Patellofemoral Instability in Athletes: Treatment via Modified Fulkerson Osteotomy and Lateral Release

Fotios Paul Tjoumakaris, Brian Forsythe and James P. Bradley

Am J Sports Med 2010 38: 992 originally published online March 8, 2010
DOI: 10.1177/0363546509357682

Patellofemoral Instability in Athletes

Treatment via Modified Fulkerson Osteotomy and Lateral Release

Fotios Paul Tjoumakaris,* MD, Brian Forsythe,†‡ MD, and James P. Bradley,§ MD
*From the *Department of Orthopaedic Surgery, Hospital of the University of Pennsylvania, Penn Sports Medicine, Philadelphia, Pennsylvania, the ‡Department of Orthopedic Surgery, UPMC Center for Sports Medicine, University of Pittsburgh, Pittsburgh, Pennsylvania, and the §Pittsburgh Steelers and the University of Pittsburgh Medical Center (UPMC) St Margaret, Pittsburgh, Pennsylvania*

Background: Surgical treatment of patellofemoral instability can successfully diminish episodes of subluxation and dislocation, as well as symptoms of pain and instability.

Hypothesis: Surgical treatment of lateral patellar instability in a strictly athletic population will facilitate return to sports.

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

Methods: From 1999 to 2004, 41 Fulkerson osteotomies combined with an arthroscopic lateral release were performed in 34 athletes for patellofemoral instability. Three patients were lost to follow-up. All patients participated in sports at least 3 times per week in at least one sport for 4 months of the year. There were 4 male and 30 female patients; 7 patients underwent bilateral, staged procedures. There were 14 high school, 12 collegiate, and 8 recreational athletes. Results were obtained by an independent examiner.

Results: The mean age was 20.05 years (range, 14-54 years) with a mean follow-up of 46 months (range, 22-71 months). Patients averaged 1.3 dislocations before reconstruction (range, 0-6). The average Lysholm score was 91.8 (range, 67-100) at follow-up. The International Knee Documentation Committee (IKDC) scores were A (normal) in 27 knees, B (near normal) in 12, and C (abnormal) in 2. Seventeen patients had symptomatic hardware removed at an average of 8 months. There were 2 complications: one saphenous neuroma that resolved, and one recurrent dislocation in a patient later diagnosed with Ehlers-Danlos syndrome.

Conclusion: This series is the largest to date documenting the successful treatment of patellofemoral instability in athletes with concomitant Fulkerson osteotomy and arthroscopic lateral release. Forty-nine percent of patients in our series required removal of screws from the osteotomy site.

Keywords: patellofemoral instability; tibial tubercle osteotomy; lateral release; knee injuries in athletes

The treatment of athletes with patellofemoral instability poses a significant challenge to orthopaedic surgeons. Athletes place high demands on their patellofemoral joints, as demonstrated by studies in joggers measuring peak patellofemoral joint compressive forces between 5 and 6 times the body weight.[9,17] Patients treated nonoperatively after a patellofemoral dislocation have responded well to treatment; one study reports a 73% satisfaction rate after nonoperative management.[13] A minority of patients develop persistent laxity of medial restraints after dislocation, within the medial patellofemoral ligament and its deep capsular layer, and they experience persistent symptoms of instability.[12,14]

Athletes who have sustained a patellar dislocation or who experience recurrent instability without dislocation should initially undergo a prolonged course of nonoperative management. If they fail aggressive functional rehabilitation, patellar bracing, and/or taping, they may require surgical intervention to facilitate return to their respective sport. Many studies have described surgical

†Address correspondence to Brian Forsythe, MD, University of Pittsburgh, UPMC Center for Sports Medicine, Department of Orthopedic Surgery, 3200 South Water Street, Pittsburgh, PA 15203 (e-mail: brian.forsythe@gmail.com).

Presented at the interim meeting of the AOSSM, San Diego, California, February 2007.

The authors declared that they had no conflicts of interest in their authorship and publication of this contribution.

The American Journal of Sports Medicine, Vol. 38, No. 5
DOI: 10.1177/0363546509357682

techniques for recurrent patellar instability and associated patella pathological conditions[||]; however, no series has documented the success of treatment in a strictly athletic population.

The natural history of patellar dislocation after nonoperative management yields a recurrence rate between 15% to 44%.[4,14,15] In an athletic population, the recurrence rate may be higher because of the demands placed on the patellofemoral joint during athletic competition. The need for an effective and durable surgical intervention is thus highlighted. The purpose of this investigation was to review a series of athletes with patellar instability and failed nonoperative management, who ultimately underwent surgical correction via modified Fulkerson osteotomy and arthroscopic lateral release.

MATERIALS AND METHODS

Between 1999 and 2004, the senior author (J.P.B.) performed 44 modified Fulkerson osteotomies, combined with arthroscopic lateral release, in 37 athletes with symptoms of recurrent patellofemoral instability. All patients were identified from a prospective database that categorized patients by surgical procedure. Of these 37 patients, 34 (totaling 41 osteotomies) were included in this series, given that they had fulfilled criteria for adequate follow-up.

