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Tibial tubercle proximalization as quadriceps lengthening in treating severe habitual patellar dislocation in adults

Guan-yang Song, Hui Zhang, Jin Zhang, Zhi-jun Zhang, Hua Feng *

Sports Medicine Service, Beijing Jishuitan Hospital, No.31, Xin Jie Kou East Street, Xi Cheng District, Beijing, China

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ABSTRACT

Background: To describe a novel 'four-in-one' procedure – including tibial tubercle proximalization, extensive lateral release, tibial tubercle medialization, and medial patellofemoral ligament reconstruction – for treating severe habitual patellar dislocation (HPD) in adults, and to report its early clinical outcomes.

Methods: Thirteen patients (13 knees) with severe primary HPD received this procedure. Results of the physical examinations, including apprehension tests and patellar tracking throughout full range of motion, were recorded pre-operatively and at final follow-up. Radiological assessments included standard anteroposterior view, true lateral view at 30° knee flexion, axial views of the patellofemoral joint at both 30° and maximum angle of knee flexion, and computed tomography scans at full knee extension pre-operatively and at final follow-up. Subjective patellofemoral functions were evaluated with the Kujala functional score before the index procedure and at final follow-up visit.

Results: All 13 patients were followed for an average period of 35.5 months (range, 25–49). After the index 'four-in-one' procedure no patient reported reoccurrence of patellar dislocation at the final follow-up visit. Radiographically, there was a statistically significant improvement in the congruence angle from 75.2 ± 16.3° pre-operatively to −7.2 ± 5.4° postoperatively ($P < 0.01$) and in the lateral patellofemoral angle from −66.3 ± 8.3° pre-operatively to 6.3 ± 2.6° postoperatively ($P < 0.01$). The average pre-operative Kujala functional score was 41.4 and average postoperative score was 94.9 ($P < 0.05$).

Conclusion: The novel 'four-in-one' procedure effectively treated HPD in adults with severe quadriceps contracture.

1. Introduction

Habitual patellar dislocation (HPD) is a rare condition. In HPD, the patella dislocates whenever the knee flexes, exhibiting a different pathological state from recurrent patellar dislocation (RPD), in which the patella occasionally dislocates as a result of traumatic episodes [1,2]. The cardinal physical sign of HPD is that if the patella is forcibly held in the midline, it is impossible to flex the knee >90°. Further flexion is then only possible if the patella is allowed to dislocate, when a full range of motion (ROM) is readily obtainable [2,3].

Various pathological factors have been described in the pathogenesis of HPD. The most important is the contracture of soft tissues proximal and lateral to the patella. In 1963, Jeffreys described an abnormal attachment of the iliotibial tract to the patella, producing HPD in knee flexion [4]. Later, in 1964, Gunn described the association of quadriceps fibrosis with intramuscular injections to the

* Corresponding author.
E-mail address: fenghua20080617@126.com (H. Feng).

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thighs. He also put forward the idea that quadriceps contracture may sometimes give rise to dislocation of the patella [5]. A number of realignment procedures have been described in the literature for managing HPD in children. Among them, a treatment algorithm focusing on quadriceps lengthening is mandatory to reduce the patella in deep knee flexion [6]. Adult patients who have suffered from HPD often show more severe degrees of quadriceps contracture. Usually, the patella is forcibly held in the midline and it is impossible to flex the knee more than 30–40°, implicating that the degree of quadriceps contracture is more severe than that in children. It is believed that HPD in adults with severely contracted quadriceps requires combined lengthening procedures. Until now, no study has reported the effectiveness of tibial tubercle proximalization for quadriceps lengthening to address severe quadriceps contracture for the treatment of HPD in adults.

The purpose of this study was to describe a novel 'four-in-one' procedure for treating severe HPD in adults, and to report the early clinical outcomes. The 'four-in-one' procedure consists of tibial tubercle proximalization, extensive release of the soft tissue lateral to the patella, tibial tubercle medialization, and medial patellofemoral ligament (MPFL) reconstruction. It was hypothesized that adult patients with severe HPD would have satisfactory clinical outcomes after receiving the index 'four-in-one' procedure.

