Good short-term results following arthroscopic deepening trochleoplasty combined with medial patellofemoral ligament reconstruction: surgical technique and outcomes

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ABSTRACT

Purpose: To report short-term results and clinical outcomes of arthroscopic deepening trochleoplasty combined with medial patellofemoral ligament (MPFL) reconstruction utilizing standard arthroscopic instruments in patients of recurrent patellar dislocation and trochlear dysplasia.

Methods: This is a case series of 13 patients between the ages of 14 and 20 years who presented with recurrent patellar dislocation and severe trochlear dysplasia (Dejour grade D). They were treated surgically using an arthroscopic technique from February 2017 to January 2019 and were followed for 18 months. Patients were assessed preoperatively and postoperatively (at 6, 12, and 18 months) with clinical scores (Tegner Activity Score, Lysholm Knee Score, and Kujala Score).

Results: There were 69.2% females, and the mean age was 16.4 ± 2.0 years. There were statistically significant improvements in the mean Lysholm and Kujala scores when comparing pre-operative and post-operative scores at every follow-up landmark (p < 0.05). Comparing the preoperative and 18-month postoperative scores—the Lysholm score improved from 68.2 ± 10.3 to 98.7 ± 2.1 (p < 0.001), and the Kujala score improved from 50.3 ± 12.0 to 95.4 ± 4.8 (p < 0.001). Five patients were able to achieve premorbid Tegner activity levels at 12 months, with an additional 5 patients achieving the same premorbid Tegner activity at the 18-month mark. The remaining 3 patients were able to attain >90% of their activity level at 18 months' follow-up. No complications were observed during the follow-up period.

Conclusions: This proposed arthroscopic deepening trochleoplasty technique combined with MPFL reconstruction has demonstrated excellent and reproducible early clinical outcomes.

Level of evidence: IV.
INTRODUCTION

Recurrent patellar instability is a disabling condition that results in feelings of insecurity in the affected knee, mostly associated with pain and discomfort. Often, this has a bearing on one’s activity level and quality of life [1,2]. Several risk factors have been identified [3,4]. The primary risk factors comprise of trochlear dysplasia, patella alta, lack of patellofemoral engagement, and excessive tibial tubercle and trochlear groove (TT-TG) distance. Secondary risk factors, on the other hand, include excessive femoral anteversion, genu valgum, and patellar dysplasia. The mainstay of surgical management is to identify these risk factors, which will ultimately direct the “menu à la carte” approach [5] to treatment. A deepening trochleoplasty is the treatment of choice for high-grade trochlear dysplasia, while a distalizing and medializing tibial tubercle osteotomy corrects patella alta and excessive TT-TG distance, respectively. Other adjuncts include medial patellofemoral ligament (MPFL) reconstruction and/or lateral release, which are procedures that balance the soft tissue restraints.

Studies have supported trochlear dysplasia as the single most important factor for recurrent patellar dislocation [3,6-9], where 96% of cases with objective patellar instability had trochlear dysplasia, compared to 3% in controls [3]. A biomechanical study demonstrated abnormal kinematics in high-grade trochlear dysplasia, which improved to a level comparable to normal knees following trochleoplasty [10]. Without surgical intervention, there is a risk of the early development of patellofemoral osteoarthritis [11,12]. Trochleoplasty has been proven to improve patellofemoral instability, pain, and satisfaction in high-grade dysplasia, particularly Dejour types B and D with a supratrochlear spur of ≥5 mm [4]. Multiple techniques of trochleoplasty have been described, including the improved Dejour technique [13], Goutallier recession trochleoplasty [14], and the Bereiter-Gautier technique [15]. Bloed and Schöttle [16] were the first to describe an arthroscopic approach using the Bereiter technique in 2010. The purported advantages include improved post-operative pain, scar formation, reduced length of rehabilitation, and reduced risk of infection and arthrofibrosis compared to the open approach, which was later proven in their follow-up study [17]. In their latest study, they demonstrated good clinical improvements in patient-reported outcomes and standardized magnetic resonance imaging (MRI) measurements compared to those obtained by open trochleoplasty [18]. However, their technique requires the use of special instrumentations.

