ABSTRACT

Background: In patients with patellar instability and severe trochlear dysplasia, trochleoplasty has become increasingly used as part of the surgical management.

Hypothesis: Deepening trochleoplasty for severe dysplasia in patellofemoral instability improves function and increases sports participation.

Study Design: Case series; Level of evidence, 4.

Methods: Between 1995 and 2010 the thick-flap deepening trochleoplasty was performed in 90 patients (107 knees) with severe troclear dysplasia. Data was collected prospectively pre-operatively, at 6 weeks and 1-year follow-up. The patients were surveyed retrospectively to determine the clinical and functional outcomes including sports and exercise participation at a minimum of 2 years, with complete data available in 92%.

Results: With a minimum follow-up of 2 years, average of 6 years (range 2 – 19 years). The Kujala score had a median and interquartile range (IQR) of 63 (47-75) pre-operatively rising to 79 (68-91) at 1 year follow-up and 84 (73-92) at final follow-up (p< 0.05). Seventy-two per cent were satisfied with their knee function at 1 year follow-up rising to 79% at final follow-up (p <0.0001). Sports and exercise participation increased from 36 patients (40%) pre-operatively to 60 (67%) at final follow-up. The numbers involved in competitions increased slightly from 10 (11%) to 11 (12%). Of those sports that involved twisting (e.g. soccer, cricket, badminton), the proportion of patients participating increased from 16 (18%) to 22 (24%), whereas in non-twisting sports (e.g. running, swimming, cycling) it increased from 24 (27%) to 47 (52%) of whom 14 (16%) used walking as exercise.

Conclusion: The thick-flap deepening trochleoplasty improves the clinical and functional outcomes for patients with symptomatic patellar instability with severe troclear dysplasia. These results improve over time and beyond the 1 year clinical follow-up. However trochleoplasty does not lead to a significant improvement in sports participation at a competitive level. It does improve the sports and exercise patient participation, principally in non-twisting sports activities.

Keywords: Patellar dislocation; trochleoplasty; mid-term; clinical outcomes, sports
What is known about the subject: Trochleoplasty is an increasingly popular operation for severe trochlear dysplasia. A number of series have shown satisfactory outcomes with minimal complications.

What this study adds to existing knowledge: This is the first study to report sports outcomes for this operation. A new variant of the operation is presented using a thick osteochondral flap and arthroscopy-assisted technique.
INTRODUCTION

Trochlear dysplasia is increasingly recognised to be an important anatomical abnormality in those patients presenting with patellar instability. Correction of the dysplasia encompasses a number of techniques which can be classified into: trochlear lengthening osteotomy, proximal open trochleoplasty, deepening trochleoplasty and arthroscopic deepening. The deepening trochleoplasty has two main described methods; the Bereiter and the Dejour. The former raises a thin flexible flap of articular cartilage and then removes the excess subchondral bone fashioning a groove. The thin flap is then anchored by an absorbable tape along the depth of the groove. In the latter subchondral bone is removed but leaves an even thickness of subchondral bone along the flap and the new groove is formed by an osteotomy of the flap and depressing the two sides. These are then held with staples.

This paper reports the results of a cohort of patients who have undergone a deepening trochleoplasty that is a modification of the Dejour technique. Two triangular flaps (lateral and medial trochlear facets) are created where the subchondral bone is removed under arthroscopic guidance leaving cancellous bone attached. The flaps are depressed and held with absorbable sutures. The principle is that the patella articulates and maintains congruence with the lateral trochlear facet. The medial facet is depressed posteriorly to avoid incongruence. The aim of this paper is to report the mid-term results of this trocheoplasty including the sports and exercise activities of the cohort. Our hypothesis was that the operation would improve knee function and lead to an increase in sports participation in the patients.

PATIENTS AND METHODS

Patients

Between January 1995 and December 2010, 102 patients (122 knees) underwent a trocheoplasty at the Norfolk & Norwich University Hospital identified from the institution’s prospective database. All had been referred to a dedicated Patellar Instability Clinic from various parts of the United Kingdom and abroad.

The indications for the trocheoplasty were patients with recurrent symptomatic patellar instability, with at least one documented dislocation of the patella that had either failed physical therapy and/or previous
patellar stabilisation procedure(s), with a severe trochlear dysplasia as defined on a lateral plain radiograph with a boss height of ≥ 4mm.