2. Material and methods

2.1. Study design

This was a retrospective study. From March 2014 to December 2016, 56 consecutive adult patients (60 affected knees) with HPD were surgically treated at the current department and retrospectively reviewed. Inclusion criteria were: 1) HPD with severely contracted quadriceps muscle (knee flexion angle of patellar dislocation <30°); 2) the index procedure should be the 'four-in-one' procedure, including tibial tubercle proximalization, extensive release of the soft tissue lateral to the patella, tibial tubercle medialization, and MPFL reconstruction; and 3) the follow-up time should be >24 months after the index procedure. Exclusion criteria were: 1) skeletal immaturity; 2) revision case; 3) severe malalignment of the affected lower extremity (> 10° valgus); 4) generalized joint laxity (more than 5/9 on the Beighton score); and 5) severe trochlear dysplasia that required combined trochleoplasty procedure. Application of the selection criteria left 13 patients (13 affected knees) (Figure 1). The patient group included seven men and six women, with right-side involvement in eight patients and left-side involvement in five patients. The average age at surgery was 28.8 years (range, 15–46). The average follow-up period was 35.5 months (range, 25–49) (Table 1). This study was approved by the Institutional Ethics Board and complied with patients' consent.

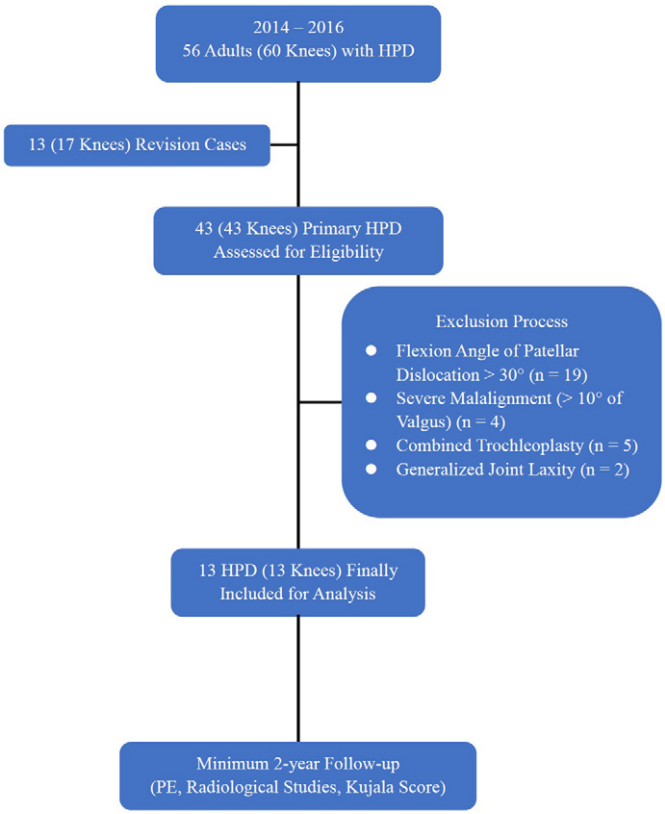

Figure 1. Flow chart of patient selection. Abbreviations: HPD, habitual patellar dislocation; PE, physical examination.

Table 1
Summary of patient data.

Case	Gender	Age	Side	Duration of symptoms (years)	Follow-up (months)	Degrees of knee flexion when patella dislocated
1	M	46	L	8	34	30
2	M	24	R	11	42	30
3	M	35	R	20	39	20
4	M	19	L	9	44	20
5	M	35	L	20	25	10
6	F	38	L	25	28	10
7	F	15	R	8	30	30
8	F	33	R	19	46	30
9	F	28	R	18	28	30
10	F	32	R	16	33	30
11	M	20	R	12	35	30
12	F	24	R	14	49	20
13	M	26	L	16	28	10

Abbreviations: M, male; F, female; L, left; R, right.

