Trochlear Morphology and Cartilage Viability After Mini-Open Lateral Approach Trochleaplasty for Patellar Dislocation – 5 Year MRI Follow-Up Study

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Background

Patellar dislocation is a common knee complaint and anatomical patellofemoral abnormalities, especially trochlear dysplasia, increase the risk for recurrent dislocations. To stabilize the dislocating patella, trochleaplasty to correct trochlea dysplasia has become an accepted surgical management strategy. The postoperative changes of trochlear morphology and the cartilage viability after trochleaplasty are poorly understood. The purpose of this five-year MRI follow-up study was to analyze the changes in cartilaginous shape of the trochlea and articular cartilage viability after mini-open lateral approach trochleaplasty. The surgical technique for a mini-open lateral approach trochleaplasty is presented

Methods

From January 2010 to December 2017, 109 patients underwent a mini-open lateral approach trochleaplasty combined with medial patellofemoral ligament reconstruction for the diagnosis of recurrent lateral patellar dislocation. Additionally, if no overlapping of patellar and trochlear cartilage was present intraoperatively, indicating abnormal patello-trochlear index, distalizing tibial tubercle osteotomy (DTTO) was performed to correct patellar alta. Demographics and presence of MRI variables included ages at time of surgery, trochlea dysplasia measurements and patello-trochlear index. Thirty patients underwent a control MRI assessment of post-operative trochlear status at a minimum 5 year postoperatively.

Results

Mean age at the time of surgery was 16.9 years (SD 4,63). Majority of the patients were females (23/30, 77%). In follow-up MRI's, at minimum 5 year post-operatively (range 5 to 8 years), no significant cartilage lesions such as delamination or avascular necrosis were seen. The articulating cartilage at the region where trochleaplasty was performed did not revealed any greater than one ICRS grade cartilage deterioration in control MRI and in majority of the knees (21/30, 70%), no changes

were detected. The most common postoperative trochlear shape was somewhat shallow, graded as type A according to Dejour classification - all study patients with grade B and D dysplasia with bump deformity were corrected to normal shaped or grade A trochlea. The preoperative sulcus depth was mean 1,3mm (SD 0,93) and post-operatively mean 3,9mm (SD 1,20). Sulcus angle improved from preoperative mean 162° (SD 9,72) to post-operative mean 149° (SD 5.14) and lateral trochear inclination angle changed from preoperative mean 4° (SD 3,92) to post-operative mean 13° (SD 1,38). Trochleaplasties combined with additional DTTO (9/30, 30%) were not associated with increased cartilage lesion deterioration. Preoperatively, 83% of patients (25/30) had some articular cartilage damage on the patella. Patellar lesions remained comparable with preoperative status at 5-year follow-up MRI.

Conclusion

Mini-open lateral approach trochleaplasty is a safe procedure – in a minimum 5-year MRI follow-up, none of the patients presented significant cartilage lesions such as delamination or avascular necrosis. Trochlea dysplasia can be corrected to normal or nearly normal trochlea with mini-open lateral approach trochleaplasty, based on post operative MRI analysis. Satisfying subjective long-term outcome can be expected for trochleaplasty.

What is known about the subject:

Trochleaplasty to correct trochlea dysplasia has become an accepted surgical management strategy for patients with severe trochlea dysplasia. The postoperative changes of trochlear morphology and the cartilage viability after trochleaplasty are poorly understood.

What are the new findings

Mini-open lateral approach deepening trochleaplasty resulted in satisfying morphological change in

cartilaginous trochlea shape – normal or nearly normal anatomical features were achieved based on post operative MRI analysis. In a median 5-year MRI follow-up, none had significant cartilage lesions such as delamination or avascular necrosis and cartilage deterioration was minimal. The surgical technique for a mini-open lateral approach trochleaplasty is presented