Clinical assessment and outcome scores

The data was collected using the Bluespier Data Management software (Bluespier Int, Droitwich, UK). Its use for research purposes and report writing has been granted by the National Research Ethics Service. A standard pre-operative clinical assessment that included assessment of patellar apprehension (graded from 0 to three pluses where 0 equalled no apprehension, + discomfort on extreme lateral, translation of the patellar in extension, ++ true apprehension with voluntary quadriceps contraction on lateral translation in extension and +++ when the patient stops the clinician touching the patella), patellar tracking and patellofemoral crepitus.

Pre-operatively, all patients completed the Kujala Patellofemoral Disorder Score. Post-operative outcome scores were performed by postal questionnaire and collected between June and December 2013. Data routinely collected included: questions on return to sports, satisfaction (very satisfied, satisfied, disappointed, unsatisfied), and the Norwich Patellar Instability (NPI) Score. The NPI score is a 19 item validated patient reported outcome measure for patellar instability symptoms. The best score is 0% and worst 100%. For all non-responders of the postal questionnaire, data was collected through a supplementary telephone questionnaire one month after the initial posting to collect the same data.

Sporting activity was defined by the major exercise performed. This was graded as to whether the patient took part in competitions, played regularly, or participated as a leisure activity according to the Arpège scoring system. Those that were active in sports had this graded by the Tegner Activity score where swimming was defined as level 4. Walking was defined as a sport if undertaken regularly as part of a deliberate attempt to stay fit.

Patients were stratified into weight classes according to their body mass index. Obesity was defined as a BMI ≥ 30kg/m². Hypermobility was measured using the Beighton score and was defined as a score ≥ 4. The Beighton score was only routinely recorded from 2007.

Successful outcome at sports and exercise
A successful outcome was defined as returning to sports and exercise at the same level or better, or commencing sports and exercise having previously not done so. An unsuccessful outcome was defined as reducing sporting activity including downgrading level of sport e.g. from competitive to recreational.

**Radiographic assessment**

Radiographic assessment included: plain anteroposterior, true lateral and skyline weight-bearing radiographs performed at 30 degrees knee flexion. Trochlear dysplasia was defined radiographically on the true lateral radiograph as a boss height measuring more than 4 mm (see Fig 1). Dejour defined the boss height at 6mm. This was reduced by the senior author in the light of experience; 6mm in a tall patient may not be significant whereas 4mm in a short patient is. The dysplasia was classified using both Dejour systems. Patellar height was measured using the Caton-Deschamps classification.

**Operative intervention**

All operations were performed by the senior author using a previously reported technique which was a development of that described by Ntagiopoulos et al. In summary, through a standard medial parapatellar approach, a wedge of subchondral bone is removed deep to the trochlea with its apex at the anterior end of the intercondylar notch (see Fig 2). Viewed from the anterior surface, the wedge on the lateral view is a rhomboid shape (see Fig 3). The new groove is cut with an osteotome or fine saw from the apex in line with the anatomical axis of the femur. This results in two triangular osteochondral flaps. The lateral flap has a more acute angle so that as it folds down it re-creates the lateral flare. The medial flap folds on a near transverse line to displace it posteriorly; this helps avoid impingement on the medial facet of the patella when it is realigned. The flaps are depressed after removing bone up to the cartilage along the flap line (see Fig 4). They are then held in place with absorbable sutures, although a variety of materials from metallic and absorbable screws, as well as suture anchors were used in the cohort. A bare area of cancellous bone is created proximally that that is partially covered by the synovium overlying the supracondylar fat pad (see Fig 5). Lateral release is rarely needed as the retinaculum is relaxed by reducing the patella into the new groove. Double-breasting medial reefing was always performed as the medial retinacular flap overlies the new patellar position. The medial soft tissue is reinforced with a medial patellofemoral reconstruction when the double-breasting medial reefing is deemed inadequate due to poor quality tissue allowing lateral tracking of the patella.
No chemical thromboprophylaxis was given at the start of the study. For the last 5 years the patients are given chemical thromboprophylaxis according to hospital guidelines. The rehabilitation protocol has been previously reported. In essence, patients are immediately commenced on unrestricted continuous passive motion (CPM) whilst an epidural catheter is in situ. This continues until the patient can independently manage their early exercise regime of knee range of motion exercises and a quadriceps strengthening regime. Patients commence mobilisation as soon as possible, with no restriction on range of motion or weight-bearing. Only patients who undergo a tibial tubercle transfer require a brace; this is initially limited from 0° to 90° during the initial 6 post-operative weeks. Rehabilitation continues in an out-patient setting. This focuses on a graded-exercise programme with the aim of returning patients to their desired level of functional and sporting capability. The patients are routinely followed up at 6 weeks where complications are recorded and at 1-year where they undergo clinical and radiological assessments.