Indications for surgery consisted of failed nonoperative treatment with bracing, physiotherapy, or taping with recurrent sensations of instability or dislocation. All patients had valgus lower extremity alignment, with 17 of 20 patients having Q angles of 20° or more. All patients were athletes who met our inclusion criteria. All patients were unable to participate in their respective sport preoperatively. During the study period, no other surgeries for patellofemoral instability were undertaken (ie, lateral release, medial reefing, medial patellofemoral ligament reconstruction alone or in combination thereof). Fourteen patients had recurrent dislocations, and the remainder sustained either 1 dislocation or the sensation of recurrent instability.

There were 4 male and 30 female patients in this series. Two male and 5 female patients from this cohort underwent bilateral procedures, and both knees are included from these patients in the follow-up. There were 19 left and 22 right knees in this series. The mean age of the patients was 20 years (range, 14-54 years). The mean number of dislocations before surgical intervention was 1.3 (range, 0-6). Within the cohort, there were 14 high school, 12 collegiate, and 8 recreational athletes (Table 1) (see Appendix 1, available in the online version of this article at http://ajs.sagepub.com/supplemental/). The average length of follow-up in this series was 46 months (range, 22-71 months).

All 34 patients included in this review underwent initial nonoperative treatment for patellar dislocation or recurrent instability without dislocation for a minimum of 3 months. All patients completed a course of formal, supervised physical therapy. After nonoperative management, patients were unable to participate in their respective sports. It is important to note that all patients in this study were identified as athletes by the following criteria: if they were actively part of an organized team or individual sport in high school or college or engaged in repeated athletic activity in a sport for 3 or more times per week for at least 4 months of the year.

TABLE 1
Summary of Demographic Data

	No./Mean (Range)
Mean age, y	20 (14-54)
Follow-up length, mo	46 (22-71)
Males	4 (2 bilateral)
Females	30 (5 bilateral)
Left	19
Right	22
Athletic level	
High school	14
Collegiate	12
Recreational	8
No. of dislocations on initial presentation	1.3 (0-6)

The operative reports and clinical record were reviewed to confirm that eligibility criteria were met. Patients were evaluated at final follow-up, and results were tabulated by an independent examiner (F.P.T.) using the following outcome measures: return to sport, Lysholm score, and the objective portion of the International Knee Documentation Committee (IKDC) instrument. The objective portion of the IKDC instrument was modified to confer specificity to the patellofemoral joint. Harvest site pathological changes were changed to incisional/hardware pain, and ligament examination was correlated with apprehension, patellar glide, and dislocation of the patella on examination. The objective outcome measure was performed by the senior author (J.P.B.). All complications from the procedures were obtained from a retrospective review of the medical record and patient interviews. Statistical comparisons were performed using the Student t test ($\alpha = .05$).

Preoperative Assessment

All patients in this series underwent the same preoperative examination for patellofemoral instability (see Appendix 2, available in the online version of this article at http://ajs.sagepub.com/supplemental/). The physical examination included palpation for medial and lateral facet tenderness. The apprehension test was then performed in both full extension and 30° of flexion. Medial, lateral, superior, and inferior translations were likewise assessed. The patella was also displaced in a distal-lateral direction by approximately 2 cm with the knee flexed 30° to detect disruption of the medial patellofemoral ligament (MPFL). Positive patellar instability test criteria included ease of patellar translation and a softer end point compared with a normal knee.[30] The knee was brought through a range of motion to detect crepitation of synovial versus arthritic origin (the former was deemed present by a snapping sensation, whereas the latter was marked by a fine, grinding

||References 2, 3, 7, 10, 20-23, 25, 27, 28, 32.

Figure 1. Preoperative flexion lateral radiograph demonstrates patella alta, with the inferior pole of the patella significantly higher than the Blumensatt line.

sensation). The patellofemoral compression test was likewise performed. The presence or absence of a J sign was also noted.

Preoperatively, all patients had radiographs taken to assess patellar position: a standing anteroposterior (AP) view, bilateral axial views (45° of knee flexion), bilateral standing films in 45° of flexion (Rosenberg view), and a 30° flexed lateral radiograph (as confirmed by goniometer) (Figures 1-3). Patella alta versus baja and the presence of osteochondral fragments or arthritic changes were noted. The Insall-Salvati ratio was used to determine the presence of patella alta versus patella baja: patellar tendon length (TL) to the length of the patella (PL), >1.2 and <0.8, respectively.[16] Preoperative magnetic resonance images were also obtained on all patients to assess for associated meniscal and chondral injuries and to evaluate the status of the MPFL. In cases where the MPFL was attenuated and demonstrated persistent laxity, a medial reefing procedure was performed (n = 2) to further enhance patellar stability.

