocation of the patella occurred in 3 knees (4.0%), all of which underwent revision surgery (Table 3); the PROM scores for these 3 knees were not included in the final analysis. Subjective sensation of a patellar subluxation episode occurred in 18 knees

TABLE 1
Demographic and Pathoanatomic Features at Baseline (n = 75 Knees)[a]

Variable	Value
Right knee treated	34 (45.3)
Female sex	42 (56)
Former PI surgery	11 (14.7)
Acute surgery (osteochondral injury)	2 (2.7)
Outerbridge ≥3 preoperatively	7 (9.3)
Follow-up ≥5 y	21 (28)
LTI angle, deg	–2.9 ± 7.8 (–42.7 to 10.2)
TT-TG distance, mm	16.5 ± 4.6 (8.2 to 27.0)
Patellotrochlear index	0.42 ± 0.16 (0.0 to 0.82)

[a]Data are presented as No. of knees (%) or mean ± SD (range). LTI, lateral trochlear inclination; PI, patellofemoral instability; TT-TG, tibial tuberosity–trochlear groove.

TABLE 2
Concomitant Procedures (n = 75 Trochleoplasties)[a]

Procedure	Value
MPFLR	73 (97.3)[b]
Quadriceps	19
Gracilis	49
Semitendinosus	5
Lateral procedure	75 (100)
Lateral release	13
Lateral lengthening	62
Tibial tubercle osteotomy	38 (50.7)
Medialization	24
Distalization	2
Both	12
Cartilage surgery	6 (8)
Chondroplasty/debridement	3
Refixation of osteochondral injury	3

[a]Data are presented as No. of knees, with data in parentheses indicating percentage. MPFLR, medial patellofemoral ligament reconstruction.
[b]Two knees had undergone a previous MPFLR with an intact graft at the time of the trochleoplasty procedure.

(24%). Furthermore, 4 knees (5.3%) underwent revision surgery because of pain, and 13 knees (17.3%) underwent nonrevision-related surgery, such as hardware removal and/or arthroscopic synovectomy (Table 3). No infections or thromboembolisms were observed. At follow-up, the median VAS-U was 19.0 (IQR, 2.8-36.0; range, 0-88) and the median BPII score was 78.2 (IQR, 54.8-92.5; range, 12-99). There were preoperative BPII scores available for 11 knees, and a comparison of scores by time demonstrated an improvement from a median preoperative BPII score of 41.5 (IQR, 35.8-71.0) to 77.7 (IQR, 54.0-92.2); however, the change was not statistically significant ($P = .062$). Overall, 88% of the responses indicated improved knee function from pre- to postoperative, and 78.9% indicated a satisfactory state of their current symptoms (Table 4).

TABLE 3
Types of Reoperations (n = 20 Knees)[a]

Procedure	No. of Knees
Nonrevision surgery	
Hardware removal	6
Arthroscopic synovectomy	7
Revision surgery due to instability	
MPFL revision (quadriceps to gracilis)	2
MPFL revision (quadriceps to gracilis) + medTTO	1
Revision surgery due to pain (reason for revision)	
MPFL and trochleoplasty revision (graft failure and recurrence of J-sign)	1
MedTTO (increased TT-TG distance not addressed at index surgery)	1
DFO (increased femoral anteversion not addressed at index surgery)	2

[a]DFO, derotational femoral osteotomy; medTTO, tibial tubercle osteotomy (medialization); MPFL, medial patellofemoral ligament; TT-TG, tibial tubercle–trochlear groove.

TABLE 4
Patient-Reported Symptom State (n = 62 Knees)[a]

Outcome Measure	% of Responses
GRC from before to after surgery	
Much worse	0.0
A little worse	10.3
No change	1.7
A little better	25.9
Much better	62.1
My current knee symptom state is satisfactory	
Yes	78.9
No	21.1

[a]GRC, global rating of change.

