The Lyon's sulcus-deepening trochleoplasty in previous unsuccessful patellofemoral surgery

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Abstract

Purpose Trochleoplasty is a relatively rare operation with few published results and it remains a technically demanding procedure which requires careful patient selection. The ideal candidate for surgery remains to be elucidated, and some authors consider it as a good revision option in cases of previous unsuccessful operations for persisting patellar dislocation with underlying trochlear dysplasia. The purpose of this study is to record the results from the application of sulcus-deepening trochleoplasty in patients with trochlear dysplasia and previous unsuccessful surgery for patellar dislocation.

Methods Twenty-two patients (24 knees) were operated upon during the period 9/1993–9/2006; they had undergone surgery for patellofemoral instability and had persistent patellar dislocation, and were followed-up for a mean of 66 months (24–191). Trochleoplasty was performed in all patients using the same technique and rehabilitation protocol. Additional soft-tissue and bony operations were performed in every case.

Results Of all cases, 29.1 % had type B and 70.9 % had type D trochlear dysplasia. After trochleoplasty, no patient had a patellar re-dislocation up to the last follow-up. Pain decreased in 72 % and the apprehension sign was negative in 75 % of the cases ($p < 0.01$). Sulcus angle decreased from $153^\circ \pm 14^\circ$ to $141^\circ \pm 10^\circ$ ($p < 0.01$), TT-TG distance decreased from 16 ± 6 mm to 12 ± 2 mm ($p < 0.001$), and patellar tilt decreased from $31^\circ \pm 14^\circ$ to $11^\circ \pm 8^\circ$ ($p < 0.0001$). Mean pre-operative Kujala score was 44 (25–73) and at

the latest follow-up it increased to 81 (53–100), ($p < 0.001$). At the time of final follow-up, there was no case of patellofemoral arthritis.

Conclusions Trochlear dysplasia is a key factor in the treatment of recurrent patellar dislocation and its correction could be included in the surgical options. Sulcus-deepening trochleoplasty is an acceptable revision option for the surgical treatment of patients with persisting patellar dislocation and high-grade trochlear dysplasia.

Introduction

Deepening trochleoplasty procedures are a relatively rare option in the surgical treatment of recurrent patellar dislocation [1]. Recent studies reveal satisfactory results after trochleoplasty on patients with patellar dislocation and underlying trochlear dysplasia [2–10]. But the variety of surgical methods [4, 11–14], the technical difficulty of the operation and the lack of agreement on the inclusion criteria are the main reasons that trochleoplasty is not yet systematically included in the treatment of patellar dislocation by all knee surgeons. There is scepticism on the indication of trochleoplasty in the primary treatment of recurrent patellar dislocation, but some authors state that it remains a revision option for specific patients with unsuccessful previous operations for patellofemoral instability where the trochlear dysplasia was the main factor for the dislocation and was underestimated [15].

The patellofemoral articulation and its pathology is probably the least understood field in an otherwise extensively studied knee joint. Nevertheless, recurrent patellar dislocation has generated numerous publications over the last years, in an effort to properly diagnose its exact aetiology and focus on a proper treatment regime [16]. Osseous or soft-tissue anatomical factors have been identified as key features in patellar dislocation [16]. A myriad of surgical techniques have been described in the literature from

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tuberosity osteotomy to medial patellofemoral ligament reconstruction and all-arthroscopic techniques [17] to address patellar instability [18], while other authors have emphasised the importance of correcting the abnormal anatomy of the trochlea [19] or the patella [20]. This is attributed to the lack of consensus in the literature regarding the exact aetiological factors of patellar dislocation and their exact threshold values that need to be corrected [16, 21].

