Original article

Results of operative 4-in-1 patella realignment in children with recurrent patella instability

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ABSTRACT

Purpose: Recurrent patellar instability is a cause of knee dysfunction, limitation and pain for children. If non-operative treatment fails to stabilise the patella, operative realignment and stabilisation have been advocated. Operative techniques in the paediatric population must preserve physal growth while ensuring stability. We aimed to determine the outcome of children and adolescents who underwent a 4-in-1 patellar realignment (lateral release, medial reefing, Insall tube realignment and Roux-Goldthwaite patella ligament transfer).

Methods: Consecutive skeletally immature patients operated in our institution were included in the study. A total of 16 operated knees in 12 patients were recruited. All patients underwent the same procedure after attempting a minimum period of 6 months of non-operative treatment with unsatisfactory results. The main outcome measured was recurrent dislocations. Functional outcomes were assessed using the Kujala score and the Paediatric form of the International Knee Documentation Committee Subjective Knee Form (Pedi-IKDC).

Results: Patients were followed up for a minimum of 3 years. None of the patients sustained further patella dislocations following the operation. In 3 cases, minor patellar maltracking was noted post-operatively but all 3 remained asymptomatic. Three patients had a small area of numbness lateral to the operative incision, which coincided with hypertrophic scarring. There was one case of superficial wound infection. The mean Kujala score was 83.4 ± 11.47 and the mean Pedi-IKDC was 79.5 ± 12.56 at the latest follow-up (minimum of 36 months).

Conclusions: The 4-in-1 patellar realignment is a good procedure in paediatric and adolescent patients with recurrent patella instability. Satisfactory results were observed with a minimal complication and redislocation rate in our series.

1. Introduction

Patellar dislocations are common knee injuries in the paediatric and adolescent population with a reported annual incidence of 0.04% in those younger than 16 years of age.^{1–6} Sequelae following a first episode of acute patellar dislocation may include anterior knee pain, decreased activity level, and recurrent instability.^{6–7}

Recurrent instability is defined as a patellar dislocation that occurs more than once. According to a recent study, up to 38.4% of paediatric and adolescent patients with acute patella dislocation will experience recurrent dislocations.⁸ Another study by Cash and Hughston found a recurrence rate of 60% in patients younger than 14 years, which suggests a higher risk in young active individuals.⁹

The treatment of choice for acute patellar dislocations continues to be non-operative except for specific circumstances including osteochondral fractures, grossly malaligned patella, or patients that fail to improve with appropriate rehabilitation.^{5,6} In these cases, operative

realignment and stabilisation of the extensor knee mechanism have been advocated.¹⁰ Many techniques have been described for surgical management of this condition although there is no consensus as to which one is best. A proximal “tube” realignment was described by Insall with good results in the paediatric population.¹¹ The Roux-Goldthwait procedure and modifications of the original technique have also yield good outcomes in children.^{12,13} Numerous methods of the medial patellofemoral ligament (MPFL) reconstruction have been described^{14–16} including anatomic reconstruction sparing the physes in children.¹⁷

The rates of recurrent dislocation are unacceptably high (67%–71%) when performing only lateral release, with or without direct repair of the medial structures.⁵ To overcome the risk of redislocation in children who generally present with predisposing factors we believe that, in addition to proximal realignment, a distal patellar tendon transfer should be included in the procedure. To the best of our knowledge, the outcome of a 4-in-1 technique in children has not been reported in this

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present form including lateral release, medial reefing, Insall tube realignment and Roux-Goldthwait patella ligament transfer.

The aims of this study were to examine the results of the 4-in-1 procedure performed in a tertiary centre and to assess any complications. We provide a detailed description of the procedure as it is performed in our centre to minimize the risk of technical complications.

2. Materials and methods

This study included a cohort of consecutive skeletally immature patients with recurrent patella instability operated on by the senior author (MR) in our institution between October 2009 and April 2014. The patients underwent a 4-in-1 procedure for patellar realignment (lateral release, medial reefing, Insall tube realignment and Roux-Goldthwait patella ligament transfer). The Local Audit and Clinical Effectiveness Committees approved this study, and written informed consent to use the data was obtained from parents or guardians of the children.

The study included a total of 16 knees in 12 children and adolescents who have experienced at least two episodes of patella dislocation. Eleven of the knees were cases of habitual dislocation in which the patella moves in and out of its normal position in the trochlear groove whenever the knee is flexed or extended. (Fig. 1A–C) No patient had a history of trauma associated with dislocation and three had previous knee operations. Only one of these had undergone a previous failed patella stabilisation procedure (Roux-Goldthwait) at another institution. The other two procedures were a knee arthroscopy with meniscectomy plus osteochondral defect drilling at the lateral femoral condyle, and a hemiepiphysiodesis using growth guided plates for genu valgum.