Statistical analysis

Following assessment of data distribution, results were initially analysed using descriptive statistics (median and inter-quartile range) pre- and post-operatively (12 months and final follow-up). Difference in pre- to post-operative clinical and radiological outcomes were assessed using non-parametric Wilcoxon Matched Pairs test with data presented with 95% confidence interval. Assessment of frequency to return to sporting participation and level of sporting participation was assessed at the final follow-up. All analyses were performed on SPSS (PASWStatistics 18.0 software), with statistical significance set at a p<0.05 level.

RESULTS

Cohort Characteristics

Of the 102 patients, six patients were excluded because the diagnosis was patellofemoral arthritis. A further six were excluded because they underwent a different type of trochleoplasty (Bereiter n = 2, modified Albee n = 1, Excision n = 3). Therefore the trial cohort consisted of 90 patients with 107 affected knees. Of these patients, 20 had had bilateral trochleoplasties but three of these knees were excluded as one knee was operated on for pain alone without patellar dislocation, and two knees were operated after the study period. Fifty-four (60%) were
female, and 36 (40%) male. The average follow-up was 6 years (range 2 to 19 years). Fifty (56%) of the patients were from outside the local area. The right knee was operated on in 49 (46%) and the left in 58 (54%). Forty-five (42%) of the knees had undergone previous surgery of which seven had had multiple procedures, 19 had a patellar stabilisation, six had had an arthroscopic lateral release and 11 had had an arthroscopy, usually to remove a loose body. Forty of the knees underwent trochleoplasty alone. At the same time as the trochleoplasty a further 14 had a medial patellofemoral ligament reconstruction in addition, and a medialisation tibial tubercle osteotomy in 10, which occurred in the first 20 knees. One patient with a permanent dislocation underwent proximalisation of the tibial tubercle because of a patella infera. The initial 10 patients had metal screw fixation following which bioabsorbable screws were used in 54 of which five had suture anchors used for the medial flap. The final 43 had absorbable sutures to fix the flaps. A patelloplasty (usually a microfracture) was performed in 16, excision of a medial ossicle in 10, and a lateral release in 28 of which five just involved releasing the deep transverse ligament from the patella. Four patients had metalwork removed from previous surgery.

The average age at first dislocation was 13.7 years (range 1 to 28 years). The mean age at operation was 23 years-old (range 12y to 49y). The average BMI was 24kg/m² with four patients underweight, 54 of normal weight, 31 overweight, six obese, and one severely obese. The Beighton score was recorded in 60 patients of whom 20 (34%) were hypermobile. The heterogeneity of the cohort with respect to positive family history, hypermobility, and obesity of those patients is shown in Fig 6.

Clinical outcomes

The clinical findings with respect to apprehension, tracking type and range of knee motion at 1 year are shown in Table 1. The mean time to return to work or school was 7 weeks (IQR 4 to 12). At 1 year six knees had persistent swelling associated with instability from poor muscle control. The Kujala score had a median and interquartile range (IQR) of 63 (47-75) pre-operatively rising to 79 (68-91) at 1 year follow-up and 84 (73-92) at final follow-up (p < 0.5, Mann-Whitney U test pre-operative vs final follow-up). The NPI score at final follow-up had a median of 29% (IQR 5% to 44%). The satisfaction scores significantly improved between 1 year post-operatively and final follow-up (Table 2).

Post-operative complications
In the first 6 post-operative weeks two patients had a venous thrombotic event, one deep vein thrombosis and one pulmonary embolus. The latter went on to require an open arthrolysis and still had a stiff knee at final follow-up. Four knees had a superficial wound infection; there were no deep infections. Four patients complained of significant crepitus at 1 year of whom two had had a patelloplasty.

Further operations

Further operations were undertaken in 19 knees of which were 10 MPFL reconstructions (for continuing instability symptoms and a mediolateral glide in extension of more than two quadrants displacement) within which two were revisions, seven arthroscopic arthrolyses (from the early cohort of patients before post-operative continuous passive motion was introduced) and two removal of loose absorbable screw heads, one was an open arthrolysis (in the patient who had had a pulmonary embolus), and one patient required arthroscopic debridement of a notch “osteophyte” where a drill hole had been inadvertently made through the notch during the trochleoplasty.

Radiological outcomes

The pre-operative dysplasia type was B in 49, C in 3, and D in 54 knees; one was unclassifiable. The operation removed the supratrochlear spur in all cases. The radiological outcomes are shown in Table 3. Patella alta was present in 16 knees prior to surgery. Patients did not undergo distalisation of the tibial tubercle. In these knees the pre-operative mean patellar height was 1.31 (sd 0.11) changing to 1.11 (sd 0.16, p = 0.0008) post-operatively. Four knees remained with a patella alta, two higher than pre-operatively.