On the one hand, trochlear dysplasia has been identified as the most recognised factor in patients with patellofemoral dislocation [22]. On the other hand, there are only a small number of surgeons who perform trochleoplasty for the treatment of patellar dislocation [23], in comparison to tibial tuberosity osteotomy for realignment procedures or patella alta, or more recently MPFL reconstruction. Consequently, there is a group of patients with patellofemoral instability, in whom the key aetiological factor of instability, i.e. trochlear dysplasia, is under-estimated or not addressed. Furthermore, the evaluation of the results from the application of trochleoplasty presents certain difficulties, because there is no agreement on the appropriate clinical (patellofemoral pain [7, 13], patellar dislocation [2, 3, 8] or both) or radiographic (type of dysplasia, height of prominence, sulcus depth [3, 4, 8]) indications for trochleoplasty. For sulcus-deepening trochleoplasty [14], authors agree that it is indicated for severe cases of Dejour type B and D dysplasia (high-grade dysplasia), where the presence of trochlear prominence is amenable to correction with this technique [3, 4, 14].

Up to now, the reports from trochleoplasty include mixed patient populations treated for patellofemoral pain, for patellar dislocation or for both and patients undergoing primary treatment or after having previous surgery [2, 3, 5, 7–9, 13, 23]. The purpose of this study was to evaluate the mid-term results of sulcus-deepening trochleoplasty in selected patients with recurrent patellar dislocations that had undergone previous failed patellofemoral surgery. The hypothesis tested was that in these patients, persistent patellar dislocation could be addressed with deepening trochleoplasty because of a missed high grade trochlear dysplasia.

Materials and methods

Inclusion criteria

Patients treated for recurrent patellar dislocation after previous surgical treatment for patella dislocation during the period September 1993–September 2006 were retrospectively included. Inclusion criteria were skeletally mature patients with recurrent patellar dislocation, presence of trochlear dysplasia and history of previous surgery for the

treatment of patellar dislocation. Patients with patellofemoral arthritis and patients with patellofemoral pain syndrome with no documented patellar dislocation were excluded from the study.

Peri-operative evaluation

Pre and postoperative patient evaluation included clinical examination (apprehension test, lateral patellar glide test and patellar tracking), subjective evaluation (patellofemoral pain and/or feeling of instability). Radiographic examination included the study of the type of trochlear dysplasia in true lateral X-rays, measurement of sulcus angle in patellar axial views in 30° of knee flexion, and measurement of patellar height according to Caton-Deschamps index [24] in lateral views in 20° of knee flexion. Tibial tuberosity–trochlear groove (TT–TG) distance and lateral patellar tilt (without quadriceps contraction) were measured in sagittal computed tomography (CT) slices. Postoperatively, patients were examined at one, three, six and 12 months and the last follow-up was during May–August 2008. At the last follow-up patients completed a general satisfaction questionnaire, IKDC [25] and Kujala [26] scores.

Surgical technique and additional operations

Trochleoplasty was performed according to Dejour's 'sulcus-deepening trochleoplasty' in all patients [14]. In this technique subchondral bone is removed under the trochlea, leaving a 5-mm osteochondral flap, and then the new trochlea is fixed with metallic staples. The goal is to decrease the trochlear bump and deepen the sulcus angle. The trochlear groove's new position is set more laterally, according to the pre-operative TT–TG distance, in order to reach a postoperative value of 10–15 mm. In all cases, trochleoplasty was combined with soft-tissue surgery, which involved augmentation of medial structures, such as a vastus medialis obliquus (VMO) plasty or medial patellofemoral ligament (MPFL) reconstruction combined with lateral release or lengthening. All additional procedures were addressed surgically in one stage; excessive TT–TG (> 20 mm) was corrected by medialisation osteotomy of the tuberosity, patella alta was corrected with distalisation osteotomy of the tuberosity, and increased lateral patellar tilt (>20°) was addressed with the aforementioned soft-tissue interventions according to previously-published criteria [27].

Rehabilitation protocol

A common postoperative rehabilitation protocol included full weight bearing using crutches in an extension knee brace for three weeks and continuous passive motion between 0° and 100°. During the first six weeks the patients

were encouraged to perform exercises for early range of motion as well as isometric quadriceps and hamstring strengthening. From sixth to 12th postoperative weeks the protocol also included closed-chain and weight bearing proprioception exercises. After the 12th postoperative week, patients started running and gradually training in their preferred sport and were allowed to undertake full sports activities after six months.

Statistical analysis

Differences between pre- and postoperative mean values were compared by the paired *t*-test. Level of statistical significance was <0.05 .