We would like to report the short-term results and clinical outcomes of arthroscopic deepening trochleoplasty combined with MPFL reconstruction utilizing standard arthroscopic instruments in patients with recurrent patellar dislocation and trochlear dysplasia. We modified the existing techniques described in the literature to make them more reproducible by the experienced arthroscopic surgeon who would want to eventually adopt this method of treating trochlea dysplasia. This is achieved via 1) preoperative planning to site the new groove, 2) the use of standard readily available instruments and implants, and 3) more laterally based working portals (used for viewing and burring). In this paper, the surgical technique as well as the early outcomes will be presented. We hypothesize that this technique will produce consistent early results with good outcomes.
ant lateral (AL) and anteromedial (AM) portals. Three additional arthroscopic portals are required in this technique: (i) distal supero-lateral (DSL), (ii) proximal supero-lateral (PSL) and (iii) supero-central (SC) (Fig. 2). The DSL is the viewing portal, while the PSL and SC represent the working portals. Using the standard AL and AM portals, the condition of the patellofemoral joint is initially assessed. Debridement, loose body removal, and microfracture can be performed depending on the intraoperative findings. Thereafter, the degree of trochlear dysplasia is assessed, and the preplanned groove can be marked on the cartilage by gently producing a small indentation via a radiofrequency probe (Fig. 3). The preplanned groove is determined preoperatively by identifying the cartilage peak of the dysplastic trochlea on the MRI axial cut (Fig. 3, thick arrow). The distance from the lateral edge of the trochlea to the cartilage peak is measured (Fig. 3, thin arrow) and used to guide intraoperative measurements.

Thereafter, with the knee in full extension, the DSL portal is established approximately 1 cm proximal and 1 cm lateral to the patella. A radiofrequency probe is introduced into the DSL portal. The probe is used to remove the synovium surrounding the proximal boundary of the distal femur cartilage. This also facilitates exposure of the bone-chondral junction of the distal femur (Fig. 4) and prepares the area for subsequent procedures described below. Once adequate bone is exposed and hemostasis achieved, the PSL portal is established, approximately 2 cm proximal and 2 cm lateral to the DSL portal. As the PSL portal is the main working portal, its position is critical to achieve good access to all areas of the cartilage to perform the trochleoplasty. Therefore, it is recommended to use a long needle to localize the best position for this portal under direct visualization.

A 5 mm oval burr (Arthrex Inc., Naples, FL) is then inserted into the PSL portal, and the camera is switched to the DSL portal. The surgeon then positions himself lateral to the operated knee before initiating the subchondral burring. The burr is used to create an indentation along the bone-chondral junction first, which is then deepened carefully and gradually. The burring is directed in the medial to lateral direction in a sweeping manner. Once sufficient depth is achieved, the burring is directed into the subchondral area progressively, in a similar fashion, and subsequently distally to create and elevate a subchondral flap. To determine the adequacy of the subchondral resection, two conditions must be met: 1) the cartilage flap is flexible upon palpation with the burr (Fig. 5) and 2) there is a complete resection of the supratrochlear spur on intraoperative lateral radiographs of the knee. A sufficient thickness of the flap means a flap size that is approximately 2 mm thick and is deemed flexible via gentle palpation with the hooded burr intraoperatively. The scope is directed under the flap periodically to ensure sufficient flap thickness and safety from cartilage penetration. The elasticity of the flap can be assessed by the gentle pressure of the hooded part of the burr onto the surface of the raised osteochondral flap. The subchondral bone under the planned new groove of the cartilage undergoes further burring of an additional depth of 2–3 mm to create a groove. Once the osteochondral flap is adequately prepared, the camera is then moved to the AL portal. A vicryl 1/0 and an absorbable tape are placed approximately 1 cm above the intercondylar notch via a 4.75 mm Arthrex SwiveLock®, producing two equal arms of each strand via the AM portal (Fig. 6).

The final SC portal is then created, approximately 1 cm superior to the midpoint of the patella. The camera is then moved to the DSL portal once again. One arm of the suture tape is retrieved via the SC portal, placed 5 mm proximal to the osteochondral flap at the preplanned and premarked groove, and secured proximally via a 1 × 4.75 mm Arthrex PushLock® anchor. As the suture tape is tensioned onto the bone, it deforms the underlying cartilage flap into the groove (Fig. 7). Subsequently, the second arm of the suture tape is retrieved, and the procedure is repeated in the same fashion. The second arm of the tape is placed just adjacent to the first tape in order to create a gentler, sloping V-shaped groove (Fig. 8). The vicryl 1/0 arms are used to reduce the lateral areas of the elevated cartilage flap to bone using smaller 3.0 mm Arthrex PushLock® anchors. The excess free ends of the tapes and sutures are cut flush with

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**Fig. 2. Arthroscopic portals:** – AL, anterolateral; AM, anteromedial; DSL, distal supero-lateral; PSL, proximal supero-lateral; SC, supero-central.

