



Combination of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release for patellofemoral instability provides good middle- to long-term outcomes in adolescents

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Abstract

Purpose There are limited studies that have reported the middle- to long-term outcomes of combined procedures consisting of more than two procedures for patellofemoral instability. The current study aims to investigate and report the middle- to long-term outcomes of a combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release for patellofemoral instability in patients aged 18 years and below.

Methods In the cohort study, all patients aged 18 years old or younger who underwent a combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release for recurrent patellofemoral instability were included.

Results A total of 21 patients were included in the study. All patients had no further patellofemoral dislocation, pain and apprehension following the 4-in-1 surgery ($p < 0.01$). There was a significant improvement in the Kujala score from 36.1 (SD 12.9) pre-operatively to 93.1 (SD 3.6) post-operatively ($p < 0.001$). The patients also had a statistically significant improvement in their radiological factors, including the patellar tilt angle ($p < 0.001$), sulcus angle ($p = 0.001$), trochlear groove depth ($p = 0.041$), tibial tubercle-trochlear groove distance ($p < 0.001$) and Caton–Deschamps index ($p = 0.001$).

Conclusion A combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release leads to good middle- to long-term subjective, functional and radiographic outcomes for patients with recurrent patellofemoral instability and underlying predisposing factors of increased TT-TG distance of more than 20 mm, Dejour B or D trochlear dysplasia and medial patellofemoral ligament rupture.

Level of evidence IV.

Keywords Patellofemoral instability · Patellar instability · Tibial tubercle transfer · Medial patellofemoral ligament reconstruction · Trochleoplasty · Lateral release

Introduction

Patellar instability is a common orthopaedic complaint, affecting up to 50 in 100,000 children and adolescents per year. The incidence of recurrent patellar instability is higher in female adolescents aged 10 to 17 years [1–4]. The

recurrence rate ranges from 15 to 88% amongst patients managed non-operatively, and many of these patients require subsequent operative intervention [5, 6].

The management of recurrent patellofemoral instability remains challenging. This is because the aetiology of the instability is multifactorial, requiring the examination of the lower limb alignment, relationship of the patella to the trochlear groove and tibial tubercle, and the soft tissue restraints. Some of the many risk factors for chronic patellar instability include patella alta, increased tibial tubercle-trochlear groove (TT-TG) distance, trochlear dysplasia, insufficiencies in the medial soft tissues and tightness of the lateral retinaculum [7, 8].

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Surgical management is used for recurrent patellofemoral dislocations as compared to non-operative management which is primarily used for primary dislocations [7]. The type of surgery for patellar instability is “à la carte”, specially designed to target the risk factors for each patient [3]. To date, multiple studies have reported good outcomes for surgeries comprising one or two procedures targeted for patellofemoral instability [7, 9–18]. However, there are limited studies that have reported the middle- to long-term outcomes of combined procedures consisting of more than two procedures [7, 16]. Understandably, patients who have been selected to undergo combined procedures consisting of more than two procedures have more risk factors than those undergoing isolated procedures. Given the multiple risk factors, the outcomes of the surgery for these patients might not be similar to those with only isolated risk factors for patellar instability.

The current study, therefore, aims to investigate and report the middle- to long-term outcomes of a combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release for patellofemoral instability in patients aged 18 years and below. The hypothesis is the combined procedure would result in good middle- to long-term outcomes for recurrent patellofemoral instability and can be suitably used for patients with recurrent patellofemoral instability with underlying predisposing factors of increased TT-TG distance of more than 20 mm, Dejour B or D trochlear dysplasia and medial patellofemoral ligament rupture.

Patients and methods

Inclusion and exclusion criteria

In the retrospective study, all skeletally mature patients aged 18 years old or younger who underwent a combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release for recurrent patellofemoral instability from January 2012 to January 2016 in a single institution were included. The indication for surgery was recurrent patellofemoral instability, which was defined as having two or more patellofemoral subluxations or dislocations, as well as the presence of underlying predisposing factors including increased TT-TG distance of more than 20 mm, Dejour B or D trochlear dysplasia and medial patellofemoral ligament rupture. Patients with syndromic conditions that could predispose to patellofemoral instability and miserable malalignment syndrome were excluded.

Pre-operative evaluation

Pre-operatively, all patients were evaluated on an outpatient basis and noted to have recurrent patellofemoral instability. These patients were assessed pre-operatively and noted to be skeletally mature, with increased TT-TG distance of more than 20 mm with or without patella alta, Dejour B or D trochlear dysplasia and medial patellofemoral ligament rupture. They were also examined to ensure that they did not have other risk factors of patellofemoral instability. These included syndromic conditions that could predispose to patellofemoral instability and miserable malalignment syndrome.