Sports and exercise

The pre- and final follow up sports and exercise data are shown in Table 4. The dominant post-operative sport was swimming (n = 16 or 27% of the sports active cohort). A further 18 (30%) undertook exercise that directly reflected activities undertaken during rehabilitation (gym, and walking) of whom 10 had not undertaken regular exercise pre-operatively. The median time to return to sports was 24 weeks (IQR 20 to 36).

Successful outcome for sports and exercise

A successful outcome with respect to sports was found in 54 patients and unsuccessful in 33 (three were excluded for lack of data). Success at sports did not correlate with gender, age at first dislocation, age at
operation, whether the patient had had previous surgery, a positive family history, hypermobility syndrome, pre-
operative Kujala score, pre-operative apprehension grade, pre-operative tracking type or the presence of a
quadriceps lag pre-operatively.

DISCUSSION

This study shows that patients undergoing the thick-flap deepening trochleoplasty for symptomatic recurrent
patellar dislocation improve significantly functionally and that this improvement continues over time. Sports
and exercise participation, in an amateur population, improved from 40% of the cohort to 67% with the
dominant activity being non-twisting. Swimming was the commonest exercise undertaken following the
operation. Improvements in Kujala score matched those from other studies, however it should be noted
that the thick-flap trochleoplasty does not require normal articular cartilage whereas the thin flexible flap created
in the Bereiter technique does. Therefore this study’s cohort of patients overall had a severity of trochlear
dysplasia with chondral changes not matched by other series. Patients with severe troclear dysplasia and
chondral damage are treated with patellofemoral arthroplasty.

Patient selection for a deepening trochleoplasty depends on the level of symptoms, the aims of the
patient with respect to activities, and the severity of the troclear dysplasia. The definition of severe troclear
dysplasia is imprecise and has not been universally agreed. Both quantitative measurements and the Xray
classification are used. The quantitative measurements are not stated but the use of measurements such as the
sulcus angle is implied. The inter- and intra-observer reliability of the radiological measurements used in
patellar instability is generally poor. David Dejour’s classification based on troclear shapes classified from
Type A to D is also recommended. However the prevailing view is that severe troclear dysplasia is defined
by Dejour Types B to D. Henri Dejour’s classification was used in this study with the indication being a
boss height of > 4mm. Having said that the senior author’s view is that there is still a qualitative element in the
decision making. This includes the patient’s personality and the likelihood of their undertaking rehabilitation.

Patients who are obese are routinely advised to lose weight are generally excluded from this surgery. In addition
patients with hypermobility may be treated with an MPFL reconstruction alone since the elasticity of the
ligaments allows for the anterior displacement of the patella as it tracks over the troclear boss. Patients with a
positive family history often decline surgery and treat by self-reduction and rehabilitation after a dislocation
episode.
In this cohort the patients underwent the Dejour protocol with medialisation of the tibial tubercle for an excessive tibial tubercle-trochlear groove (TTTG) distance (>20mm). It subsequently became apparent that the TTTG is reduced by the trochleoplasty and that a distal procedure was unnecessary. Although the current view is that distalisation of the tibial tubercle should be performed when patella alta is present, it should be noted, from this study, that the trochleoplasty procedure itself tends to lower the patella. This suggests that the combination of an open approach and medial reefing leads to a distal soft tissue contracture. It is unlikely that the posterior displacement of the patella is automatically coupled with a distalisation. The distalisation is an advantage as most patients have a patella alta, which is then corrected. The patient with a significant pre-operative patella infera was corrected with a formal proximalisation of the tibial tubercle (the osteotomy also aided exposure). As a rule distal procedures are avoided as it typically stops kneeling. However patients with a permanent dislocation always need extensive multiple procedures that may include lateral release and disinsertion of the quadriceps, tibial tubercle osteotomy, and rotational osteotomies of the femur and/or tibia.

Combining an MPFL reconstruction with the trochleoplasty as a routine has been advocated. This is stated to improve the stability of the patellofemoral joint. In this study, where 14 of the cohort had an MPFL combined with the trochleoplasty, a further eight required the procedure subsequently. However 81 (87%) did not. An unstable patella can be due to a severe trochlear dysplasia and/or an abnormal soft tissue envelope. The MPFL stops lateral displacement of the patella and can be measured clinically by the mediolateral glide test. A trochleoplasty alone should not be expected to correct patellar maltracking per se. It is probable that those patients who needed a subsequent MPFL reconstruction had insufficient medial tissues and reflects a failure of the double-breasting medial reefing. It is therefore perfectly logical to suggest that an MPFL reconstruction should be always added to a trochleoplasty.