Introduction

Acute lateral patellar dislocation is one of the most common knee injuries in the adolescent population[1-3]. In addition to the injury of soft-tissue patellar medial stabilizing structures, primarily the medial patellofemoral ligament (MPFL), anatomical features of the patellofemoral joint have significant effect on patellar stability[4-6]. Patellofemoral joint anatomical abnormalities, such as trochlear dysplasia and patella alta have been reported to be major anatomical risk factors for recurrent dislocations[4]. The aim of a deepening trochleoplasty is to create a more normal shape of the trochlear groove providing a better stability of the patella[7, 8]. Deepening trochleaplasty corrects patellar tracking (J-sign)[9] in early flexion. Several trochleplasty surgical techniques have been described. Most commonly deepening trochleoplasty is based on thin cartilaginous flap technique, originally described by Bereiter et al.[10], in which trochlear cartilage contour changes in direction of a normal sulcus groove. To stabilize the dislocating patella, trochleaplasty to correct trochlea dysplasia has become an accepted surgical management strategy. The postoperative changes of trochlear morphology and the cartilage viability after trochleaplasty are, however, poorly understood.

Recent studies and systematic reviews have found low rate of re-dislocation and complications after trochleaplasty procedure[11, 12]. Increasing numbers of different kind of deepening trochleplasty surgeries are performed in orthopedic community, indicating trochleaplasty as a surgical option in first line treatment in severe trochlea dysplasia, not only as a salvage procedure.[13-15] Majority of the trochleaplasty studies report concomitant MPFL reconstruction surgery, based on a biomechanical

features of the patellofemoral joint, including both bony architecture and soft tissue restraints. Deepening trochleaplasty has been described to be indicated in a case of patellar dislocation with severe trochlea dysplasia, which cannot be addressed by soft tissue (MPFL) reconstruction only [11]. Severe trochlea dysplasia can be considered as not only shallow, but also flat or even concave trochlear cartilaginous shape, which does not provide lateral support to the patella. More precisely, severe trochlea dysplasia can be diagnosed as low (less than 10) lateral trochlear inclination angle (LTI)[16, 17], classically considered as grade B or D trochlear dysplasia according to Dejour et al[18] [15].

To our knowledge, no previous studies have analyzed systematically Magnetic Resonance Image (MRI) [19] measurements of the trochlea cartilaginous pre- and postoperatively. The purpose of this study was to analyze the changes in cartilaginous shape of the trochlea and articular cartilage viability after modern, deepening mini-open lateral approach trochleaplasty. The surgical technique for a mini-open lateral approach trochleaplasty is presented.

Methods

From January 2010 to December 2017, 109 patients underwent a mini-open lateral approach deepening trochleaplasty combined with medial patellofemoral ligament (MPFL) reconstruction for the diagnosis of recurrent lateral patellofemoral dislocation. To be considered for surgery, a diagnose of severe trochlea dysplasia by MRI was required, determined as LTI angle less than 10 degrees, measured by study surgeons, indicating either Dejour grade B or D trochlea cartilaginous configuration[18]. In addition, to be included in this surgical cohort, a relatively well-preserved trochlear cartilage status was necessary. Preoperative extensive ICRS [20]grade III or more severe lesions in the trochlea (more than one third of the mediolateral width affected, Figure 1) were considered as a contraindication for trochleaplasty, with exemption if cartilage lesion was located on

very lateral corner of the trochlea (lateral margin of the lateral third, Figure 1), where any kind of cartilage lesion was tolerated and included in the study. For patellar side, no limitations on cartilage status in preoperative MRI was set, even up to ICRS grade IV lesion was not considered as a contraindication for trochleaplasty. Additionally, if no overlapping of patellar and trochlear cartilage was present intraoperatively, when trochleaplasty was performed, indicating abnormal patello-trochlear index[21], distalizing tibial tubercle osteotomy (DTTO) was performed to correct abnormal patellar height [22]. Demographics and presence of MRI variables were collected prospectively and included ages at time of surgery, following trochlear dysplasia measurements: LTI angle[16], sulcus depth[23, 24], sulcus angle[25], trochlear bump height[18] and patello-trochlear index[26]. In this cohort, failures of trochleaplasty were defined as recurrent dislocation of the patella or post operative clinical complication warranting revision surgery. The most likely cause for failure was determined by review of the patient factors. To analyze the post-operative changes in cartilaginous shape of the trochlea and articular cartilage viability after mini-open lateral approach deepening trochleaplasty, 30 patients underwent a control MRI assessment of post-operative trochlear status at a minimum 5 year postoperatively.