Correlation and Between-Group Analyses

A poor positive correlation was found between Wiberg-W index and postoperative VAS-U (Table 5). However, this was not statistically significant, indicating that the detected correlation may have occurred by chance. Increased trochlear dysplasia (LTI) had a poor negative correlation with patellar dysplasia/Wiberg-W ($r_S[62] = -0.14$; $P = .28$), and a longer follow-up time since surgery had a fair negative correlation with VAS-U ($r_S[58] = -0.37$; $P = .004$). No significant correlations were found between postoperative PROMs and preoperative LTI, TT-TG distance, or PTI (Table 5).

No significant differences in patient demographics and severity of pathoanatomic risk factors were found between the groups with suboptimal versus desired outcomes (Table 6). Neither preoperative Outerbridge grade ≥3 chondral status nor concomitant TTO was associated with higher (ie, worse) VAS-U scores; however, an association was found regarding patient sex, with significantly

TABLE 5
Correlations Between Preoperative MRI Measurements and Postoperative PROMs[a]

	VAS-U			BPII		
Parameter	n	r_S	*P*	n	r_S	*P*
LTI angle	55	–0.24	.08	58	–0.01	.96
TT-TG distance	55	–0.11	.44	58	–0.02	.90
PTI	53	0.07	.61	56	–0.08	.58
Wiberg-W	56	0.16	.23	59	0.06	.65
Wiberg-D	56	0.02	.89	59	0.02	.87

[a]BPII, Banff Patellofemoral Instability Instrument 2.0; LTI, lateral trochlear inclination; MRI, magnetic resonance imaging; PROMS, patient-reported outcome measures; PTI, patellotrochlear index; TT-TG, tibial tubercle–trochlear groove; VAS-U, visual analog scale for usual pain; Wiberg-D, Wiberg index at the most distal cartilaginous part of the patella; Wiberg-W, Wiberg index at the widest cartilaginous part of the patella.

TABLE 6
Comparison Between Responses With Suboptimal Versus Desired Outcomes (n = 62 Knees)[a]

Variable	Suboptimal Outcome (n = 14)[b]	Desired Outcome (n = 48)	*P*
Pathoanatomic risk factors on MRI			
LTI	–6.4 ± 11.2	–1.89 ± 6.3	.055
TT-TG distance	15.5 ± 5.1	16.8 ± 4.4	.34
PTI	0.46 ± 0.15	0.41 ± 0.16	.30
Wiberg-W	0.63 ± 0.05	0.63 ± 0.04	.78
Wiberg-D	0.69 ± 0.07	0.68 ± 0.06	.59
Demographic features			
Age at surgery, y	18.3 ± 5.6	19.7 ± 5.1	.36
Bilateral surgery	42.9	40.4	≥.99
Female sex	64.3	55.8	.79
Preoperative Outerbridge grade ≥3	0	12.0	.33
Concomitant TTO	64.3	50.0	.52
Quadriceps graft for MPFLR	42.9	24.0	.19

[a]Values are presented as mean ± SD or %. LTI, lateral trochlear inclination; MPFLR, medial patellofemoral ligament reconstruction; MRI, magnetic resonance imaging; PTI, patellotrochlear index; TTO, tibial tubercle osteotomy; TT-TG, tibial tubercle–trochlear groove; Wiberg-D, Wiberg index at the most distal cartilaginous part of the patella; Wiberg-W, Wiberg index at the widest cartilaginous part of the patella.
[b]Suboptimal outcome was defined as postoperative patellar dislocation, major reoperation, or deterioration/no improvement in knee status from pre- to postoperative (global rating of change scores 1-3).

higher VAS-U scores seen in female versus male patients (Table 7).

DISCUSSION

The main finding of this study was that more pronounced patellar dysplasia had no significant correlation with postoperative pain. As part of an individualized surgical approach for treating patellar instability, trochleoplasty leads to good mid- to long-term patient-reported outcomes with a redislocation rate of 4%, a median BPII score of 78.2 and 88% of the patients reporting an improvement in knee function. However, 21.1% of patients were dissatisfied with their current knee symptom state, and the rate of reoperation due to revision surgery (9.3%) or arthroscopic synovectomy (9.3%) was high.