Results

Patients' demographics

Twenty-two patients (24 knees) with mean age 23 ± 5.5 years (14–33) were operated upon during the study period (female to male ratio of 1.33). Thirty-three per cent had a positive family history (1st degree relative) of recurrent patellar dislocation and 9 % had had bilateral surgery. At the time of surgery, 29.1 % of the patients had type B and 70.9 % had type D trochlear dysplasia. Mean follow-up was 66.5 ± 45.4 (24–191) months and no patient was lost to follow-up. Average number of previous unsuccessful operations for patellofemoral instability was two per patient and included medialisation of the tibial tuberosity, distalisation of the tibial tuberosity, soft-tissue surgery, VMO plasty, lateral retinaculum release and arthroscopy (Table 1). Patellar and trochlear cartilage lesions were recorded intra-operatively (Table 2).

Clinical evaluation

Pre-operative examination showed that lateral patellar dislocation was present in 100 % of the patients, patellofemoral pain was positive in 32.5 %, positive apprehension sign in 91.6 %, abnormal patellar tracking present in 81 % and feeling of patellar instability documented in 100 %. Postoperatively, none of the patients had a recurrent patellar dislocation up to the last follow-up. Pain decreased in 72 % of the cases and remained unchanged or increased in 28 % (*p*: NS). The apprehension sign was negative postoperatively in 75 % of the cases ($p < 0.01$), patellar tracking was normal in all of the cases ($p < 0.001$), and lateral patellar tracking was less than one quadrant in 72 %, less than two quadrants in 28 % of the knees ($p < 0.01$). No patient had postoperative feelings of instability at the last follow-up. There was no case of postoperative stiffness during the study period.

Table 1 Patient demographics, pre-operative clinical evaluation and associated procedures to trochleoplasty

Characteristic or parameter	Value
No. of knees	24
Age	23 ± 5.5 years (14–33)
Abnormal patellar tracking	81 %
Apprehension sign	91.6 %
Feeling of instability	100 %
Associated pain	12.5 %
Previous operations	Yes
Concomitant procedures	
1. VMO plasty	41.6 %
2. MPFL reconstruction	45.8 %
3. Distal transfer of tibial tuberosity	20.8 %
4. Medial transfer of tibial tuberosity	29.1 %
5. Lateral retinaculum release	25 %
6. Patellar osteotomy	4.1 %
7. Patellar tendon lengthening & Proximal tibial tuberosity transfer	16.6 %

Mean pre-operative IKDC score was 51.4 ± 21.8 (23–75) and at last follow-up it increased to 76.7 ± 13.0 (53–100), ($p < 0.001$). Mean pre-operative Kujala score was 44.8 ± 15.0 (25–73) and at last follow-up it increased to 81.7 ± 13.9 (61–100), ($p < 0.001$). During the last follow-up, 95.4 % of the patients had returned to their previous activities, including recreational sports. All of the patients responded that they were satisfied with the surgery. In one case, hardware removal was performed after staples' breakage. There were no major complications recorded during the study period.

Additional operations

Sulcus-deepening trochleoplasty was combined with an additional operation in all cases, whereby MPFL reconstruction was performed in 58.3 % of the cases ($n=14$), VMO plasty in 41.6 % ($n=10$), tibial tuberosity distalisation in

Table 2 Patellar and trochlear cartilage lesions at the time of the trochleoplasty procedure

ICRS grade ^a	Trochlear cartilage lesions	Patellar cartilage lesions
Grade 0	62.4 %	45.5 %
Grade I	8.3 %	4 %
Grade II	20 %	21 %
Grade III	8.3 %	17 %
Grade IV	0 %	12.5 %

^a International Cartilage Repair Society

20.8 % ($n=5$), tibial tuberosity medialisation in 29.1 % ($n=7$), patellar tendon lengthening and proximal tibial tuberosity transfer (for pre-operative patella infera) in 16.6 % ($n=4$), lateral release in 25 % ($n=6$) and patellar osteotomy in 4.1 % ($n=1$) (Table 1).