The preoperative MRI scans were performed with a 1.5T Signa Excite HD imager (GE Healthcare, Milwaukee, WI) between June 2009 and December 2016. The follow-up MRI scans were performed between November 2016 and December 2022 using a 3T MRI scanner (Siemens Magnetom Skyra 3T XQ -grad, Siemens Healthcare, Erlangen, Germany). The images were acquired with a 15-channel receiver/transmitter extremity coil. The 3T MRI sequences and their parameters are shown in Table 1. The cartilage of the trochlear groove was dived into three subregions (Figure 1). The patellofemoral cartilage were assessed for defects according to Brittberg and Winalski [27] (modified ICRS classification). The measurements are shown in Table 2.

Table 1. 3T MRI sequences and parameters for follow-up evaluation of cartilage status. Sag sagittal, Cor coronal, Ax axial, TSE turbo spin echo, SE spin echo, FS fat saturation, TR time to repeat, TE time to echo, NEX number of excitations, FOV field of view

	TR [6]	TE [6]	NEX	Slice Thickness / gap (mm/mm)	Matrix	FOV (cm)
Sag PD TSE	3030	19	1	2.5 / 0.25	404 x 448	15
Sag PD TSE FS	4110	54	1	3.0 / 0.6	346 x 384	15
Cor PD TSE FS	3590	28	2	3.0 / 0.3	404 x 448	16
Cor T1 SE	750	12	2	2.5 / 0.25	358 x 448	14
Ax PD TSE FS	4990	41	1	3.5 / 0.35	384 x 384	15

Figure 1. Right knee. Axial PD fat sat image at the level of the trochlear cartilage. Cartilage is divided into three subregions: medial third (1), central third (2), and lateral third (3).

Surgical technique

Details of this surgical technique are provided in supplemental video. A mini-open lateral approach deepening trochleaplasty is based on thin flap technique, originally described by Bereiter et al, modified by the study surgeon. A midline 4-8 cm skin-incision is performed, depending on soft-tissue thickness. Same incision is used for concomitant MPFL reconstruction. Lateral joint capsule is incised and opened in two layers, at region of lateral patellofemoral ligament (LPFL). Superficial incision is located near the patella lateral margin, a soft tissue layer between LPFL and joint capsule is identified and prepared, and joint capsule is opened 10-20mm lateral from patellar lateral margin. Therefore, lateral lengthening can be performed, which is essential due to medialized patellar position in a new trochlear groove, and during closure, lateral retinacular lengthening reproduces anatomical lateral joint stability (LPFL integrity) instead of lateral release.

Thin flap deepening trocheaplasty is performed by opening proximal bone-cartilage interface, in a fashion which keeps both the trochlear cartilaginous flap and lateral condyle trochlear bone-cartilage junction intact (instead of Bereiter style more extensively mobilized cartilage flap detached from lateral condyle trochlear bone-cartilage junction). In author's trochleaplasty technique, trochlear cartilage remains intact, subchondral bone is removed from proximal to distal, to an extent that allows the new trochlear groove to be located more laterally for better patellar engagement in trochlea. Importantly, lateral condyle trochlear bone-cartilage junction remains intact, preventing loss of lateral condyle height (improving LTI angle) and optimizing trochlea flap healing. The newly shaped trochlear cartilaginous flap is fixated with a single 2.7mm bio-absorbable compress screw (Inion) at deepest point of the new trochlear groove.