To our knowledge, no study has investigated the relationship between patellar dysplasia and pain after trochleoplasty. There is increasing evidence that trochleoplasty, regardless of the surgical technique (thin/thick flap), is a safe and effective procedure in experienced hands.[38] Nevertheless, the long-term risk and incidence of postoperative stiffness, persistent pain, and cartilage deterioration/future patellofemoral OA remain a matter of ongoing debate.[18,24,33] A possible explanation for such complications could be altered patellofemoral congruency, because only the trochlear side of the patellofemoral joint changes with trochleoplasty, as demonstrated by the dynamic simulation study of Elias et al.[14] This can be a problem, especially in patients with patellar dysplasia, since the dysplastic patella might not "fit" in a reshaped trochlea that is closer to a normal anatomy. In comparison, some studies on total knee arthroplasty without patellar resurfacing have found a correlation between more pronounced patellar dysplasia and increased postoperative pain, possibly due to a mismatch between the existing

TABLE 7
VAS-U and BPII Scores Compared According to Selected Group Features[a]

	Follow-up ≥5 y			Concomitant TTO			Outerbridge Grade ≥3			Female Sex		
Measure	Yes	No	P^b	Yes	No	P^b	Yes	No	P^b	Yes	No	P^b
VAS-U score	22.0	20.0	.07	14.5	24.0	.16	9.5	20	.44	24.0	8.5	.013[c]
BPII score	78.1	77.7	.69	78.9	75.9	.89	86.5	76.7	.16	75.8	78.9	.71

[a]Values are reported as medians. BPII, Banff Patellofemoral Instability Instrument 2.0; TTO, tibial tubercle osteotomy; VAS-U, visual analog scale for usual pain.
[b]The Mann-Whitney *U* test was used to compare groups based on ranks.
[c]Statistically significant difference between groups as shown (U = 574.5).

patella and the new trochlea.[1,7] Another study on this topic from Cao et al[9] found that in addition to increased risk of postoperative anterior knee pain, a highly dysplastic patella could also lead to altered patellofemoral tracking. Hence, whether patellar morphology alone or its impact on patellofemoral tracking generates pain after unresurfaced total knee arthroplasty remains unknown.

In contrast to the findings described above, the current study did not find a similar association between a higher grade of patellar dysplasia and pain after trochleoplasty. This corresponds to a study by Balcarek and Zimmermann,[2] who reported that MPFLR and deepening trochleoplasty actually normalized patellofemoral congruence and alignment, further suggesting that a dysplastic patella fits better within a normal trochlea than within a dysplastic trochlea. If this is the case, an improvement in patellofemoral congruence may also explain why the time from surgery was not related to increased pain at the follow-up examination in our study.

Cartilage injury, either preexisting or incurred during the trochleoplasty procedure, could also be an explanation for increased postoperative pain and patellofemoral OA development.[18,22,34] However, the risk of iatrogenic cartilage damage during trochleoplasty may not be as big a concern as previously thought, as several studies have demonstrated persistent cartilage viability both histologically during the first year[35] and on MRI up to 8 years after trochleoplasty.[6,17] Additionally, the current study did not find any difference in postoperative VAS-U between those with Outerbridge grade ≥3 chondral injury and those with no/mild chondral changes (Outerbridge grades 0-2) at the time of surgery. Although no clear association between some of the potential causes of pain and VAS-U was found in this study, the significantly worse VAS-U and BPII scores in the group who reported their knee status as unsatisfactory indicates that reasons for pain are multifactorial and related to the overall self-perceived knee function.

Whether trochlear and patellar dysplasia mutually reflect each other is a matter of discussion. Both Meissburger et al[27] and Panni et al[31] found an association between the most dysplastic Wiberg type 3 patellar and high-grade trochlear dysplasia. In these studies, the measures of both trochlear and patellar dysplasia were evaluated using qualitative classifications. In contrast, the current study used quantitative measures, such as the Wiberg index and LTI, demonstrating only a poor negative, nonsignificant correlation between increasing patellar dysplasia and trochlear dysplasia. This is in line with the findings of only a minimal association between measurements of patellar anatomy and trochlear dysplasia in a recent study from Jimenez et al,[20] indicating that patellar morphology rarely should be considered a contraindication for performing trochleoplasty.