2.2. Physical examinations

Pre-operatively, dynamic patellar tracking throughout the whole ROM was evaluated. The degree of knee flexion when the patella dislocated laterally was then recorded. In addition, results of the apprehension tests and patellar tracking were evaluated at the final follow-up.

2.3. Radiologic diagnosis

Radiologic diagnosis included routine anteroposterior (AP) views, true lateral view at 30° knee flexion, and axial views of the patellofemoral joint at both 30° and maximum angle of knee flexion. Computed tomography (CT) scans of both knees were performed with the knees at full extension. On the lateral knee radiographs, the Caton-Deschamps index method was used to measure patellar height. The shape of the patella according to the Wiberg and Baumgartl classification, congruence angle, and lateral patellofemoral angle were evaluated on the axial views of the patellofemoral joint.

2.4. Surgical techniques

Patellar dynamic tracking and lateral dislocation of the patella were routinely evaluated before surgery under anesthesia (Video 1) and intraoperatively after each step of the combined 'four-in-one' procedure was performed. A midline incision was made from 5 cm above the patella to 10 cm below the patella to expose the quadriceps muscle and tibial tubercle (Figure 2). Intra-articular pathologic findings were recorded, including the grade of chondromalacia in each facet of the patella and the lateral femoral condyle, according to the Outerbridge classification.

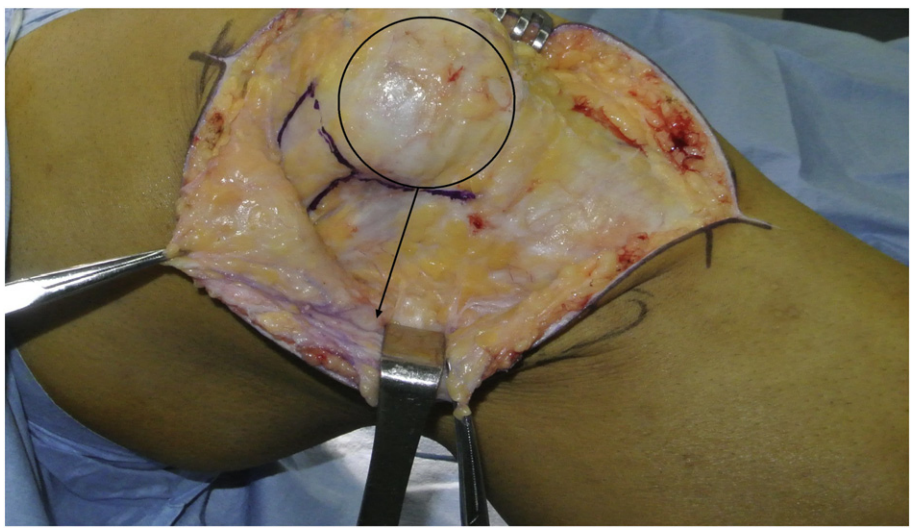

Figure 2. The patella (black circle) dislocates laterally (black arrow) at about 30° of knee flexion.

2.4.1. Step-by-step extensive lateral release

Release of the lateral retinaculum was performed first. Then the abnormal connection between the iliotibial band and the patella was released. The release was then extended proximally along the patella to resect the vastus lateralis tendon. Usually, an L-shaped release was first performed by a horizontal release to resect the distal part of the vastus lateralis tendon from its patellar attachment site, followed by a longitudinal release along the interval between the vastus lateralis tendon and the rectus femoris tendon. Finally, the distal part of the vastus lateralis tendon was sutured back to the proximal part of the rectus femoris tendon without tension (Figure 3) at 90° knee flexion. Patellar tracking was then checked by flexing the knee joint. Usually, the patella could be stabilized in the trochlear groove during early knee flexion; however, it would re-dislocate laterally when the knee was flexed beyond 90°. Further distal realignment procedures were needed.