The demographic information of the patients including the age and the gender of the patients were recorded. The presence or absence of pain and patellofemoral apprehension were also assessed pre-operatively. The patients were also examined pre-operatively radiographically, and the pre-operative patellar tilt angles, sulcus angles, trochlear groove depth, tibial tubercle-trochlear groove distance and Caton–Deschamps index were recorded up to 1 decimal point. All patients also filled up the Kujala score pre-operatively. Clinical assessments of the patients were performed by the attending specialist, while the Kujala score was administered by a research assistant blinded to the study’s purposes.

Surgical technique

After obtaining informed consent, all patients underwent a combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release for patellofemoral instability by one of two senior orthopaedic surgeons. The procedure was performed with the patient positioned supine on a standard operating table. A well-padded thigh tourniquet was applied to the operative limb. A lateral parapatellar incision was made approximately 1 cm lateral to the patellar tendon. A lateral release was first performed from the level of the tibial tubercle to the level of the insertion of the vastus lateralis tendon on the proximal patella. The release was considered adequate when the patellar articular surface can be everted laterally. The patella was everted for inspection and treatment of chondral injuries if needed, then retracted. Following which, the trochlea was examined, and trochleoplasty was performed. The trochlea was exposed by incising the peritrochlear synovium and periosteum along their osteochondral junction and reflected. The new trochlear limits were drawn using the intercondylar notch as the starting point, with the line directed proximally and 3 to 6 degrees laterally through the condyle-trochlear grooves

with the superior limit being the osteochondral edge. The osteochondral flap was raised using a drill with a depth guide set at 5 mm to ensure uniform thickness of the osteochondral flap raised and to maintain an adequate amount of bone attached to the cartilage. Cancellous bone was removed from the undersurface of the trochlea up to the notch, especially from the central portion where the new trochlear groove was planned. Light pressure was used to mould the flap to the underlying cancellous bone bed. If the correction obtained was satisfactory, the new trochlea was fixed with two staples, with one in each side of the groove and with one arm in the cartilaginous upper part of each facet and the other arm in the anterior femoral cortex. The periosteum and synovial tissue were sutured to the osteochondral edge and anchored with staples. Tibial tubercle transfer was then performed. An oscillating saw followed by osteotome was used to raise a flat 6-cm-long and 7-mm-thick osteoperiosteal flap at the tibial tubercle, tapering anteriorly and hinging distally with the periosteal. The osteoperiosteal flap raised was shifted medially or anteromedially and held in place by a Kirschner wire. The knee was moved through a full passive range of motion to evaluate for patellar tracking. If satisfactory, the transferred tibial tubercle was flushed with the underlying tibia and fixed with two 4.5-mm cortical lag screws. Finally, medial patellofemoral ligament reconstruction was performed using hamstring allograft. The femoral tunnel was created using a 3-cm vertical incision over the medial femoral epicondyle, dissecting down to the fascia to expose the medial epicondyle and adductor tubercle. The guide pin for the femoral tunnel was placed at the isometric point just anterior to the posterior femoral cortex and slightly proximal to the Blumensaat's line at the Schlottle's point. The pin was drilled medial to lateral, heading slightly from distal to proximal and posterior to anterior. The patellar tunnels were performed using a 3-cm incision which is over the medial aspect of the patella heading from the superior pole of the patella then extending distally. Dissection was performed down to the vastus medialis obliquus and continued distally until the layer between the capsule and retinaculum. The tunnels for the anchors were marked, and a curette was used to roughen up the bone to help with tendon healing. Two anchors were placed just anterior to the articular surface, with the distal anchor placed before the proximal anchor. The graft was secured to the suture anchors, prepared and passed superficial to the capsule and deep to the retinaculum towards the femoral tunnel. Graft isometry was checked, and the graft was marked at the femoral tunnel orifice 20 mm away from the tunnel with the patella engaged in the trochlea. The graft was fixed on the femur using a biotenodesis screw with the assistant holding the patella still so that it did not over-reduce as the screw was advanced. Meticulous haemostasis was ensured

prior to layered closure of the wound. Following the procedure, the patients were admitted overnight for observation and discharged the next day. The patients were placed on non-weight bearing with crutches for 6 weeks until the tibial tubercle osteotomies showed signs of union (Fig. 1).

Post-operative evaluation

Patients were reviewed in clinic regularly post-operatively and evaluated for recurrent patellofemoral instability, presence or absence of pain, presence or absence of patellofemoral apprehension, patellar tilt angles, sulcus angles, trochlear groove depth, tibial tubercle-trochlear groove distance, Caton–Deschamps index and Kujala score. All patients included in the study had a minimum of three-year follow-up duration prior to the conclusion of the study. The evaluation at their final follow-up prior to the conclusion of the study was used for the study's purpose.