Imaging findings

Trochlear dysplasia classification before surgery was type B in 29.1 % of the cases and type D in 70.9 %. Postoperatively, 33.3 % of the knees had type A trochlear dysplasia and 66.7 % had normal trochlea or were not amenable to classification due to the disturbance of normal anatomy or inability to clearly visualise the groove line in the radiographs. Sulcus angle decreased from $153^\circ \pm 14^\circ$ (130 – 177°) pre-operatively to $141^\circ \pm 10^\circ$ (122 – 163°) postoperatively ($p < 0.01$), (Table 3). TT–TG distance decreased from 16 ± 6 mm (5 – 30) to 12 ± 2 mm (5 – 20), ($p < 0.001$). More specifically, TT–TG distance decreased from a mean of 14.5 mm (5 – 21) to 12.1 mm (5 – 20) in cases that had only trochleoplasty, while TT–TG distance decreased from a mean of 19.4 mm (8 – 30) to 12.8 mm (8 – 19) in cases that had trochleoplasty combined with tibial tuberosity osteotomy. The actual medialisation effect of the trochleoplasty as a ‘proximal’ re-alignment procedure on the TT–TG distance was 2.5 mm on average. Patellar tilt decreased from $31^\circ \pm 14^\circ$ (0 – 58°) to $11^\circ \pm 8^\circ$ (1 – 31°) ($p < 0.0001$), (Table 3). Caton-Deschamps ratio decreased from 1.03 ± 0.28 (0.5 – 1.48) to 0.95 ± 0.22 (0.69 – 1.29) (p : NS). At the time of final follow-up, there was no case with patellofemoral arthritis according to Iwano criteria.

Table 3 Pre and postoperative imaging findings in patients that underwent trochleoplasty and had previous surgery for patellar dislocation

Parameter	Pre-operative	Postoperative
Sulcus angle	$153^\circ \pm 14.7^\circ$ (130 – 177°)	$141^\circ \pm 10.2^{**}$ (122 – 163°)
Caton-Deschamps index	1.03 ± 0.28 (0.5 – 1.48)	0.95 ± 0.22^a (0.69 – 1.29)
TT–TG distance	16.6 ± 7.7 mm (5 – 30 mm)	12.6 ± 4.2 mm** (5 – 20 mm)
Patellar tilt	$31.4^\circ \pm 14.3^\circ$ (0 – 58°)	$11.8^\circ \pm 8.0^{**}$ (1 – 31°)
Trochlear dysplasia		
Type A	0 %	33.3 %
Type B	29.1 %	0 %
Type C	0 %	0 %
Type D	70.9 %	0 %
Normal or non-classifiable	0 %	66.7 %

* $p < .01$, ** $p < .001$,

^a Not significant, when compared to pre-operative values

Discussion

The mid-term results of sulcus-deepening trochleoplasty in patients with previous operations and recurrent patellar dislocation showed satisfactory correction of patellar stability, improved radiological findings of patellofemoral instability, increase of functional scores and good patient satisfaction with no major complications.

The goal of sulcus-deepening trochleoplasty is to re-shape the abnormal trochlear shape, but the instability of the patella is also caused by the presence of co-existent anatomical factors that must be addressed (e.g. tuberosity osteotomy for patella alta or increased TT–TG distance), and its treatment almost always requires a combined soft-tissue procedure such as MPFL reconstruction [14, 27, 28]. This is because patellar stability during early flexion is accomplished by MPFL which is tight in full knee extension and acts as a dynamic stabiliser during early flexion (15 – 20°), brings the patella into the trochlear groove which is necessary for the normal further tracking of the patella, and in greater degrees of flexion ($>30^\circ$) is loose and the normal concave trochlear geometry acts as a static stabiliser [1, 22, 29, 30]. MPFL rupture is the *consequence* of pathological lateral patellar translation, while the actual *causes* are the underlying bony abnormalities including trochlear dysplasia and patella alta [22, 28], and most important, a normal trochlea with a deep groove and an elevated lateral facet is necessary for MPFL to provide stability [28, 31]. This is the reason why, although MPFL has a fundamental role in patellar stability, isolated MPFL reconstruction should not be considered a panacea for patellar dislocation, without excluding the presence of other factors contributing to instability [28].