2.4.2. Tibial tubercle proximalization and medialization

Meticulous separation was first performed to expose the tibial tubercle and insertion of the patellar tendon. Further separation was then performed between the patellar tendon and the infra-patellar fat pad. Osteotomy of the tibial tubercle was performed with a saw and osteotome. The length of the osteotomy created was about eight centimeters. The fibrotic medial capsule around the inferior portion of the patella was then released so that the tibial tubercle could be proximally displaced to lengthen the extensor. Usually, the bone block was initially displaced about 10 mm and then temporarily fixed with two guide pins, after which patellar tracking was again checked with the same maneuver described above.

Meanwhile, if the tibial tuberosity-trochlear groove (TT-TG) distance was >15 mm, the tibial tubercle was medially displaced, aiming to correct the TT-TG distance to <10 mm. When both proximal and distal realignment procedures were complete, the knee should have been able to flex >90° with no tendency for lateral dislocation or subluxation. If lateral dislocation still existed in a deep flexion angle, further tibial tubercle proximalization was performed until the patella did not laterally dislocate throughout the whole ROM of the knee joint. After confirmation of normal patellar tracking, the bone block was secured with two or three cortical screws (Figure 4).

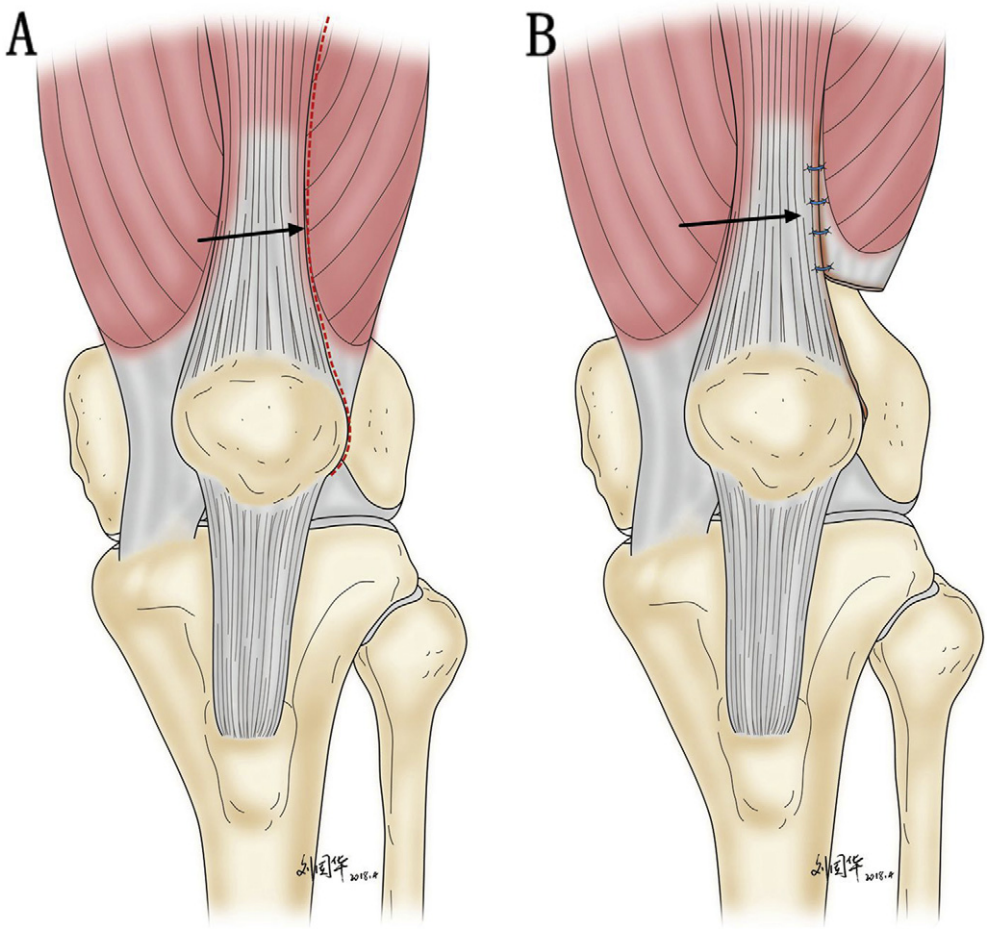

Figure 3. (A) An L-shaped release is first achieved by a horizontal release, to resect the distal part of the vastus lateralis tendon from its patellar attachment site, followed by a longitudinal release along the interval between the vastus lateralis tendon and the rectus femoris tendon (black arrow). (B) The distal part of the vastus lateralis tendon is sutured back to the proximal part of the rectus femoris tendon (black arrow).