Additionally, if no overlapping of patellar and trochlear cartilage was present intraoperatively in knee full extension, after trochleaplasty is performed, indicating abnormal patello-trochlear index (< 0%)[26], distalizing tibial tubercle osteotomy (DTTO) was performed to correct patella alta (minimum 2mm intraoperative cartilage overlap was considered necessary). Concomitant MPFL

reconstruction is performed, after trochleaplasty and optional DTTO have been finalized. Postoperatively, immediate free ROM is allowed, as tolerated and crutches were supervised to use for three to four weeks. Full weight-bearing (FWB) immediately (if DTTO was performed, FWB only on straight leg for the first 4 weeks and crutches for four to five weeks). Study hospital's MPFL reconstruction post-operative protocol was used, no additional restrictions were given for trochleaplasty patients.

Statistical analysis

The Wilcoxon test was used to evaluate differences in nonparametric ordinal data between the variables, and an independent-samples t test was used to assess differences in the continuous normally distributed data between the groups. Differences in the two-way tables were determined with Pearson's chi-square test or Fisher's exact test when the expected cell count was less than five. A p value of 0.05 was considered statistically significant. SPSS 22.0 for Windows software (SPSS, Chicago, Illinois) was used for the statistical analysis.

The study was approved by the Human Ethics Committee of the local research institute (D.nr. 18128).

Results

Mean age at the time of surgery was 16.9 years (SD 4,63). Majority of the patients were females (23/30, 77%). In follow-up MRI's, at minimum 5 year post-operatively (median 5.6, range 5 to 9 years), no significant cartilage lesions such as delamination or avascular necrosis were seen. The articulating cartilage at the region where trochleaplasty was performed, did not revealed any greater than one ICRS grade cartilage deterioration in control MRI when compared to preoperative cartilage status (Table 3.). In majority of the knees (21/30, 70%), no cartilage deterioration was detected in follow-up MRI. Intact preoperative cartilage status predicted preservation of the cartilage (19 patients with intact preoperative trochlear cartilage and no deteriorations in follow-up MRI), if compared with

ICRS grade II preoperative trochlear cartilage lesions (9 patients), p=0.005.

The most common postoperative trochlear shape was somewhat shallow, graded as type A (21/30, 70 %) according to Dejour classification - all study patients with grade B and D dysplasia with bump deformity were corrected to normal shaped or grade A trochlea. The preoperative sulcus depth was mean 1,3mm (SD 0,93) and post-operatively mean 3,9mm (SD 1,20). Sulcus angle improved from preoperative mean 162° (SD 9,72) to post-operative mean 149° (SD 5.14) and lateral trochear inclination angle changed from preoperative mean 4° (SD 3,92) to post-operative mean 13° (SD 2,38). Trochleaplasties combined with additional DTTO (9/30, 30%) were not associated with increased cartilage lesion deterioration if compared with isolated trochleaplasty surgeries. Preoperatively, 83% of patients (25/30) had varying articular cartilage lesions on the patella, primarily on the medial facet of the patella. Patellar lesions remained comparable with preoperative status at 5-year follow-up MRI.

One clinical failure was found from this surgical cohort with persisting post-operative J-tracking and patellar instability symptoms. In our analysis the reason for failure was patella alta not addressed during trochleaplasty surgery and secondary DTTO was performed. Additionally, one patient underwent secondary arthroscopic debridement of scar tissue from the proximal trochlear cartilage-bone junction, due to crepitus sensation at near extension of the knee. Arthroscopic visualization is available as supplemental video file.

Table 2. Patellofemoral trochlear dysplasia measurements pre- and postoperatively.

Trochlear dysplasia MRI measurements	**Preoperative measurements**	**Post-trochleaplasty measurements**	**P-value**
Mean (median, range)			
Lateral trochlear inclination angle, degrees	4.0 (4.8, 0-9.3)	13.0 (13.6, 10.5-21.3)	<0.001
Sulcus angle, degrees	162 (167, 141-180)	149 (147, 140-166)	0.003
Trochlear depth, mm	1.3 (1.2, 0-3.0)	3.9 (4.0, 2.8-5.0)	0.001
Bump height, mm	4.8 (4.9, 3.1-10.8)	1.8 (1.9, 0-4.8)	<0.001
Patello-trochlear index, %	0.25 (0.28, 0-0.56)	0.34 (0.32, 0.16-0.57)	0.448

TT-TG distance, mm	16.8 (16.4, 7.1-22.5)	14.0 (14.3, 7.2-21.5)	0.012

Table 3. Patellar cartilage injury in initial and follow-up MRI. Patellofemoral joint is divided into six subregions [28] and articular cartilages were assessed for defects according to the ICRS classification.