Surgical Technique

Regional blocks were administered in the preoperative holding area, as indicated by patient preference. The patients were then brought to the operating room, and after administration of sedation, or general anesthesia, the operative limb was examined. Knee stability was evaluated by Lachman, pivot-shift, and anterior/posterior drawer tests at 90°, varus/valgus stress test in extension and 30° of flexion, and the dial test at 30° and 90°. After this, patellar stability was evaluated

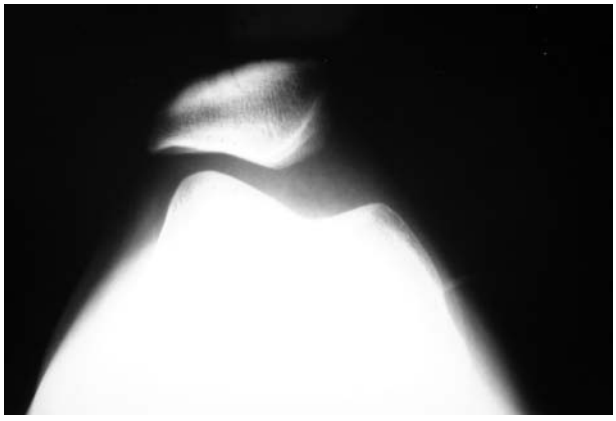

Figure 2. Preoperative sunrise view of the knee demonstrating lateral patellar subluxation and lateral tilt.

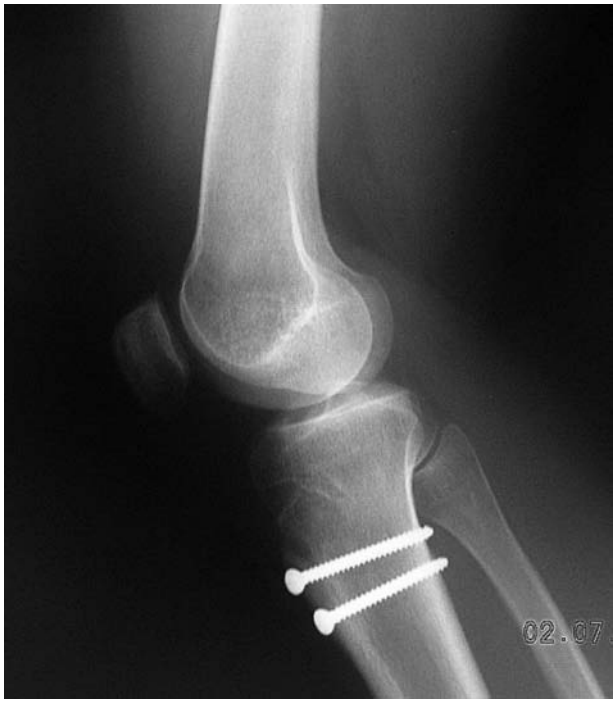

Figure 3. Postoperative radiograph demonstrates a healed osteotomy and correction of patella alta.

with respect to medial, lateral, superior, and inferior glide. The presence or absence of an end point on lateral glide at 30° and the ease of distal-lateral translation of the patella served as the basis for determining the need for MPFL reefing. No patients in this study underwent MPFL reconstruction.

After sterile preparation and draping, diagnostic knee arthroscopy was performed. All compartments were inspected, and associated pathological conditions were treated as indicated (Appendix 1). Standard anteromedial and anterolateral portals were established. Loose bodies were removed arthroscopically. Cartilage lesions of the

TABLE 2
Summary of Lysholm Scores

	Mean Score	No. of Patients (or Procedures)	*P* Value and Range
Lysholm scores			
All patients	91.8	N = 41	
Males (M)	94.8	M = 4	
Females (F)	91.5	F = 30	
Group difference, M vs F			*P* = .611
Lysholm scores by subcategory			
Pain	21.6/25		10-25
Instability	24/25		15-25
Locking	14.5/15		10-15
Stair climbing	8.2/10		2-10
Swelling	8.9/10		6-10
Squatting	4.5/5		2-5
Requiring support	5/5		5-5
Limp	4.7/5		3-5
Lysholm stratified by dislocation			
0 dislocations	91.9		74-100
1-3 episodes of dislocation	90.7		74-100
Comparison with 0 dislocations			*P* = .689
>3 episodes of dislocations	96.2		95-100
Comparison with 0 dislocations			*P* = .368
Lysholm, with associated procedures			
Medial reefing	86	2	81-91
Loose body (from patella)	95.5	2	91-100
Partial medial meniscectomy	97.8	5	89-100
Chondroplasty for distal, medial facet: Outerbridge II	90.2	5	74-100
Lysholm, no associated procedures	91.1	27	67-100
Group comparison, with vs without associated procedure			*P* = .317

trochlea were debrided to stable margins; no microfractures were performed. Careful attention was paid to the superior aspect of the medial facet with respect to the presence of arthritic changes. Patients with significant arthrosis did not undergo Fulkerson osteotomies and were therefore not candidates for this study. Articular lesions of the medial and lateral facets of the patella were likewise debrided to stable articular margins.