2.4.3. Medial patellofemoral ligament reconstruction

Patellar glide test at 30° knee flexion was then performed. If the result was positive, MPFL reconstruction was indicated. The MPFL was reconstructed using a semitendinosus tendon autograft. Two double-loaded suture anchors were inserted into the patella. One of the suture anchors was inserted into the near proximal margin of the patella and the other one into the center of the medial facet of the patella. The femoral tunnel was positioned under fluoroscopy using the method described by Schottle et al. [7] The double-strand semitendinosus tendon was fixed by sutures loaded on the suture anchors. Then, the free ends of the graft were transmitted between the second and third layer of the knee joint, which was fixed with an interference screw within the femoral bone tunnel. The graft was fixed at 20–30° knee flexion. As a result of the 'four-in-one' procedure, the patella stabilized throughout the whole ROM (Video 2).

2.5. Postoperative rehabilitation

A protective knee brace without ROM limitation was applied for the first six weeks after surgery. Crutches provided protective weightbearing during this period. In addition, isometric quadriceps muscle training started immediately after surgery. The degree of knee flexion that was allowed was gradually increased with time, depending on the stability of the patella and the strength of the quadriceps muscle.

2.6. Follow-up evaluation

Healing at the osteotomy site of the proximal tibia was evaluated by radiography. A postoperative CT scan of the affected knee joint was performed at the final follow-up. The patellofemoral function of the knee joint with severe HPD was evaluated preoperatively and at the final follow-up visit using the Kujala patellofemoral functional score, which includes a variety of symptoms of anterior knee pain related to daily activities and signs of patellar instability.