	Pre-oper MRI (N=30)		**Follow-up MRI (N=30)**		**p-values**
Patellofemoral cartilage subregion	**Cartilage injury, number of patients**	**Median ICRS (range 0-4)**	**Cartilage Injury, number of patients**	**Median ICRS (range 0-4)**	
Patella lateral facet	10/30 (30%)	0	12/30 (40%)	1	0.092
Central patella	15/30 (50%)	2	15/30 (50%)	2	0.15
Patella medial facet	18/30 (60%)	2	19/30 (63%)	2	0.163
Trochlea lateral	7/30 (23%)	1	9/30 (30%)	1	0.026
Trochlea central	3/30 (10%)	1	4/30 (13%)	1	0.167
Trochlea medial	2/30 (7%)	0	2/30 (7%)	0	0.109

Figure 2. Surgical approach to the patellofemoral joint in mini-open lateral approach deepening trcohleaplasty. Anterolateral aspect of left knee. Before trochleaplasty (left) and after trochleaplasty flap is fixated (right).

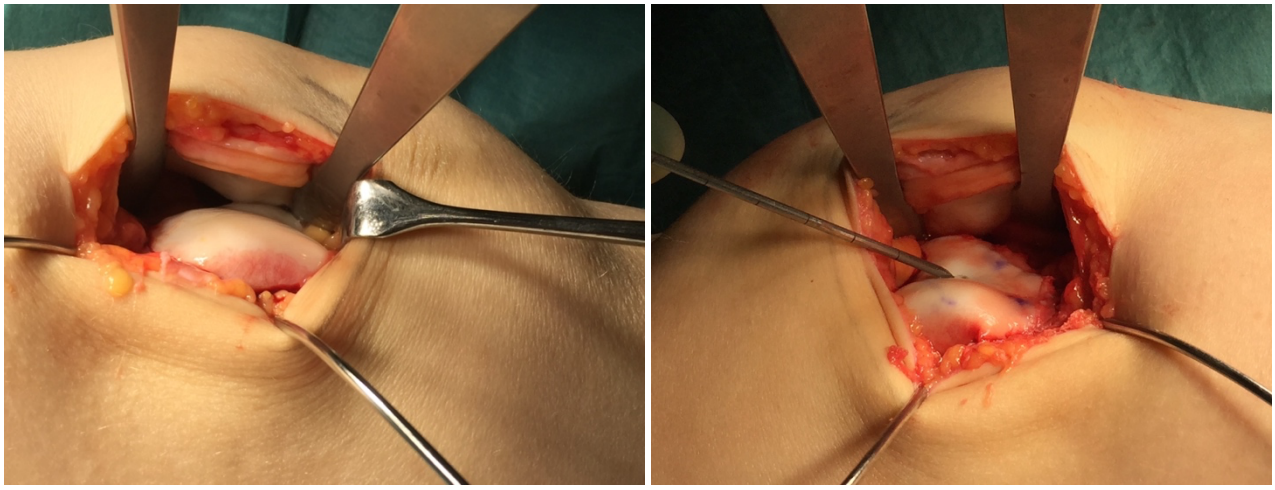
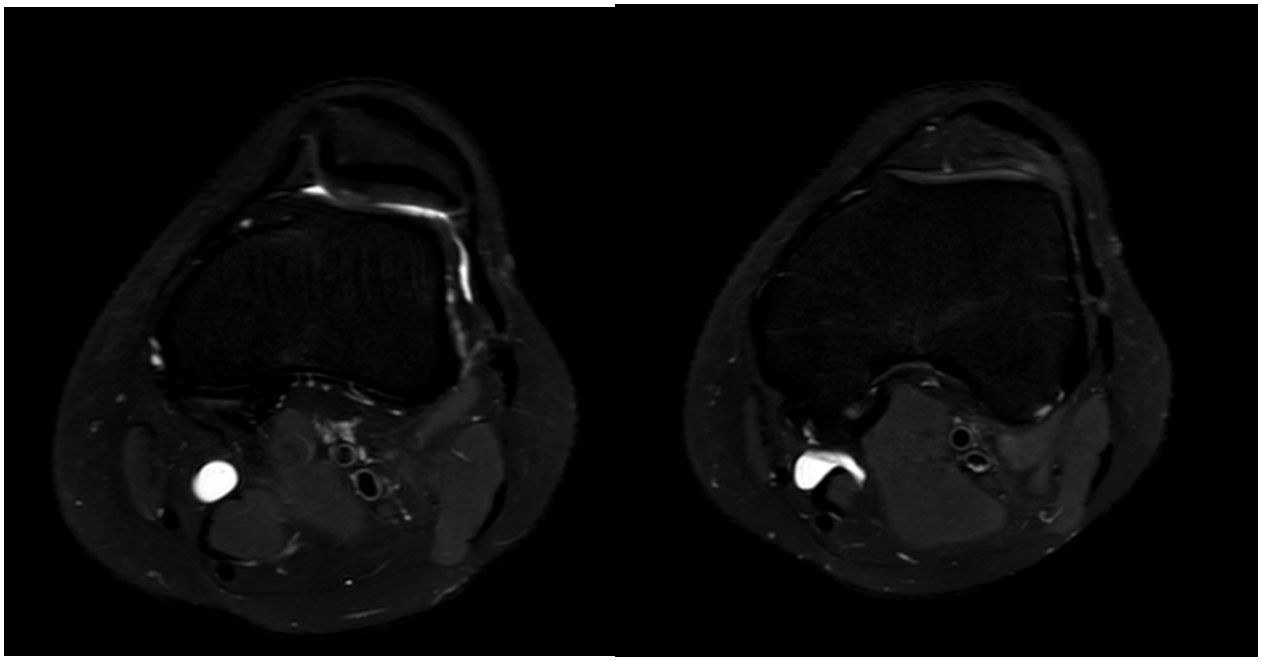
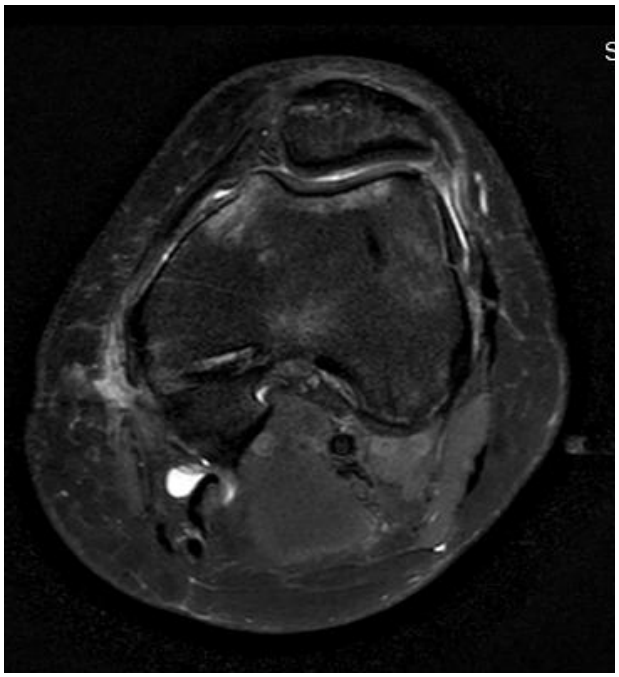