Few studies have evaluated the results after trochleoplasty with validated PROMs for patellar instability, such as the BPII. Our finding of a median BPII score of 78.2 at 44 months after surgery indicates that many of the patients achieved good function and quality of life; it corresponds to the median BPII score of 74.3 after 64 months in the study by Blønd and Barfod[6] on arthroscopic trochleoplasty and the mean BPII score of 80.4 after 39 months in the study by Mengis et al[28] on open thin-flap trochleoplasty. In contrast, Ng et al[30] found a mean BPII score of 58.4 after 37 months with Bereiter trochleoplasty, but the response rate in that study was only 42%. Although the overall BPII score in the current study was high, 21.1% remained dissatisfied with their current knee symptom state. The high proportion might be explained by the fact that patients with such pronounced patellofemoral anatomic abnormalities, as present in this cohort, experience a chronic congenital disease in which it is difficult to achieve knee function comparable with that of healthy individuals. In addition, the proper indications for the different surgical procedures are yet to be determined. Nevertheless, the redislocation rate of 4.0% in the current cohort is similar to previously reported rates between 0% and 8%,[38] indicating that trochleoplasty combined with other procedures is effective for stabilizing the patella.

This is one of the first studies in which bioabsorbable nails were used to secure the new trochlear sulcus in trochleoplasty. Although we did not reexamine patients with postoperative MRI, the clinical outcomes suggest that this is a suitable alternative to suture tapes commonly used in both open and arthroscopic trochleoplasty procedures.[13] However, future studies should prospectively compare the different fixation techniques.

Limitations

The current study had several limitations. The retrospective nature of the study increases the risk of recall bias,

and the results are prone to type 2 errors since a priori power testing was not possible. Nevertheless, the high response rate ensured that the results probably accurately reflected this consecutive cohort. In addition, the median follow-up time of 44 months is not long enough to evaluate long-term results, but the similar outcomes in the groups with follow-up $\geq$5 years and <5 years imply that postoperative improvement is maintained over time. Furthermore, only 11 trochleoplasty procedures had both pre-and postoperative BPII scores available because BPII was not routinely implemented at our institution until recently. Additionally, the evaluation of patellar dysplasia using only 2 axial MRIs does not accurately represent its 3-dimensional anatomy and interaction with the trochlea throughout the knee range of movement. However, in previous studies, the Wiberg index demonstrated a good ability to distinguish patellar anatomy between patients with patellar instability and the normal population.[3,16] By including the more dysplastic distal cartilaginous part of the patella that first enters the reshaped trochlea in this study, we believe that the measurements represent a relevant patellar anatomy.[3]

Also, the inter- and intrarater reliabilities of the cartilaginous Wiberg index were not perfect. We found that both the variable quality of the MRI images and chondral injuries could render difficult the decision of which axial image to use for measurements. Nevertheless, it is less likely that this influenced the final outcomes since more severe patellar dysplasia, as found on the distal part, had an even lower correlation with postoperative pain compared with the less dysplastic widest part. Another potential bias is that surgical and/or patient-specific variables other than those examined in this study can lead to postoperative pain. However, if all potential risk factors for pain are to be investigated, a regression analysis in a much larger cohort is required. Furthermore, the high frequency of additional procedures makes it difficult to determine the effect of the trochleoplasty. Finally, the follow-up evaluation did not include radiological or clinical examination as this would require considerably more resources and was considered less important for the primary outcome.

CONCLUSION

A more dysplastic patellar configuration had no significant correlation with increased postoperative pain after mini-open, thin-flap trochleoplasty. This procedure, in combination with other procedures for surgical treatment of patellar instability, yielded good patient-reported outcomes and a low risk of redislocation, but the reoperation rates were high, and 21% of the patients remained dissatisfied with their current knee function.

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