In this study, we recruited a patient population with previous failed patellofemoral operations for the treatment of patellar dislocation, where these aforementioned anatomical parameters had been addressed, with the exception of trochlear dysplasia. We tested the hypothesis that in this group of patients, the presence of trochlear dysplasia was the key factor for patellar dislocation. This could be explained with the following mechanisms. In the case of a convex trochlea, there is a centrally located sulcus prominence that the patella needs to override during flexion and that leads to patella dislocation off the lateral facet [32, 33]. This prominence is present in type B and D trochlear dysplasia (high-grade dysplasia), where the central groove is elevated. In this scenario of underlying high-grade trochlear dysplasia, if patellar dislocation is approached with no regard to dysplasia and the elevated groove, and only by medial soft-tissues augmentation, the patella will obtain firm medially stabilising structures and a medial tilt, but the elevated and abnormal trochlear groove will still be present. This could lead to undesirable impingement between the patella and the trochlear prominence and subsequent

increased contact pressures and graft loosening, effects similar to overmedialising the patella after MPFL reconstruction [34, 35] or to the pattern of MPFL rupture recorded in patients with trochlear dysplasia [36].

Moreover, the isolated correction of patella alta and the under-estimation of a concomitant high-grade trochlear dysplasia would have similar inefficient results to treat patellar dislocation; a distalisation osteotomy of the tuberosity would correct patellar height, but would only lower the patella in front of an abnormally-shaped trochlear groove, if trochlear dysplasia were not corrected. The absence of a deep trochlear groove would not provide the patella with the required lateral stability to prevent lateral dislocation (Fig. 1). Similarly, in our patient population, patellar height had been corrected in previous operations (mean pre-operative Caton-Deschamps ratio 1.03 ± 0.28) and in some cases an over-correction to patella infera was observed (Table 3). Likewise, the correction of patellar height from previous operations was not sufficient to prevent recurrent patellar dislocation, thus emphasising the importance of high-grade trochlear dysplasia in the aetiology of patellar dislocation. After trochleoplasty, mean patellar height did not change by a significant value but patellar stability was achieved in every case.

Excessive patellar tilt is often associated with the presence of trochlear dysplasia [37–42] and should probably not be considered as an instability factor but as a consequence of high-grade trochlear dysplasia. In this patient population, it is interesting that mean pre-operative patellar tilt had a wide range, even within normal values (0 – 58°), and that in some cases there was over-correction of the patellar tilt to 0° . This was attributed by authors to previous surgery and to the occasional presence of patella infera. But similarly to the normal pre-operative values observed for mean patellar height, the recorded correction or over-correction of patellar

tilt from the previous operations was not sufficient to treat recurrent patellar dislocation, thus highlighting the importance of trochlear dysplasia. After the deepening trochleoplasty, patellar tilt changed significantly with a narrower range ($11.8^\circ \pm 8.0^\circ$) and patellar stability was achieved in all patients.

The study of this specific patient population presented some interesting results. The prevalence of trochlear dysplasia and its different types are recorded in patients with patellofemoral pain syndrome or patellofemoral instability in the literature; trochlear dysplasia is present in 96 % of patients [22], with type A in 54 %, type B in 17 %, type C in 9 % and type D in 11 % [43]. These are imaging findings in patients with a wider range of patellofemoral pathology that do not represent the presence of dysplasia in selected patients requiring surgery for instability. The type and prevalence of dysplasia in our study group was predominately type B (29.1 %) and D (70.9 %), showing the importance of high-grade dysplasia in the aetiology of recurrent patellar dislocation that probably cannot be treated without addressing the dysplasia. The number of cases included in a long period of 13 years is relatively small ($n=24$ knees), confirming that trochlear dysplasia is a rare disease and that ‘symptomatic’ uncorrected high-grade dysplasia is even rarer. It is worth mentioning that previous operations on this group of patients had corrected two of the four studied radiographical parameters (normal mean TT–TG distance and normal mean patellar height before trochleoplasty) but without correcting patellar instability. On the contrary, sulcus angle (mean 153°) and patellar tilt were abnormal, and their correction with trochleoplasty and soft-tissue procedures to normal values resulted in patellar stability in all cases.