(Fig. 1). This enables unobstructed, full access of the operative lower limb for the surgery as well as for intraoperative imaging. A nonsterile pneumatic tourniquet is applied at the proximal thigh level. A routine knee arthroscopy is performed via standard anterolateral (AL) and

**Fig. 3. Trochlear groove –** Preoperative planning and assessment of future trochlea at the cartilage peak of the dysplastic trochlea (thick arrow) and its distance from the lateral edge (thin arrow) on the MRI axial cut (left); marking of the preplanned trochlear groove (right). MRI, magnetic resonance imaging.
the bone. Upon completion of the trochleoplasty, the MPFL reconstruction is routinely performed. An autologous gracilis or semitendinosus is harvested from the ipsilateral limb via a skin crease incision. The graft is cleaned, and the ends are whipstitched.

An incision is made over the superomedial aspect of the patella. The attachment site is debrided and refreshed until healthy bleeding is seen. 2/C2 suture anchors (3 mm Bio Suture Tak, Arthrex) are inserted. A path for the graft is created under layer 2 via blunt dissection towards the medial epicondyle. The femoral isometric point is localized under the image intensifier and drilled and reamed to 7 mm in diameter. The middle aspect of the graft is then secured to the patella via the two anchors, with the ends passing under layer two and brought into the previously reamed femoral tunnel. The graft is provisionally tensioned with the knee at 30 degrees of flexion, and the knee is ranged through the entire range of flexion and extension to ensure isometry. A 7 × 30 mm bioscrew is then used to secure the graft with the knee placed in 30 degrees flexion.

Some cases may need a lateral retinacular release prior to the MPFL reconstruction if the patellar tilt is deemed abnormal. A surgical drain is placed in situ postoperatively. All patients in this case series underwent surgical procedures as described above.

Pearls and pitfalls.

1. Controlled, low-speed burring (2000 rpm) with a hooded burr is preferred to minimize surrounding soft tissue and cartilage damage. Alternatively, burring in the reverse mode can be useful in cases of softer subchondral bone.

2. Assessment of the elasticity of the cartilage flap relies on adequate visualization of the cartilage surface as well as the subchondral area regularly, while palpating the cartilage flap with the burr.
hood in the method described above. This is crucial in order to prevent overburring and subsequent penetration into the cartilage.

(3) It is essential to reduce the elevated cartilage flap back to the lateral side of the femur. This ensures good overall bone contact and helps with hemostasis from the oozy burred surfaces of the subchondral bone.

(4) In cases needing a lateral release, this is done upon the conclusion of the trochleoplasty and before the MPFL reconstruction procedure in order to reduce bleeding and fluid extravasation, which can compromise intraoperative scope visualization.

Postoperative management

Postoperatively, all patients were fitted with a knee ranger brace locked at 30° and kept nonweight-bearing with crutches for 2 weeks. Pain was managed with oral analgesia—paracetamol, ibuprofen, and opioids unless contraindicated. All patients were discharged by postoperative day two, with drains removed. At the two-week clinic follow-up, the knee ranger brace was adjusted to allow 0°–30° range of motion and partial weight bearing with crutches for the next 4 weeks. Thereafter, patients were allowed full range of motion without the knee brace and full weight bearing.

Clinical outcome evaluation

Preoperatively, clinical evaluation included a complete history and physical examination. The age, sex, race, affected side, and symptoms such as episodes of dislocations, instability, or pain were documented. All patients were assessed with the Tegner Activity Score [19], Lysholm Knee Score [20], and Kujala Score [21] preoperatively and postoperatively at 6 months, 12 months, and 18 months (Table 1). These data were collected by independent research coordinators who were blinded to intraoperative procedures, complications, and events. The minimum follow-up duration was 18 months. Routine postoperative advanced imaging was not performed in this study, and only postoperative follow-up radiographs were taken (Fig. 9).

Statistical analysis

All data were compiled in Microsoft Excel 2010 (Microsoft Corp., Redmond, WA), and statistical analysis was performed using Statistical Package for the Social Sciences Version 23.0 (SPSS Inc., Chicago, IL). Continuous variables are presented as the mean ± standard deviation (SD). Comparisons between preoperative and postoperative 6-, 12-, and 18-month scores were performed by using the paired t-test for normally distributed data and the Wilcoxon signed-rank test for non-normally distributed data.

Ethical aspect

This study was approved by our Institutional Review Board (reference No. 2020/2177).

RESULTS

Thirteen patients met the inclusion criteria. In this study, a minimum 18-month follow-up was conducted on all thirteen patients who underwent arthroscopic deepening trochleoplasty with MPFL reconstruction, ensuring a complete dataset without any loss of follow-up. There were nine (69.2%) females and four (30.8%) males. Among them, seven were Chinese (53.8%), five were Malays (38.5%), and one was an Indian (7.7%) patient. The mean age was 16.4 ± 2.0 years (range 14–20).