Lateral patellar tracking and tilt were subsequently assessed. An arthroscopic lateral release was then performed on all patients. With use of an arthroscopic electrocautery device (Arthrex Opes, Naples, Florida) and beginning at the level of the superior pole of the patella, the release was extended inferiorly to the level of the anterolateral portal. With respect to depth, the release was performed through both synovial and lateral retinacular layers. Careful attention was paid to preserving the attachment of

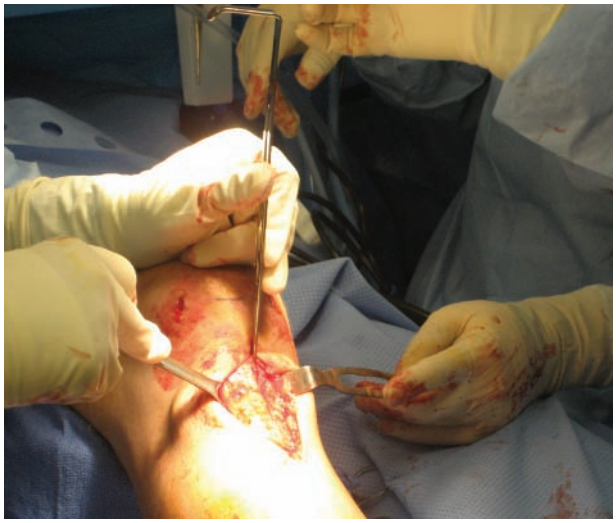

Figure 4. After arthroscopy, an incision is made along the medial aspect of the tibial tubercle. After exposure of the patellar tendon distally, a soft tissue plane is developed between the posterior aspect of the patellar tendon and the tibia, just proximal to the tubercle insertion. Note the placement of the army-navy retractor.

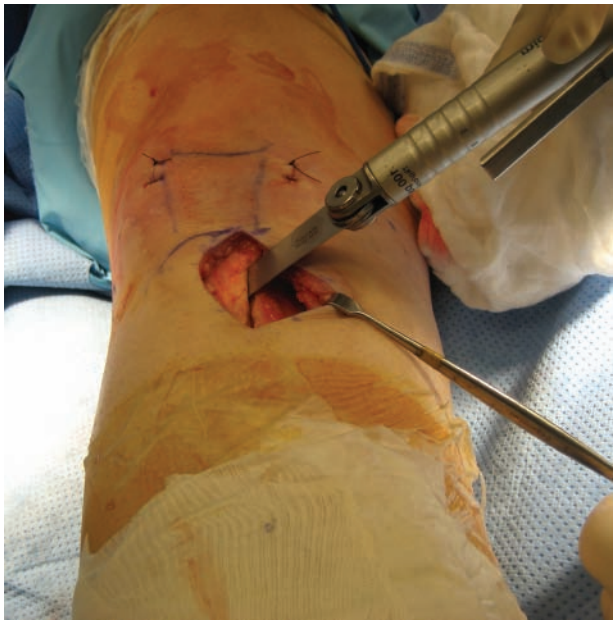

Figure 5. The osteotomy is directed posterolaterally while beginning along the medial border of the patellar tendon.

the vastus lateralis tendon. The superolateral geniculate artery was likewise identified and cauterized.

Attention was subsequently turned to the tubercle osteotomy. An anterior incision was based on the medial aspect of the proximal tibia tubercle, beginning approximately at the level of the tubercle and extending distally approximately 6 to 8 cm to the inferior aspect of the tibial

tubercle. The length of the incision and osteotomy was proportional to the size of the patient. Subcutaneous tissue was sharply dissected, and the tibial tendon was thus exposed. A soft tissue plane was developed at the superior aspect of the tibial tubercle, beneath the patellar tendon, to allow mobilization of the subsequent osteotomy (Figure 4).

The osteotomy was marked beginning superiorly just above the tibial tubercle, below the subchondral bone, and extending distally to the most inferior aspect of the tubercle. Note that the tubercle fragment was predrilled across its central, anterior cortex, before the osteotomy was performed, to facilitate subsequent AO lag technique. The osteotomy plane was directed posteriorly and laterally to allow for subsequent anteriorization and medialization of the tubercle[10] (Figure 5). The thickness of the tubercle osteotomy fragment proximally was approximately 1.5 to 2.5 cm in its AP dimension on the lateral tibial cortex. With respect to the lateral tibial cortex, the cut was tapered anteriorly as it extended proximally to distally to minimize cortical notching of the anterior tibial cortex at the inferior aspect of the tibial tubercle. The average length of the tubercle fragment was 6 to 7 cm.