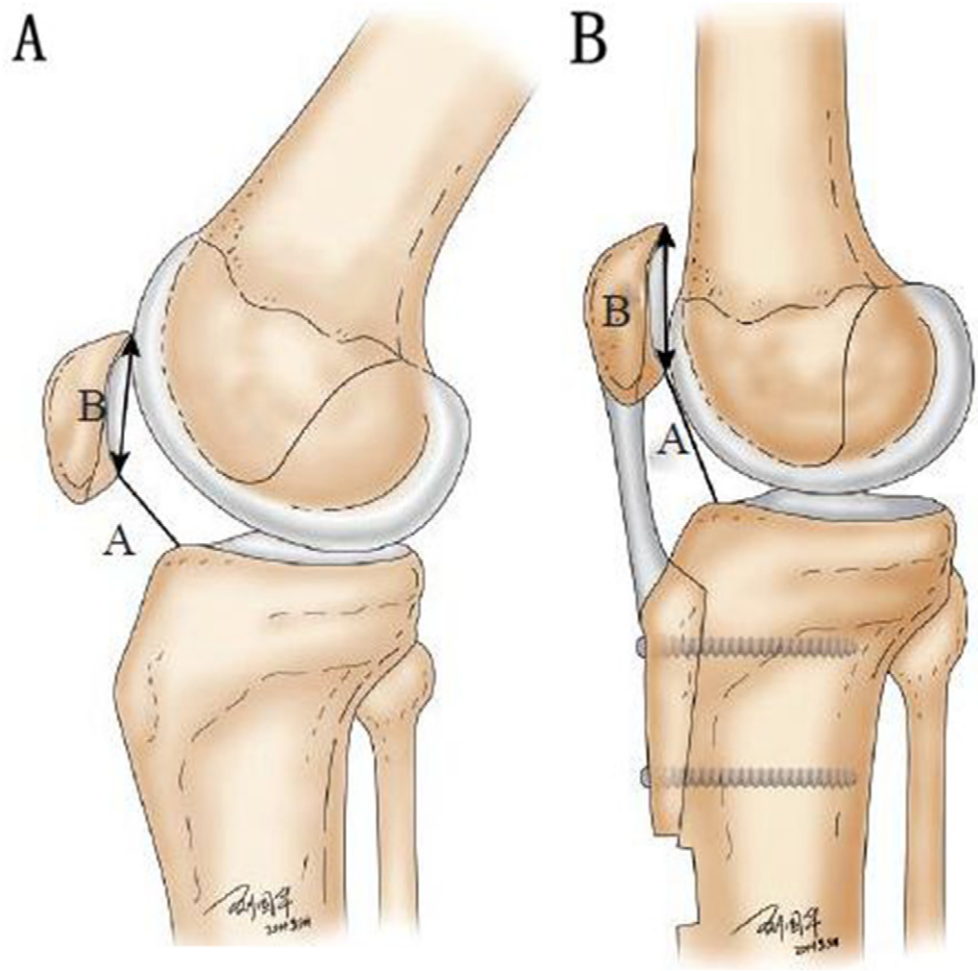

Figure 4. (A) Osteotomy of the tibial tubercle is performed and the tibial tubercle is proximally displaced to lengthen the extensor. (B) After confirmation of normal patellar tracking, the bone block is secured with two cortical screws.

2.7. Statistical analysis

Results of the physical examinations, radiological measurements, and functional evaluations of all the affected knee joints were performed and collected. Pre-operative and postoperative results were compared by performing paired *t*-tests using the SPSS 18.0 software package (SPSS, Chicago, Ill). Statistical significance was set at $P < 0.05$.

3. Results

All patients experienced an insidious onset of HPD, with no obvious history of multiple muscular injections in the involved thigh during childhood. No case was associated with significant trauma that had induced HPD. During follow-up, no patient reported reoccurrence of patellar dislocation after the index 'four-in-one' procedure. There were complications related to bony healing of the tibial tubercle osteotomy. No complications involving skin necrosis or postoperative fracture of the tibia or patella were observed.

The average knee flexion angle when the patella dislocated was 23° (range, 10–30). The major intraoperative finding was contracture of the lateral patellar retinaculum with fibrotic bands in the superolateral aspect of the patella. Chondromalacia of the patella was Grade 3 in four knees and Grade 4 in eight knees, according to the Outerbridge classification system. Most involvement was at the medial facet. Erosion of the corresponding lateral femoral condyle was noted in every knee. The amount of correction averaged 15.4 mm (range, 10–30) for tibial tubercle proximalization and 12.8 mm (range, 10–15) for tibial tubercle medialization (Table 2).

Radiographically, there was a statistically significant improvement in the congruence angle from 75.2° ± 16.3° (range, 55–102) pre-operatively to −7.2° ± 5.4° (range, −20 to −3) postoperatively ($P < 0.01$) and in the lateral patellofemoral angle from −66.3° ± 8.3° (range, −83 to −54) pre-operatively to 6.3° ± 2.6° (range, 3–11) postoperatively ($P < 0.01$). There was significant change in the Caton-Deschamps index with an average 0.92 ± 0.09 (range, 0.82–1.10) before surgery and 1.17 ± 0.11 (range, 1.04–1.35) after surgery ($P < 0.05$) (Table 3).

The Kujala patellofemoral functional scores for the 13 knees improved from a mean value of 41.4 pre-operatively to 94.9 post-operatively ($P < 0.05$). All patients returned to their daily walking activities without any trouble. Twelve of the 13 patients were able to participate in running with no limitations. One patient had painful crepitus and constant pain during squatting, and prolonged sitting with the knee flexed because of severe patellofemoral arthrosis. No further dislocation of the patella was noted after the index procedures (Table 4, Video 3).