There was a statistically significant (p < 0.05) improvement in Kujala and Lysholm scores at every follow-up compared to preoperative scores (Table 2). The Lysholm score improved from a preoperative mean of 68.2 ± 10.3 to 87.6 ± 9.5 (p < 0.001) at 6 months, 94.7 ± 6.4 (p < 0.001) at 12 months, and 98.7 ± 2.1 (p < 0.001) at 18 months follow-up. Similarly, the Kujala score improved from a preoperative mean of 50.3 ± 12.0 to 77.0 ± 14.7 (p < 0.001) at 6 months, 90.4 ± 6.7 (p < 0.001) at 12 months, and 95.4 ± 4.8 (p < 0.001) at 18 months (Table 2). At 18 months, the average Kujala score was 95.4 (out of a possible 100) and the average Lysholm score was 98.7 (i.e. excellent rating). Five patients were able to achieve premorbid Tegner activity levels at 12 months, with an additional five patients at the 18-month mark. Three patients were able to attain more than 90% of their activity level at 18 months’ follow-up. All the patients in this study were able to achieve full range of knee movements within 3 months of surgery. No complications (surgical site

Fig. 7. View from the DSL portal: Tensioning and securing the retrieved suture tape 5 mm proximal to the most proximal edge of the cartilage flap depresses the flap to create a groove. DSL, distal supero-lateral.

Fig. 8. View from the DSL portal: creation of a new trochlear groove. DSL, distal superolateral.
infection, arthrofibrosis, recurrent dislocations, need for repeat surgery) were noted during follow-up. There was no incidence of cartilage penetration in this study.

**DISCUSSION**

Trochleoplasty is indicated in patients with patellofemoral instability and high-grade trochlear dysplasia. In this study, we proposed a modified arthroscopic deepening trochleoplasty technique combined with MPFL reconstruction that offers several advantages over other techniques described in the literature. Firstly, this technique utilizes standard arthroscopic instruments and tools. Secondly, it includes preoperative planning of the new trochlear groove. We compared preoperative and postoperative Lysholm and Kujala scores and noted statistically significant improvement. A comparison of preoperative and postoperative Tegner scores revealed that most of the patients were able to return to preoperative activity levels.

The need for trochleoplasty has been a hotly debated topic, given that the patella can be sufficiently stabilized by doing an MPFL reconstruction alone. However, this does not address the underlying pathology and risks of recurrence of patellar dislocation. High-grade trochlear dysplasia leads to abnormal kinematics and increased patella femoral contact pressures [10]. This is demonstrated in the axial plane, where there is persistent lateral patellar tilt, and in the sagittal plane, where the patella impinges onto the supratrochlear spur during flexion and extension [3]. Without surgical correction of these underlying bony abnormalities, the risk of early patellofemoral osteoarthritis remains high [11,12].

At present, the open trochleoplasty remains the gold standard and most widely used procedure to address trochlear dysplasia. Open trochleoplasty involves a formal arthrotomy and a larger incision. Bland and Schottle [16] proved in their initial case series of nine knees that there was reduced pain, faster mobilization, less risk for the development of arthrofibrosis, reduced scar formation, and a shorter length of hospital stay following arthroscopic surgery. Patients in this study were similarly discharged from the hospital the day after surgery with regular oral analgesics. In contrast, patients with open trochleoplasty require 3–5 days of hospitalization for mobilization and pain control [22,23].

Multiple series have reported outcomes following open trochleoplasty [24–30], with a systemic review by Hiemstra et al. [31]. Utting et al. [24] prospectively studied a series of 59 knees with a mean follow-up of 24 months. All patients underwent open trochleoplasty, with 39% receiving additional soft tissue procedures (e.g. MPFL reconstruction, vastus medialis obliquus advancement), and 6.8% receiving additional tibial tubercle osteotomy. The Kujala score improved from a mean of 62 (range 29–92) to 76 (range 26–100), and the Lysholm score improved from 57 (range 25–91) to 78 (range 30–100), p < 0.001. In addition, there were 2 cases of superficial wound infection and 1 case of manipulation under anesthesia due to postoperative stiffness. In more recent studies, it appears that the postoperative Kujala and Lysholm scores have increased over time compared to earlier studies [31]. Overall, based on the absolute values of patient-reported outcome scores, the findings from this series are superior to the standard open procedure. Although the proposed technique is technically demanding, it has excellent outcome scores. No cases of arthrofibrosis, stiffness, infection, or other complications were noted in this study as compared to the open technique [31].