The osteotomy was performed with a microsagittal saw and completed with an osteotome. The entire tubercle fragment was osteotomized for the transfer. To facilitate distal transfer, no pedicle was left in place during the osteotomy: The fragment was elevated en bloc and mobilized to achieve the desired correction. The angle of the osteotomy performed was typically 30° from the horizontal plane. The procedure was mainly a medialization, with slight anteriorization of the tubercle. This was approximated in all instances. See Figure 5 for the relative angle and depth of osteotomy. Distal transfer of the tubercle was likewise performed depending on the degree of alta, ranging from 10 to 15 mm.

All patients in this series had documented evidence of patella alta. Intraoperative correction of this anatomical variant was achieved by distal transfer of the tubercle. The position of the patella was evaluated on a 30° flexed, lateral fluoroscopic image. The tubercle was advanced distally until the inferior pole of the patella was flush with the Blumensatt line, as confirmed fluoroscopically. A goniometer was used to ensure that the knee was at 30° of flexion when the lateral image was obtained. Once the desired tubercle position was determined, with respect to medialization, anteriorization, and distalization, provisional fixation was achieved with a 2.5-mm drill bit. Two to 3 AO 4.5-mm cortical screws were then placed through the predrilled tubercle holes. Bicortical purchase was achieved while utilizing AO lag screw technique. Each screw was placed in a slightly different plane to resist rotational forces. Screws were stacked vertically to prevent convergence (Figure 3).

Patients were evaluated at regular intervals postoperatively, at 2 weeks, 6 weeks, 3 months, 6 months, 1 year, and at final follow-up. All patients followed the same postoperative protocol. All patients were placed on continuous passive motion for 7 to 10 days postoperatively until they regained 110° of flexion and full extension. For the first 6 weeks, all patients were allowed to bear weight as tolerated with the brace locked in extension. Goals during this phase included quadriceps activation and acquiring range of motion from 0° to 90° of flexion. After 6 weeks, the brace was unlocked, and closed chain exercises and strengthening were initiated. The brace was discontinued once full range of motion and quadriceps control were achieved, typically around 8 weeks postoperatively. Return to full, unrestricted activity was usually allowed by 4 to 5 months after surgery, given adequate quadriceps strength and range of motion.

TABLE 3
International Knee Documentation Committee (IKDC) Results and Return to Athletics

	Percentage and Ratio
IKDC criteria	
A: normal	66%, 27/41
B: near normal	29%, 12/41
C: abnormal	5%, 2/41
Return to preinjury sport	97%, 33/34[a]

[a]Patient who failed tested positive for Ehlers-Danlos syndrome.

RESULTS

All patients were corrected to a Q angle of less than 15° as measured by intraoperative criteria. In addition, all patients were corrected intraoperatively with fluoroscopic assessment for patella alta. At latest follow-up, only 1 patient had recurrent instability. All other patients returned to their preinjury sport without recurrent instability (40 of 41 knees). All patients returning to sports improved at a minimum to their preoperative level of competition (Tables 1 and 3). The sole patient who was unable to return to sport sustained several recurrences of dislocation after a traumatic fall 2 years postoperatively. She was later found to be positive for Ehlers-Danlos syndrome by genetic testing.

The average Lysholm score at latest follow-up was 91.8 (range, 67-100). Within the subcategories of the Lysholm score, the average pain score was 21.6 of 25 (range, 10-25). The average instability score was 24 of 25 (range, 15-25). The average locking score was 14.5 of 15 (range, 10-15). The average score for stair climbing was 8.2 of 10 (range, 2-10). The average squatting score was 4.5 of 5 (range, 2-5), and the average score for requiring support was 5 of 5 (range, all patients 5/5). The average score for swelling was 8.9 of 10 (range, 6-10), and the average score for limp was 4.7 of 5 (range, 3-5) (Table 2).

With regard to objective outcome measures, there were 27 normal (A) knees at latest follow-up by objective IKDC criteria. Twelve knees were graded as near normal (B), and 2 knees received grades of abnormal (C) (Table 3).

Two patients underwent a medial reefing procedure in addition to the Fulkerson osteotomy and arthroscopic lateral release. Each of these patients had increased distal lateral translation of the patella with the knee in 30° of

flexion and an attenuated appearance to the MPFL at the level of the proximal patella on magnetic resonance imaging. This finding was later confirmed by arthroscopy. The reefing consisted of reattachment of the ligament to its patellar insertion, with imbrication to restore tension. The reefing was attached to the medial cuff of the tissue on the medial border of the patella. This was not directly attached to bone. An imbrication was also undertaken to restore tension in the MPFL. The average Lysholm score for these 2 patients was 86 (range, 81-91).