Statistical analysis

Statistical Package for the Social Sciences (SPSS) 22.0 was used for statistical analysis. McNemar's exact test was used to compare categorical variables. Paired student t-test was

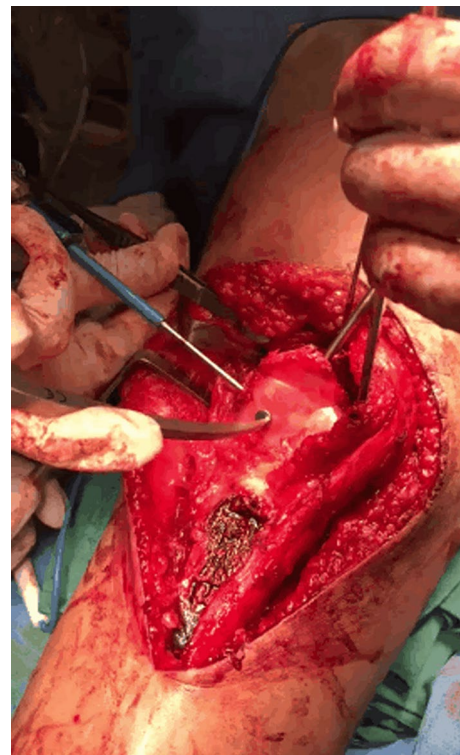


Fig. 1 Intraoperative photo demonstrating the combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release

used to compare continuous variables. A p -value of <0.05 was considered statistically significant.

Results

A total of 21 patients were included in the study. This included 18 females and 3 males. The mean age of the patients was 16.1 years with the range being 13.0 to 18.0 years. The mean duration of follow-up was 58.0 months, with the range being 37.0 to 90.0 months (Table 1).

The pre-operative and post-operative parameters of all the patients are reflected in Tables 2 and 3. All patients had no patellofemoral dislocation, pain and apprehension pre-operatively, but these were no longer present post-operatively ($p < 0.001$). There was a significant improvement in the Kujala score from 36.1 (SD 12.9) pre-operatively to 93.1 (SD 3.6) post-operatively ($p < 0.001$). The patients also had a statistically significant improvement in their radiological factors, including the patellar tilt angle ($p < 0.001$), sulcus angle ($p = 0.001$), trochlear groove depth ($p = 0.041$), tibial tubercle-trochlear groove distance ($p < 0.001$) and Caton–Deschamps index ($p = 0.001$).

Discussion

The principal finding of the study is that a combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release leads to good middle- to long-term outcomes for recurrent patellofemoral instability.

Table 1 Demographic details of the patients

	Demographic details
Total number of patients	21
Gender	18 females/3 males
Age	16.1 years (13.0 to 18.0 years)
Duration of follow-up	58.0 months (37.0 to 90.0 months)

Table 2 Pre-operative and post-operative subjective and functional outcomes

	Pre-operative		Post-operative		P -value
	Frequency	Percentage	Frequency	Percentage	
Patellofemoral dislocation (yes/no)	21/0	100.0/0.0%	0/21	0.0/100.0%	<0.001
Patellofemoral pain (yes/no)	21/0	100.0/0.0%	0/21	0.0/100.0%	<0.001
Patellofemoral apprehension (yes/no)	21/0	100.0/0.0%	0/21	0.0/100.0%	<0.001
	Mean	SD	Mean	SD	
Kujala score	36.1	12.9	93.1	3.6	<0.001

Table 3 Pre-operative and post-operative radiographic outcomes

	Pre-operative		Post-operative		P -value
	Mean	SD	Mean	SD	
Patellar tilt angle (degree)	41.3	15.0	17.2	12.8	<0.001
Sulcus angle (degree)	152.9	9.3	146.1	7.8	0.001
Trochlear groove depth (mm)	3.0	1.6	3.8	1.6	0.041
Tibial tubercle-trochlear groove distance (mm)	22.5	3.0	9.6	2.7	<0.001
Caton–deschamps index	1.2	0.03	1.0	0.1	0.001

To date, multiple studies have reported good outcomes for surgeries comprising one or two procedures targeted for patellofemoral instability [7, 9–18]. These surgeries include tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release, when performed in isolation or in combination with one other procedure [7, 9–18]. These patients often only have one or two predisposing risk factors for patellofemoral instability that are addressed during the surgery, with good outcomes post-operatively [7, 9–18].