Bland and Haugegaard [17] subsequently reported the outcomes of 29 knees who underwent the arthroscopic Bland technique with MPFL...
reconstruction, with a minimum of 12 months' follow-up (average 29 months, range 12–57 months). There were 10 Dejour type B, 11 type C, and 16 type D trochlear dysplasias. In Blond and Haugegaard study [17], the Kujala and Tegner pre- and post-operative scores improved from a median of 64 (12–90) to 95 (47–100) and 4 (1–6) to 6 (4–9), respectively, \( p < 0.001 \). This study also demonstrated improvement in the Kujala score from a mean of 50.3 (SD 12.0) preoperatively to 95.4 (SD 4.8) post-operatively, \( p < 0.001 \). In this series, we reported the pre-morbid Tegner score mean of 6.5 (SD 1.5, range 5–10) and postoperative mean of 6.2 (SD 1.2, range 5–9). The significant difference in this study is that instead of obtaining preoperative Tegner scoring, we have obtained premorbid Tegner scoring. This not only enabled us to compare preoperative status (through Lysholm and Kujala scores) but also premorbid condition (through Tegner scores). We believe comparison and return to premorbid activity level are better measures of successful surgical outcomes. In our study, five patients returned to premorbid activity levels in 12 months and another five in 18 months. The remaining three patients were able to attain >90% of their activity level at 18 months' follow-up. In addition, this study also reported improvement in the Lysholm score from a mean of 68.2 (SD 10.3) preoperatively to 98.7 (SD 2.1) postoperatively, \( p < 0.001 \).

Cartilage degeneration has always been a cause of concern in patients undergoing trochleoplasty. Schottle et al. [27] reported good cartilage viability by a histological study from three patients at 6, 8, and 9 months after trochleoplasty. They concluded that trochleoplasty should be seen as a primary intervention for patellar instability because of trochlear dysplasia, as the risk for cartilage damage is low. No factors have been encountered so far that cartilage degeneration should occur using arthroscopic technique. As established in biomechanical studies, the added advantages of the arthroscopic technique are the preservation of the lateral patellofemoral soft tissue complex and the quadriceps mechanism, which can potentially be compromised in open procedures utilizing medial or lateral parapatellar approaches [32–34].

There are a few limitations of this study. Firstly, there were a fairly small number of subjects. This was largely due to strict selection criteria. Additionally, looking exclusively at type D trochlea dysplasia would naturally limit the volume of cases that can be selected. Secondly, this study represents a case series devoid of a control group for comparison. The inclusion of a matched group of patients who underwent open deepening trochleoplasty would have bolstered the reliability of the findings. Thirdly, the complexity of the technique itself, especially the estimation of the appropriate depth of the new trochlea, is challenging and has a steep learning curve. There is also a lack of postoperative image analysis of the newly created trochlea groove in this study. However, in the mid-to-long-term follow-up, an MRI study will be useful to assess the state of the patellofemoral joint post-trochleoplasty. Lastly, we used trochlear dysplasia type D exclusively in this study, as the trochlea in this instance is convex-shaped with a large supratrochlear spur of size greater than 4 mm. Hence, the minimum height of the spur itself should be 4 mm or more in order to utilize this arthroscopic method.

Nevertheless, to our knowledge, this surgical technique is the first to utilize an all-arthrosopic approach with standard, widely available arthroscopic instruments and include preoperative planning to accurately site the new trochlear groove for restoration of good patellar tracking. This study is also the first to show that excellent outcomes can still be achieved even in the most severe form of trochlear dysplasia (type D) via an all-arthrosopic method. Despite the steep learning curve, the good outcomes of this preliminary study justify continued use of this technique in future practice and warrant further studies to analyze the mid-to-long-term results in comparison with the outcomes of open techniques.

CONCLUSION

We report a modified technique of arthroscopic deepening trochleoplasty with MPFL reconstruction for recurrent patellar instability. We have shown through early clinical outcomes that it is a safe and effective procedure with the added benefits of a minimally invasive arthroscopic approach and the utilization of standard arthroscopic instruments and tools.

Ethics approval and consent to participate

We declare that Sing Health Institutional review board approval was obtained before the initiation of this study (CIRB 2020/2177). This study does not involve use of any animals.

Consent for publication

Not applicable.

Availability of data and material

The data will not be shared as per our hospital policy.

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Authors' contributions

All authors contributed significantly by collecting data, analyzing data, statistical analysis, drafting and finalization of manuscript. All authors read and approved the final manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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