There were 12 associated arthroscopic procedures performed during the index procedure. Two patients underwent a loose body removal for fragments that had broken off of the patella; their average Lysholm score was 95.5 (range, 91-100). Five patients underwent concomitant partial medial meniscectomy; their average Lysholm score was 97.8 (range, 89-100). Five patients underwent chondroplasty for Outerbridge grade II changes on the distal medial facet of the patella; their average Lysholm score was 90.2 (range, 74-100). There was no statistically significant difference in final Lysholm score between patients who underwent concomitant procedures and those who did not (mean, 91.1; range, 67-100; $P = .317$). In addition, there was no statistically significant difference in Lysholm scores between male (mean, 94.8; range, 74-100) and female (mean, 91.5; range, 67-100; $P = .611$) patients. When patients were stratified by the number of dislocations they had experienced on initial presentation, we found no significant differences in Lysholm scores for patients who had no previous dislocation (mean, 91.9; range, 74-100), 1 to 3 episodes of dislocation (mean, 90.7; range, 74-100; $P = .689$), or greater than 3 episodes of dislocation (mean, 96.2; range, 95-100; $P = .368$).

Twenty patients in our series had symptoms related to hardware at an average of 8 months' follow-up. All of these patients subsequently had their hardware removed. One patient developed patellar tendinitis postoperatively that resolved with nonoperative treatment. One patient developed a saphenous neuroma. This patient underwent a medial reefing procedure that was thought to have contributed to the development of this condition. At final follow-up, this patient had mild pain over the neuroma and refused formal treatment. One patient in our series developed a hypertrophic scar. There were no nonunions or malunions in this series. All patients healed the osteotomy at an average of 8 weeks postoperatively. There were no tibial fractures, and there was one recurrence of dislocation. No infections or wound complications occurred in this series. See Appendix 1 for a summary of results.

DISCUSSION

The treatment of patellofemoral instability has evolved considerably over the past 2 decades.[5,11,13,20,22-24] Most authors agree that the mainstay of treatment for an initial episode of instability or a first-time dislocation lies in rehabilitation. In a recent study examining the efficacy of nonoperative versus operative management for first-time patellar dislocations, investigators randomized patients to either proximal realignment or rehabilitation.[24] The results of the study supported nonoperative treatment. Young age and contralateral extremity instability were identified as risk factors for recurrence. A study by Garth et al[13] followed 58 athletically oriented patients treated for patellofemoral instability with a functional rehabilitation program without antecedent immobilization. At an average of 46 months, 73% of patients were satisfied with their knees. For patients who have completed a formal rehabilitation program and experience recurrent instability, with or without dislocation, operative intervention is perhaps warranted. Considerable debate exists with respect to establishing the optimal treatment algorithm.

Because of the challenge that patellofemoral instability presents from a surgical standpoint, combined proximal and distal procedures have received increasing attention. Realigning the patella by lateral release alone has failed to improve anterior knee pain and instability at long-term follow-up.[27]

Combined proximal-distal procedures have fared better: In a study of 20 athletes with distal malalignment who sustained unilateral traumatic patellar dislocation resulting in chronic instability,[12] a distal realignment procedure was combined with a lateral release. The Elmslie-Trillat technique[1] corrected the Q angle from an average of 25° to 15° (normal Q angle, 10°-20°). Furthermore, attenuated MPFLs were repaired in 10 knees at the patella margin; 10 MPFLs were repaired posterior to the vastus medialis obliquus. Similar to our study, patients were young (average age, 18 years), and 90% good or excellent results were obtained. A separate 26-year follow-up study of the Roux-Elmslie-Trillat procedure found recurrence of patellofemoral instability in only 7% of patients. However, there was a decline in overall knee function during the study period.[2]

The "essential" lesion in patellofemoral dislocation has been identified as a stretch or avulsion injury of the MPFL.[26] Multiple studies have demonstrated successful outcomes for recurrent patellofemoral instability with reconstruction or repair of this damaged ligament.[7,22,25,28] Interestingly, only 2 patients in our study underwent MPFL imbrication/advancement; none underwent reconstruction. In the aforementioned study of 20 athletes by Garth et al,[12] 12 were males, 9 of whom participated in football. In our series, only 4 of 34 patients were male, none of whom participated in contact sports (cycling, basketball, and 2 baseball). The preponderance of female noncontact athletes, and the lack of contact male athletes, may have contributed to the lower prevalence of discrete MPFL lesions.

We would like to stress the importance of a thorough examination of the MPFL under anesthesia, as it functions as the major medial soft tissue restraint, contributing an average of 53% of the stabilizing force preventing lateral displacement of the distal knee-extensor mechanism.[5] The MPFL end point and ease of translation are best evaluated with the patella displaced distally and laterally (about 2 cm) and the knee flexed 30°.