Prior to being offered surgical intervention, all patients had attempted a minimum period of 6 months of non-operative physiotherapy treatment with unsatisfactory results and ongoing symptomatic dislocations.

All patients showed patella maltracking on examination and generalised ligamentous laxity was scored according to the classification of Beighton.¹⁸ All patients had open knee physes as identified on plain knee radiographs (anteroposterior, lateral and skyline patella views). Radiographs were evaluated for evidence of patella alta and baja as defined by Insall and Salvati (Table 1).^{19,20} We found a considerable number of dysplastic trochleas (13 cases – 81%). All patients underwent knee magnetic resonance imaging (MRI) and these findings are detailed in Table 2.

2.1. Surgical technique. The 4-in-1 procedure

At the time of surgery, every patient's knee is examined under anaesthesia and the patellar tracking evaluated.

Patients are placed in the supine position with a thigh tourniquet (mean tourniquet time 69 min, range 50 to 82 min). A midline longitudinal 10 cm incision is performed centred over the patella down to the fascia.

Table 1
Demographics.

Characteristic	n = 16
Age at operation – years (range)	12.6 (9–16)
Male sex – no. (%)	4 (33%)
Side – no. (%)	
Right	5 (42)
Left	3 (25)
Bilateral	4 (33)
Insall-Salvati Index – mean	1.2
Patella alta (%)	3 (19)
Patella baja (%)	3 (19)
Normal (%)	10 (63)
Preop pain at rest – no. knees (%)	12 (75)
Beighton score	3.4
Sports activity – no. (%)	
Football	4 (33)
Cricket	2 (17)
Judo	1 (8)
Multiple	4 (33)

Table 2
MRI findings pre-operatively.

Findings	Cases – no. (%)
Dysplastic trochlea	13 (81)
Subluxated patella	7 (44)
Patellar facet chondropathy	5 (31)
Dislocated patella	3 (19)
Dysplastic femoral condyle	2 (13)
Femoral condyle chondropathy	2 (13)
Dysplastic tibial plateau	1 (6)
Absent abnormalities	0 (0)

Suprafascial dissection is carried out to release the adhesions that extend along the lateral intermuscular septum. A lateral release of the lateral patello-femoral ligament (LPFL) and lateral patellar retinaculum is performed continuing proximally at the insertion of the quadriceps tendon. Care must be taken to protect the capsule and to avoid accidental synovial breach.

The interval between the capsule and the vastus medialis obliquus was developed to expose the medial patello-femoral ligament (MPFL). The medial border of the quadriceps tendon is incised dividing it in thirds. This incision will continue into a medial parapatellar arthrotomy to expose the knee joint. (Fig. 2) The chondral surfaces of the trochlea and patella are carefully examined. In cases of osteochondral lesions, individualized treatment is carried out simultaneously (Fig. 3).

Vastus medialis is sutured to the free edge of vastus lateralis, forming a “tube” as described by Insall.¹¹ The tube realignment of the quadriceps tendon is performed using absorbable sutures. Using the same sutures, medial reefing of the capsule and MPFL is undertaken.

The patellar tendon is split longitudinally in halves and the LATERAL band de-inserted from the tibial tuberosity. This portion is

Fig. 1. A–C. Patient with bilateral habitual dislocation of the patella. Right knee post-operatively after the 4-in-1 procedure; left knee pre-operatively with evidence of dislocated patella in flexion of the knee.

Fig. 2. Medial parapatellar arthrotomy after having performed a lateral release while protecting the capsule and synovium and division of the quadriceps tendon in thirds.

Fig. 3. Eversion of the patella that allows for careful examination. When chondral injury is identified it can be treated accordingly.

subsequently passed medially under the MEDIAL band and tensioned to be re-attached at the MEDIAL aspect of the tibial tuberosity using 2 metallic 2.4 mm non-absorbable anchors (Mitek GII, DePuy Mitek, Raynham, MA, USA). The transferred portion makes an angle of 40°–45° with the intact patellar tendon (Fig. 4).

Patellar tracking is checked to assess congruency. The approach is closed in layers, the wound dressed and a hinged knee brace is applied postoperatively, initially locked at 0–30° of flexion.