The importance of considering the tunnel position in the presence of severe trochleoplasty has recently been reported, performing a trochleoplasty should mean that the anatomical position has become near normal. The two revision MPFLs reported were patients with open physes at the time of the trochleoplasty who had a free hamstrings MPFL reconstruction. Revision using adductor magnus tendon left distally inserted in the adductor tubercle was then chosen although this method is known to be less satisfactory in a paediatric population.
The potential problems of a trochleoplasty include chondrolysis and the development osteoarthritis. No study has reported these to have occurred \(^3,^{25,26,27,34}\), although von Knoch et al \(^35\) reported radiological changes in 33 knees out of 45 with 10 knees showing an Iwano grade of 2 or more, at an average follow-up of 8.3 years. This study did not include radiological imaging at final follow-up. It can be inferred that since the Kujala and satisfaction scores improved from 1 year to final follow-up then rapid degenerative changes are unlikely to be occurring. It is known from the historical literature \(^24\) knees operated for patellar dislocation had a higher rate of subsequent osteoarthritis than unoperated knees (NB the former were more symptomatic). The logic of the trochleoplasty is to create a groove and reduce the patellofemoral joint reaction forces, and hopefully reduce the risk of developing OA. This will require follow-up studies of 20 to 30 years duration. The alternative to a trochleoplasty for reducing the patellofemoral joint reaction force is to perform an anteromedial tibial tubercle osteotomy \(^18\). This may well be satisfactory for patients with milder forms of trochlear dysplasia, especially in the presence of severe cartilage lesions and pain, but it is difficult balancing a tennis ball on a football.

The problem with research in patellofemoral instability is that there is no consensus on; definitions of terminology \(^19\), relevant descriptors of cohort heterogeneity, clinical examination tests and their outcome measures \(^29\), or an examination tool for the unstable patella (cf. the KT-1000 for ACL rupture which revolutionised research in the subject). Only recently has a validated dedicated outcome measure become available \(^31\). The current radiological assessments have poor inter- and intra-observer agreement \(^16,29\). The weaknesses in this study relate to the retrospective nature of the final outcome data, and the lack of a dedicated patellar instability pre-operative score. In addition there is no tool available that accurately assesses the level of sports in an amateur population. Here the dominant sport was chosen, yet most amateurs undertake a number of activities, all of which contribute to their overall fitness. The definition of success at sports can also be criticised, however the population with severe trochlear dysplasia includes patients with severe problems and limited goals. Typically a young adult female wants to be able to climb and descend stairs carrying a baby safely. For them achieving regular walking as a fitness activity is a triumph.

The weakness of this study is that the final follow-up is remote and does not include a clinical and radiological assessment. However this is the first study in a population of patients with recurrent patellar dislocation that reports on their sports and exercise activities. The population cohort has an extreme level of anatomical abnormalities far greater than would be seen in a typical sports practice with a knee interest. It is
important to note that functional improvement and satisfaction continues in the follow-up period and would appear to reflect improving muscle function. This study also reports on a method of undertaking a deepening trochleoplasty where the aim is to keep patellofemoral congruence by rotating the patella with the new lateral facet of the femur in the hope of reducing the risk of later-onset osteoarthritis.

Conclusions

The thick-flap deepening trochleoplasty improves the clinical and functional outcomes for patients with symptomatic patellar instability with severe trochlear dysplasia. These results improve over time and beyond the 1 year clinical follow-up. However, trochleoplasty does not lead to a significant improvement in sports participation at a competitive level. It does improve the sports and exercise patient participation, principally in non-twisting sports activities.


Figure legends

Fig 1. Pre-operative lateral radiograph showing a type III / D trochlear dysplasia in a patient who had undergone a previous medialisation of the tibial tubercle. AB is the extension line of the anterior femoral cortex CD is the boss height (measures 6mm)

Fig 2. Lateral radiograph of the knee showing the wedge of subchondral bone removed as part of the trochleoplasty

Fig 3. Intra-operative photograph of a dysplastic trochlea with the hip to the left AB is the lateral fold line, AC is the medial fold line. AD is the proposed new groove line.

Fig 4. Intra-operative photographs of a left knee seen from the foot showing the trochlea before and after the deepening trochleoplasty

Fig 5. Intraoperative photograph showing the completed trochleoplasty from the lateral side (hip is to the right) with the supracondylar synovium reattached.

Fig 6. Diagram of the heterogeneity of the patient population with respect to family history, obesity and hypermobility.