In the clinical setting, other authors report success rates from 90 % to 100 % after trochleoplasty procedures [2, 4,

Fig. 1 Example of a patient with previous unsuccessful surgery for patellar dislocation. **a** Distalisation osteotomy of the tibial tuberosity combined with medial soft-tissue augmentation failed to prevent recurrent patellar dislocation; patella infera is present. **b** Type D trochlear dysplasia was not addressed during primary surgery. **c** Sulcus-

deepening trochleoplasty combined with medial patellofemoral ligament reconstruction and proximalisation osteotomy of the tuberosity were necessary to provide patellar stability. **d** Postoperative axial view of the patella

7–9, 13]. After trochleoplasty, recurrence of dislocation is highly uncommon and patient satisfaction is high [1]. The results of trochleoplasty as a revision option in selected patients who had had previous failed surgery for patellofemoral instability have not been recorded, and all these published data involve mixed groups of patients with and without previous operations. Some authors suggest that trochleoplasty procedures are probably an appealing revision option in cases of previously treated patients with persistent patellar instability and an undiagnosed or underestimated trochlear dysplasia [2–4, 8–10, 13, 23]. In our study, the authors chose to apply this surgery to patients that had persisting patellar dislocation after any—other than trochleoplasty—previous surgery for patellofemoral instability. The satisfying results that are recorded in these patients after trochleoplasty probably show the need for the early recognition of a subgroup of patients with trochlear dysplasia in whom the benign neglect of dysplasia and the application of conventional surgery for the treatment of patellar dislocation is ill-fated. On the other hand, it is the authors' belief that trochleoplasty is not a first option surgery to treat patellofemoral instability, but it should be reserved for patients with recurrent patellar dislocation and underlying high-grade trochlear dysplasia (type B and D), where the presence of trochlear prominence can be corrected with this technique.

There are concerns on the potential complications of trochleoplasty. Schöttle et al. studied the cartilage status after trochleoplasty and recorded normal bone healing and insignificant risk for cartilage damage [6]. Undercorrection of normal trochlear geometry in some patients was reported by Donell et al., who showed the undercorrection of patellar tilt [4]. Reports on the risk of arthrofibrosis are mixed in the literature, since it ranges from 0 % in the long-term study of von Knoch et al. [8] and 2 % in a study by Utting et al. [2] to 46 % by Verdonk et al. [7]. A major concern is the postoperative pain after trochleoplasty which varies from 15 % [2] to 100 % [9]. Von Knoch et al. [8] recorded 49 % improvement of pain and 33 % increase after eight years follow-up, and Fucentese et al. [3] recorded 7 % increase of pain after four years follow-up. As stated before, it is difficult to compare, especially in the case of patients treated for patellar pain rather than dislocation [7, 13] and mainly because of the different surgical technique and rehabilitation protocol. Although we did not observe such a pattern, some authors correlate postoperative pain with severe cartilage damage at the time of trochleoplasty [2–4]. This pre-existing cartilage damage may also contribute to the most worrying complication of trochleoplasty, which is the long-term progress to arthritis. So far, only von Knoch et al. present a long-term study with 30 % of patellofemoral arthritis eight years after trochleoplasty [8].

But, they had observed the majority of these cartilage lesions already during the primary trochleoplasty procedure [8]. Similarly, we had no case of patellofemoral arthritis on radiographs after an average of six years follow-up.

In conclusion, trochleoplasty is an important revision option in the case of previously treated patients with persistent patellar dislocation and undiagnosed or underestimated trochlear dysplasia, in whom neglect of dysplasia and conventional surgery is ill-fated. Combination of the procedure with soft-tissue surgery, such as MPFL reconstruction, is necessary to achieve patellar stability. The effects of such procedures are difficult to compare and there is need for agreement on the choice of the right candidate for trochleoplasty, the surgical technique, the rehabilitation protocol, and the postoperative parameters that must be corrected. Mid-term follow-up showed restoration of patellar stability, improvement of functional knee scores, and good to excellent patient satisfaction with no major complications such as patellofemoral arthritis.

Conflicts of interest None.

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