The high prevalence of generalized ligamentous laxity in young female patients likely plays a role in the pathogenesis of patellofemoral instability.[8,31] Furthermore, the one patient who experienced recurrent patellofemoral instability postoperatively was subsequently diagnosed

with Ehlers-Danlos syndrome. Common findings in athletes with this syndrome include joint pain, instability, tissue fragility, or joint dislocations.[29]

Although MPFL reconstruction is an accepted treatment modality for patellofemoral instability, the senior author's choice in this series of patients was to perform a modified Fulkerson osteotomy and lateral release. The rationale or bias underlying this choice was the supposition that the osteotomy may provide a more durable long-term result given the advantage of direct bone-to-bone healing intrinsic to the procedure. Furthermore, the osteotomy performed in this series provided for correction of malalignment and patella alta, as well as for unloading of the damaged or at-risk distal-medial patella facet. A long-term randomized study is necessary to elucidate respective advantages and disadvantages of MPFL reconstruction and Fulkerson osteotomy.

In some studies, slight distal placement (10-15 mm) of the tubercle was included in the procedure.[1] Fulkerson has also highlighted that this can be incorporated into the procedure if significant patella alta is present.[11] While it could conceivably increase the risk of avascular necrosis (AVN) by placing significant tension on the blood supply to the patella, this has not been reported in our series or in any other in the literature.

Another reason to perform a Fulkerson osteotomy and arthroscopic lateral release for recurrent instability, versus an MPFL reconstruction, stems from the poor results that have been obtained for patellofemoral instability with MPFL reconstruction in the setting of trochlear dysplasia.[28] Notably, trochlear dysplasia did not exist in any of our patients. Several authors have advocated trochleaplasty for trochlear dysplasia, which has shown some success in preventing recurrence at long-term follow-up.[32] However, the effect of the procedure on patellofemoral pain and the development of patellofemoral osteoarthritis is acknowledged to be problematic. Thus, we contend that trochleaplasty is best reserved for more sedentary patients versus a young, athletic population.

In our series of patients, we used a modification of the Fulkerson osteotomy to address the following issues: (1) correction of malalignment, (2) correction of patella alta, and (3) unloading of the patellofemoral joint. This procedure allowed for correction of the predisposing pathological abnormalities (patella alta and malalignment, via distalization and medialization of the tubercle, respectively) while unloading the damaged or at-risk distal-medial facet of the patella (via anteriorization of the tubercle).

With respect to anteriorization of the tibial tubercle as first described by Maquet,[19] biomechanical studies have demonstrated that patella contact areas shift proximally and laterally on the articular surface.[18] As we performed a modified Fulkerson osteotomy (with anteromedial tubercle transfer), we ultimately decreased patellofemoral contact forces laterally while improving overall alignment.[11] It is thus understood that patients with proximal, medial facet disease are poor candidates for Fulkerson osteotomy. No patients in our series had proximal, medial facet patellar disease, which may have contributed to the excellent Lysholm pain scores obtained at latest follow-up.

It should be noted that patients in this series underwent arthroscopic lateral release to facilitate distal, medial, and anterior transfer of the tibial tubercle, not as a primary treatment for patellofemoral instability. We partially attribute our low recurrence rate to distal transfer of the tubercle, which resulted in correction of the patella alta and earlier engagement of the patella during knee flexion. We would like to stress the importance of using intraoperative fluoroscopy with a goniometer to confirm correct positioning of the patella (inferior pole level with the Blumensaat line), with the knee in 30° of flexion. Furthermore, the advancement of the distal tubercle should be limited to 2 cm, given the potential for a high rate (71%) of osteoarthritis at long-term follow-up (16 years), secondary to associated increases in patellofemoral contact pressures.[6]

We note several limitations to our study. This series is a retrospective review, and no direct comparisons were made to a control group. In addition, the lack of preoperative Lysholm and IKDC scores diminishes our ability to quantify the effects of our surgical treatment on patients. The fact that all patients were unable to participate in their respective sport preoperatively, however, reflects the extent to which they were afflicted. Furthermore, it is noteworthy that all but one of the patients had returned to sports at the most recent follow-up visit.

Objective measurements were obtained by the senior author, who performed all surgeries. This potentially introduces a degree of bias. This bias was mitigated by the fact that the junior investigator interviewed all patients, computed all subjective scores, and performed analysis of all data.

Nearly half (49%) of the patients in this series reported symptoms related to hardware. We suspect that anteriorization of the tubercle contributed to this phenomenon. Preoperative counseling regarding the possible need for hardware removal is therefore essential.

In summary, this is the largest reported series of athletes treated for patellofemoral instability. No patient participated in his or her respective sport preoperatively, and 97% of patients returned to sport postoperatively. It demonstrates that our modified Fulkerson osteotomy (with distalization of the tibia tubercle) and concomitant arthroscopic lateral release can be utilized to successfully treat athletes with recurrent patellar instability. It is important and encouraging to note that associated procedures, patient sex, and the number of previous dislocations had no influence on subjective outcomes as measured by the Lysholm score.

ACKNOWLEDGMENT

The authors thank Mary Ann and BJ for their support and contributions.

REFERENCES

1. Brown DE, Alexander AH, Lichtman DM. The Elmslie-Trillat procedure: evaluation in patellar dislocation and subluxation. *Am J Sports Med*. 1984;12(2):104-109.