4. Discussion

Habitual dislocation of the patella is uncommon and usually detected in children. The typical clinical presentation of HPD in young children is an odd-looking knee and, less often, pain and instability [2]. Contracture and fibrosis of the quadriceps muscles, mainly vastus lateralis [1], and iliotibial band contracture may give rise to HPD [8,9]. Therefore, various soft tissue procedures, targeting lateral release and quadriceps lengthening, are mandatory for the treatment algorithm of HPD. Bergman and Williams reported good clinical results of a consecutive series of 35 cases of HPD in children treated with extensive lateral release and lengthening of rectus femoris [3]. Later, Gao et al. reported 87.8% satisfactory results with similar procedures [5].

Until now, there were two clinical studies describing the surgical techniques on how to address HPD in adults. Matsushita et al. reported the effectiveness of combined MPFL reconstruction and lateral soft tissue release for two adult patients with HPD [10]. Shen et al. performed both proximal and distal realignment procedures, including lateral release, medial retinacular advancement and anteromedial tibial tubercle transfer, on 13 knees with HPD in adults, and reported satisfactory results [11]. The above two studies did not provide details about the degree of quadriceps muscle contracture; in addition, they did not perform combined quadriceps lengthening procedures. In the current study, the average knee flexion angle when the patella

Table 2
Details of the operations.

Case	Grading of chondromalacia[a]	Surgical procedures	Amount of TTP (mm)	Amount of TTM (mm)
1	3; MF	LR, TTP, TTM, MPFLR	20	15
2	3; MF	LR, TTP, TTM, MPFLR	10	10
3	IV; MF, LFC	LR, TTP, TTM, MPFLR	20	15
4	IV; MF, LFC	LR, TTP, TTM, MPFLR	10	15
5	IV; MF	LR, TTP, TTM, MPFLR	30	10
6	IV; MF, LFC	LR, TTP, TTM, MPFLR	20	15
7	IV; MF	LR, TTP, TTM, MPFLR	20	10
8	IV; MF	LR, TTP, TTM, MPFLR	10	15
9	3; LFC	LR, TTP, TTM, MPFLR	10	10
10	3; MF	LR, TTP, TTM, MPFLR	10	12
11	3; MF; LFC	LR, TTP, TTM, MPFLR	10	15
12	IV; MF	LR, TTP, TTM, MPFLR	15	15
13	IV; MF, LFC	LR, TTP, TTM, MPFLR	15	10

Abbreviations: MF, medial facet of patella; LF, lateral facet of patella; LFC, lateral femoral condyle; LR, lateral release; TTP, tibial tubercle proximalization; TTM, tibial tubercle medialization; MPFLR, medial patellofemoral ligament reconstruction.

[a] Grading of chondromalacia: Outerbridge Grade 3, deep fibrillation; Outerbridge Grade 4, subchondral exposure.

Table 3
Results of radiological measurements.

Case	Congruence angle		Lateral patellofemoral angle		Caton-Deschamps Index		
	Pre-operative	Postoperative	Pre-operative	Postoperative	Pre-operative	Postoperative	Patellar type[a]
1	60	−6	−70	6	0.85	1.04	3
2	55	−8	−55	5	0.83	1.11	3
3	55	−12	−60	11	1.01	1.33	3
4	70	−10	−60	10	0.95	1.11	3
5	55	−2	−54	3	0.85	1.25	3
6	102	−20	−80	6	1.01	1.35	3
7	85	−7	−70	4	1.10	1.33	3
8	72	−5	−66	3	0.95	1.10	3
9	78	−6	−64	8	0.82	1.04	3
10	75	3	−60	7	0.97	1.09	3
11	100	−5	−83	4	0.95	1.18	3
12	80	−6	−70	6	0.85	1.13	3
13	90	−9	−70	9	0.88	1.17	3

[a] Patellar type was evaluated by Wiberg and Baumgartl classification.

dislocated laterally was 23° (range, 10–30°) pre-operatively, demonstrating severe quadriceps contracture. It was believed that combined quadriceps lengthening procedure was mandatory in treating these patients.