2.2. Post-operative rehabilitation

Full weight bearing with crutches was allowed from the day of the operation. The post-operative rehabilitation technique consisted of passive and active flexion and extension exercises of the knee,

Fig. 4. LATERAL band of the patellar tendon re-attached into the MEDIAL aspect of the tibial tuberosity using 2 anchors. (Roux-Goldthwaite procedure). The patellar tendon was split in halves and the LATERAL one DE-INSERTED from the tibial tuberosity.

strengthening of the vastus medialis obliquus muscle, and hip and ankle strengthening exercises. Further degrees of freedom are allowed for the hinged knee brace from week 2 postoperatively with a 10° weekly increment and the brace was discontinued from week 8. Jogging was allowed from week 12 and impact sport activities from 4 months following surgery.

2.3. Outcome measures

The primary outcome measure was the post-operative rate of dislocation, measured by the number of patellar dislocation episodes sustained from the date of operation until the latest follow-up. Other secondary outcome measures included postoperative patellar maltracking, time to return to sports and complications. Functional outcomes were measured using postoperative Kujala scores²¹ and Paediatric International Knee Documentation Committee Subjective Knee Form (or Pedi IKDC) which have shown good reliability in patellar dislocations²² and in children with knee disorders respectively.²³

3. Results

All patients were followed up for a minimum of 36 months (range 36–98 months; mean, 65). The mean patient age at operation was 12.6 years (range, 9–16). There were 4 male and 8 female patients and 8 had contralateral patellofemoral joint symptoms. Four of these were operated bilaterally for recurrent patellar dislocations.

There were no cases of postoperative recurrent patella dislocations. Three cases showed minor patellar maltracking that responded well to intensive physiotherapy and vastus medialis obliquus strengthening after having demonstrated postoperative muscle wasting. In two cases, pain was experienced at the latest follow-up and the majority were pain free (14/16). None of the cases had any physal disturbance.

All patients had returned to school and 10 out of 12 to full sporting activities (mean time to return to sports: 5.6 months, range 4–12). In two cases, patients reported that they were unable to jump or perform pivoting exercises at latest follow-up. (Table 3)

Data on the outcome questionnaires was available on 14 knees (88%) from the 16 operated on. (Table 3) According to the Kujala score, there were 71% good (10 knees), 21% fair and 7% poor results.

Complications after surgery were seen in 3 patients. Two cases developed a keloid scar, which coincided with a reported small skin area of numbness lateral to the wound. There was one case of superficial

Table 3
Postoperative findings.

Characteristic/score	N = 16
Mean time to FU – years (range)	5.4 (3–8.2)
Dislocations – no. patients (%)	0 (0)
Patellar maltracking – no. patients (%)	3 (19)
Pain at rest – no. knees (%)	2 (13)
Return to sports – months mean	5.4
median (range)	4.5 (4–12)
Complications – no. patients (%)	3 (19)
Numb skin area with keloid scar	2
Superficial wound infection	1
Kujala score* – mean $\pm$ SD	83.4 $\pm$ 11.47
Pedi-IKDC* – mean $\pm$ SD	79.5 $\pm$ 12.56

FU: Follow-up, SD: Standard deviation. * At latest follow-up.

wound infection that responded to a short course of antibiotics. One of the patients sustained a fall on wet floor and fractured the distal pole of the patella (sleeve fracture) at week 4 postoperatively. He was immobilized for further 4 weeks and the physiotherapy protocol was re-initiated. Due to the long immobilization time, he developed knee stiffness that warranted manipulation under anaesthesia and knee arthroscopy to release adhesions 10 weeks after the index surgery. His recovery and return to activities was significantly delayed but full range of motion was achieved at latest follow-up and he returned to judo practise at national competitive level 9 months following the index surgery.

4. Discussion

This study reports good results with the presented 4-in-1 procedure with a 0% redislocation rate. It supports our belief that in active children and young adolescents, the combination of proximal and distal realignment procedures ensures a more stable patella. The technique yields good results even in cases of hyperlaxity, habitual dislocation, or bilateral surgery. It has also been used as a salvage procedure in previously operated knees that failed to prevent recurrent dislocations. Performed in a step-by-step fashion, the surgeon can tailor the amount of realignment and re-tensioning of the stabilising structures according to the needs of every patient's knee. Overall, this 4-in-1 technique provides good versatility and consistent results.

Our cohort of patients demonstrated good functional outcomes with a majority of good Kujala scores (71%). The time required to return to full-level sports activities ranges from 3 to 6 months, with a median of 4.5 months. The procedure can interfere in the lives of these young patients at home, with sporting activities and at school. Prior to considering operative treatment, the patients and their parents must be fully counselled for expectation management.