Figure 3 A-B. Preoperative 1.5T images (PD fat sat) of the right knee in the axial plane (A), most proximal and 3mm distal slices. Post-trochleaplasty 3.0T image (PD fat sat) (B), No significant cartilage deterioration at seven years after mini-open lateral approach deepening trochleaplasty

A





B

Discussion

Mini-open lateral approach trochleaplasty is a safe procedure – in a minimum 5-year MRI follow-up, none of the patients had significant trochlear cartilage lesions such as delamination or avascular necrosis. Trochlea dysplasia can be corrected to normal or nearly normal trochlea with mini-open lateral approach trochleaplasty, based on post operative follow-up MRI analysis. At the time of the follow-up, trochlea cartilage was well preserved, despite pre-operative patellar cartilage lesions, that were visible in majority of the patients. The load distribution in patellofemoral joint might be significantly improved after mini-open deepening trochleaplasty, and since patellar J-tracking was corrected, end result may be lower peak pressures on cartilage surfaces and preventive function in deteriorative articular changes. One patient reported subsequent post-operative instability of the PF joint. Based on a finding of this study, satisfying long-term clinical outcome can be expected for mini-open lateral approach deepening trochleaplasty. To our knowledge there are no previous studies of the long-term prognosis of cartilage deterioration after thin-flap deepening trochleplasty.

The LTI angle improved statistically significantly from preoperatively 4˚ to 13˚after surgery. Previous study reported similar findings[29]. Increase in LTI angle indicates that mini-open lateral approach deepening trochleaplasty can correct severe trochlea dysplasia to normal or somewhat shallow trochlea, with minimal surgical morbidity or cartilage viability concerns. Previous studies have demonstrated some extent cartilage deterioration in patients with trocheoplasty performed [30]. Osteoarthritic changes are found in approximately 18% at long-time follow-up after Bereiter trochleoplasty [31], and in higher number after traditional thick flap trochleaplasty [32]. It is not known whether trochleoplasty may accelerate or prevent the development of patellofemoral osteoarthritis. Previous studies have described natural history of patients who have considerable trochlear dysplasia being at risk of patellofemoral osteoarthritis progression [33, 34]. Most likely surgical trochleaplasty technique may have an effect on patellofemoral joint preservation, as well as

preoperative cartilage status. Based on a literature, however, severe trochlea dysplasia that is not addressed surgically, will lead to patellofemoral osteoarthritis progression.

Limitations of the present study included the fact that primary MRI at the time of an injury was performed using a 1.5T MRI while in the follow-up MRI a 3T scanner was used. However, it has been previously shown that the accuracy of cartilage lesion detection does not vary significantly between 1.5T and 3T MRI [35], and 3T scanner improved the follow-up analysis of the cartilage. Another limitation is the mid-term follow-up period, as longer, more than 10 years follow-up will be obviously more informative whether cartilage status changes over time. The results of this follow-up MRI study only apply to the described thin flap surgical technique, which can be considered as a limitation. More extensive, invasive or different kind of surgical technique may affect cartilage healing potential and have different prognosis in terms of cartilage preservation.

A strength of this study was the minimum 5-year follow-up period, which is, to our knowledge, the longest period studied with MRI follow-up. Furthermore, all patients were young and healthy and had no significant pre-operative cartilage wear. The results of this study revealed no significant PF joint cartilage deterioration 5 years after mini open lateral approach deepening trochleaplasty. The challenge in treatment for patellar dislocation population is cartilage deterioration which tends to progress relatively fast after the primary dislocation [36]. Whether trochleaplasty can prevent cartilage wear by improved patellofemoral joint congruity and load distribution, remains unclear and warrant long-term follow-up studies.

Conclusion

Mini-open lateral approach trochleaplasty is a safe procedure – in a median 5 year MRI follow-up, none had significant cartilage lesions such as delamination or avascular necrosis. Trochlea dysplasia can be corrected to normal or nearly normal trochlea with mini-open lateral approach deepening trochleaplasty, based on post operative MRI analysis. Satisfying subjective long-term outcome can

be expected.

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