However, there exist limited studies that have reported on the outcomes of surgeries incorporating three or more procedures targeted for patellofemoral instability [7, 16]. Patients that are selected to undergo a combination of three or more procedures for patellofemoral instability may have more risk factors, which increases their risk of recurrent patellofemoral instability. The outcomes of these patients following patellofemoral instability operations could understandably be dissimilar to patients with only isolated risk factors for patellar instability.

Thus far, only three studies have reported on surgeries performed for recurrent patellofemoral instability comprising of three or more combined procedures in skeletally mature patients [7, 16, 19]. Dean et al.'s surgical technique comprised of tibial tubercle transfer, trochleoplasty and medial patellofemoral ligament reconstruction, Vogel et al.'s surgical technique comprised of medial patellofemoral ligament reconstruction, trochleoplasty and lateral retinacular

lengthening and Floyd's et al. surgical technique comprised of medial patellofemoral ligament reconstruction, tibial tubercle osteotomy and trochleoplasty [7, 16, 19]. One of the advantages for the combined techniques is that addressing all the risk factors within the same procedure allow the surgeon to balance the effect of each technique over the patellar tracking and stability [7]. However, it has been acknowledged in the paper that the current literature still lacks outcome studies reporting results for combined techniques [7]. No outcomes of the patients are reported following the combination procedures in the studies by Dean et al., Vogel et al. and Floyd et al. [7, 16, 19].

This study, therefore, represents the first study reporting the outcomes of a combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release for patellofemoral instability. The minimum duration of follow-up of these patients following the procedure is 3 years, with the longest follow-up being 7.5 years. None of the patients have recurrent patellofemoral dislocation, pain or apprehension following the procedure with improvements in radiographic parameters, demonstrating that the combined procedure can lead to good outcomes in patients with multiple risk factors predisposing them to recurrent patellofemoral instability. Despite not performing tibial tubercle distalisation in our combined procedure, an improvement in the Caton–Deschamps index is also noted post-operatively. This is consistent with the existing literature, where an improvement in the Caton–Deschamps index is noted with isolated medial patellofemoral ligament reconstruction, with or without tibial tubercle medialisation [20–23].

The results then highlight that a combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release would result in good middle- to long-term outcomes for recurrent patellofemoral instability and can be suitably used for patients with recurrent patellofemoral instability with underlying predisposing factors of increased TT-TG distance of more than 20 mm, Dejour B or D trochlear dysplasia and medial patellofemoral ligament rupture.

Despite so, it should be cautioned that there are also increased morbidities of performing a combination of procedures as compared to a single procedure alone. Each procedure of the combination procedure comes with its risks and complications; thus the risks of the procedures should be weighed with the severity of the patients underlying risk factors to determine the necessity of each procedure. A combination of procedures done in a single setting also comes with a longer operative time, and therefore, patient selection is critical to ensure that the patients are fit to undergo a longer procedure and surgical expertise in each procedure is required to ensure an efficient and shorter operative time. Newer technologies such as the possibility

of using arthroscopic procedures can also be considered to possibly decrease the morbidities of such procedures.

Other than being the first study to report the outcomes of a combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release for patellofemoral instability, the strength of the study also includes the relative longer follow-up period of the patients, with the mean follow-up period being approximately 5 years. Additionally, the study focused on the adolescent population including skeletally mature patients aged 18 years and below, which corresponds to the group that recurrent patellofemoral instability commonly affects, allowing a larger application of the study's findings. Lastly, the standardisation of the surgical procedure with two senior surgeons also minimises the impact of confounding variables in the analysis of the potential predictors of the outcomes of the procedure.

However, the current study does face some limitations. Most importantly, the relatively small sample size of the study limits the power of the conclusions drawn from the study. However, it is not surprising to have a small sample size for the study, given that there exist a limited number of patients with multiple predisposing risk factors that would require the combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release. It is of hope that with the positive results of the study would possibly lead to an increase in the number of patients being treated with the combined procedure, allowing for larger-scale studies to be performed. Secondly, while the follow-up period is relatively long with a mean follow-up period of approximately 5 years, further longer-term studies should be performed for longer-term outcomes, especially since these patients are adolescents, and further follow-up can reveal if the procedure can lead to good outcomes for these patients that can sustain them through life.

Conclusion

A combination procedure of tibial tubercle transfer, medial patellofemoral ligament reconstruction, trochleoplasty and lateral release leads to good middle- to long-term subjective, functional and radiographic outcomes for patients with recurrent patellofemoral instability and underlying predisposing factors of increased TT-TG distance of more than 20 mm, Dejour B or D trochlear dysplasia and medial patellofemoral ligament rupture.

Declarations

Conflict of interest The authors declare no conflicts of interests.

Ethical approval The study was performed in accordance with the ethical standards of the institutional research committee.

Informed consent Waiver of informed consent was obtained from the institutional research committee.

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