However, performing quadriceps lengthening may result in extensor lag during the postoperative rehabilitation period. In addition, a few complications related to quadriceps lengthening have been reported, including wound hematoma, wound dehiscence, or reformation of quadriceps contractures [1]. For adult patients with severe quadriceps contracture, the quadriceps lengthening procedure, which is called soft tissue release, may not be an ideal treatment option, as scar tissue formation is much worse than in children. Tibial tubercle proximalization, which is called bony release, could be another option. The biggest advantages of tibial tubercle proximalization is rigid fixation, which ensures early postoperative rehabilitation and no risk of scar tissue formation from the quadriceps muscle.

One potential concern of tibial tubercle proximalization is postoperative patellar alta. Admittedly, performing tibial tubercle proximalization will increase the patellar height and sometimes even result in patellar alta, as found from the results of this study. However, with adequate physiotherapy, there was no extensor lag phenomenon found in this study during postoperative rehabilitation. The postoperative Kujala score showed that the patients could perform daily activities without difficulties. Moreover, during the operation, the patellar height could be precisely adjusted under fluoroscopy before final fixation. Usually, the bone block was initially proximally displaced about 10 mm, and then every five millimeters each time until patellar tracking was corrected to normal throughout the whole knee ROM. Another important step while performing this combined procedure is to ensure that the patella stays in the trochlear groove in terminal knee flexion.

The fact that the MPFL is the major medial ligamentous stabilizer in lateral patellar dislocation has been clarified both anatomically and biomechanically [12]. Insufficiency of the MPFL results in lateral patellar instability with excessive lateral displacement of the patella, especially when the knee is in an early flexion angle. It should be mentioned that the main purpose of MPFL reconstruction in this 'four-in-one' procedure is to prevent the patella from dislocating when the knee is in early flexion. However, the MPFL reconstruction is not a mandatory procedure in the treatment of severe HPD in adults. It is recommended only when the patella re-dislocates laterally during early knee flexion after step-by-step extensive lateral release and tibial tubercle osteotomy have been completed.

There were some limitations in this study. First, it was a retrospective study. Second, the sample size was relatively small, as HPD in adults is a very rare condition and all patients completed comprehensive follow-up evaluations. Third, the follow-up time was

Table 4
Summary of Kujala Knee Score.[a]

	Pre-operative	Postoperative
Limp (0–5)	3.3	5
Support (0–5)	3.1	5
Walking (0–5)	3.5	5
Stairs (0–10)	6.5	10
Squatting (0–5)	3.5	5
Running (0–10)	0	8.9
Jumping (0–10)	0	9.1
Prolonged sitting with the knees flexed (0–10)	5.1	10
Pain (0–10)	3.7	7.8
Swelling (0–10)	4.6	10
Abnormal painful patellar movements (0–10)	0	10
Atrophy of thigh (0–5)	3.1	4.1
Flexion deficiency (0–5)	5	5
Total (0–100)	41.4	94.9

[a] Average score of the 13 knees.

relatively short, especially for evaluation of patellofemoral arthritis. Further studies with larger sample sizes and longer follow-up times are needed. Last, the method used to measure the patellar height pre-operatively was inaccurate because the patella dislocated laterally when the knee was in 30° flexion. Therefore, the patella had to be forcibly held in midline by the examiner to obtain a good lateral view of the knee joint.

5. Conclusion

No single procedure is fully effective in the surgical treatment of severe HPD in adults. Multiple procedures are necessary for addressing HPD in adults with severe quadriceps contracture. The procedures include tibial tubercle proximalization, extensive lateral release, tibial tubercle medialization, and MPFL reconstruction. In this study, a novel 'four-in-one' procedure effectively treated HPD in adults with severe quadriceps contracture.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.knee.2019.04.005.

Conflict of interest

One or more of the authors (HF) has received funding from the Beijing Municipal Administration of Hospitals (XMLX201613).

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