The technique that we describe has not been published in this present form for paediatric patients. Individually, the 4 steps included had been reported in isolation or as part of combined procedures.^{11–13} It is the combination of the 4 steps in one single procedure that leads to good results and minimizes the risk of redislocation. When Insall's proximal realignment of the patella is performed in isolation, it has demonstrated poor results and has been deemed insufficient to prevent redislocation.²⁴ The failure of this and other techniques has been postulated to be due to the non-anatomic repair that is achieved.^{17,25,26} The primary soft tissue stabilizer in the knee has been recognized to be the MPFL.²⁷ Anatomical repairs consequently address the torn MPFL using its original insertion points.^{17,28} Medial reefing restores adequate tension of the MPFL successfully and has been used in isolation for selected patients with normal bony anatomy.^{12,29} It can be performed arthroscopically and has shown good short- and long-term results in adults.^{30,31} Nelitz et al.,¹⁷ reported their results in a series (n = 21) of skeletally immature patients that underwent an anatomic reconstruction of the MPFL at a minimum of 2 years follow-up (mean 2.8). No

recurrent dislocations occurred and the Kujala score improved significantly from 72.9 preoperatively to 92.8 postoperatively. In their technique, they made use of fluoroscopy to confirm the anatomical placement of the tunnel at the distal femoral physis. The pes anserinus was exposed to harvest the tendon graft used for the MPFL reconstruction.

In a series of six knees with habitual dislocation, Joo et al. used a so-called 4-in-1 technique but the procedure involved a semitendinosus tenodesis. The cohort was formed of young children (mean age 6.1 years) followed up for a mean of 54.5 months, with a Kujala score of 95.3 and no recurrent dislocations.³² Although using similar terminology, there is a diversity of techniques described as “3-in-1” and “4-in-1” that may confuse the reader as they are slight variations of patellar realignments. A study by Oliva et al.³³ reports on the 3-in-1 procedure as described previously by Myers et al.³⁴ The rationale of the technique is similar to ours although differently performed operatively. The vastus medialis insertion is inserted on the surface of the patella instead of the medial reefing. By doing this, the MPFL, which is the main restraint to patellar dislocation, is not modified. The medial collateral ligament, in turn becomes a soft tissue structure to provide stability by serving as the insertion of the medial third of the patellar tendon that is transferred.

We are of the opinion that our reported technique has some potential advantages when compared to the above reports, specifically in a paediatric subset. The procedure is carried out without the need for fluoroscopy. No healthy tendon grafts are used, eliminating any donor site morbidity and preserving tendons that may become necessary for eventual reconstruction surgery. Moreover, the growth of the devitalized tendon used to reconstruct the MPFL is still a matter of debate and its consequences are not clear in a child that will comparatively overgrow the restraining tendon. In our soft tissue-only technique, there is no bone or physal violation, nor need for metalwork removal. Although some authors have reported good results with isolated MPFL reconstruction without arthrotomy,²⁶ our technique has the advantage of intraarticular evaluation and treatment if required. With the high association of chondral damage in recurrent patellar dislocations, there is a risk of underestimating the extent of the condition if the joint is not inspected. However, our technique is not minimally invasive compared to arthroscopic techniques.

The complications experienced in our series were considered minor. We acknowledge that the Kujala and Pedi-IKDC scores in our series underperform other published studies. The literature reports scores ranging from 92.8 to 96.3 in Kujala whereas our results are closer to 83.4.^{17,26,32,33} No comparable Pedi-IKDC scores were found in the literature for realignment procedure of the patella in children. A recent study assessing the surgical management of osteochondritis dissecans lesions of the patella in a paediatric and adolescent population reported a mean Pedi-IKDC of 82.4 that compares to our results of 79.5.³⁵ We hypothesize the main reason for our lower scores is a specific cohort with significant number of patients with bilateral involvement and realignment (25% bilateral operations), which would not only play a role in the recovery but is a known risk factor for complications, as reported by Parikh et al. for MPFL reconstructions in young patients.³⁶

There are further limitations to our study. We have presented a relatively small number of cases lacking a control group. Pre-operative questionnaires were not available for comparison to post-operative results. However, the main variable of the study was the number of dislocations, which we believe is the main outcome of patellar realignment techniques. Despite these limitations, we report several interesting observations.

5. Conclusions

We conclude that the reported surgery, the first series in the literature showing this combination of techniques, provides good outcomes for children. The 0% redislocation rate is an excellent indicator of its reliability. The technique is successful in the more severe habitual

cases of dislocation or as a salvage after other failed procedures, proving its versatility and reproducibility. It enables simultaneous evaluation and treatment of potential intra-articular pathology.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Authors contributions

Francesc Malagelada – Data collection and analysis, manuscript writing

Ole Rahbek – Evaluation of data, manuscript editing and correction

Cyrus Sahirad – Data collection and analysis, manuscript writing

Manoj Ramachandran – Performed operations, supervised development of work, data evaluation and manuscript editing.

Conflict of interest

The authors have none to declare.

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