2. Carney JR, Mologne TS, Muldoon M, Cox JS. Long-term evaluation of the Roux-Elmslie-Trillat procedure for patellar instability: a 26-year follow-up. *Am J Sports Med*. 2005;33(8):1220-1223.
3. Chrisman OD, Snook GA, Wilson TC. A long-term prospective study of the Hauser and Roux-Goldthwait procedures for recurrent patellar dislocation. *Clin Orthop Relat Res*. 1979;144:27-30.
4. Cofield RH, Bryan RS. Acute dislocation of the patella: results of conservative treatment. *J Trauma*. 1977;17(7):526-531.
5. Conlan T, Garth WP Jr, Lemons JE. Evaluation of the medial soft-tissue restraints of the extensor mechanism of the knee. *J Bone Joint Surg Am*. 1993;75(5):682-693.
6. Crosby EB, Insall J. Recurrent dislocation of the patella: relation of treatment to osteoarthritis. *J Bone Joint Surg Am*. 1976;58(1):9-13.
7. Fernandez E, Sala D, Castejon M. Reconstruction of the medial patellofemoral ligament for patellar instability using a semitendinosus autograft. *Acta Orthop Belg*. 2005;71(3):303-308.
8. Fithian DC, Paxton EW, Stone ML, et al. Epidemiology and natural history of acute patellar dislocation. *Am J Sports Med*. 2004;32(5):1114-1121.
9. Flynn TW, Soutas-Little RW. Patellofemoral joint compressive forces in forward and backward running. *J Orthop Sports Phys Ther*. 1995;21(5):277-282.
10. Fulkerson JP. Anteromedialization of the tibial tuberosity for patellofemoral malalignment. *Clin Orthop Relat Res*. 1983;177:176-181.
11. Fulkerson JP. Patellofemoral pain disorders: evaluation and management. *J Am Acad Orthop Surg*. 1994;2(2):124-132.
12. Garth WP Jr, DiChristina DG, Holt G. Delayed proximal repair and distal realignment after patellar dislocation. *Clin Orthop Relat Res*. 2000;377:132-144.
13. Garth WP Jr, Pomphrey M Jr, Merrill K. Functional treatment of patellar dislocation in an athletic population. *Am J Sports Med*. 1996;24(6):785-791.
14. Hawkins RJ, Bell RH, Anisette G. Acute patellar dislocations: the natural history. *Am J Sports Med*. 1986;14(2):117-120.
15. Hughston JC, Deese M. Medial subluxation of the patella as a complication of lateral retinacular release. *Am J Sports Med*. 1988;16(4):383-388.
16. Insall J, Salvati E. Patella position in the normal knee joint. *Radiology*. 1971;101(1):101-104.
17. Kaufman KR, An KN, Litchy WJ, Morrey BF, Chao EYS. Dynamic joint forces during knee isokinetic exercise. *Am J Sports Med*. 1991;19(3):305-316.
18. Lewallen DG, Riegger CL, Myers ER, Hayes WC. Effects of retinacular release and tibial tubercle elevation in patellofemoral degenerative joint disease. *J Orthop Res*. 1990;8(6):856-862.
19. Maquet P. Advancement of the tibial tuberosity. *Clin Orthop Relat Res*. 1976;115:225-230.
20. Marcacci M, Zaffagnini S, Lo Presti M, Vascellari A, Iacono F, Russo A. Treatment of chronic patellar dislocation with a modified Elmslie-Trillat procedure. *Arch Orthop Trauma Surg*. 2004;124(4):250-257.
21. Marsh JS, Daigneault JP, Sethi P, Polzhofer GK. Treatment of recurrent patellar instability with a modification of the Roux-Goldthwait technique. *J Pediatr Orthop*. 2006;26(4):461-465.
22. Mikashima Y, Kimura M, Kobayashi Y, Miyawaki M, Tomatsu T. Clinical results of isolated reconstruction of the medial patellofemoral ligament for recurrent dislocation and subluxation of the patella. *Acta Orthop Belg*. 2006;72(1):65-71.
23. Nam EK, Karzel RP. Mini-open medial reefing and arthroscopic lateral release for the treatment of recurrent patellar dislocation: a medium-term follow-up. *Am J Sports Med*. 2005;33(2):220-230.
24. Nikku R, Nietosvaara Y, Aalto K, Kallio PE. Operative treatment of primary patellar dislocation does not improve medium-term outcome: a 7-year follow-up report and risk analysis of 127 randomized patients. *Acta Orthop*. 2005;76(5):699-704.
25. Nomura E, Inoue M. Hybrid medial patellofemoral ligament reconstruction using the semitendinous tendon for recurrent patellar dislocation: minimum 3 years' follow-up. *Arthroscopy*. 2006;22(7):787-793.
26. Nomura E, Inoue M. Injured medial patellofemoral ligament in acute patellar dislocation. *J Knee Surg*. 2004;17(1):40-46.
27. Panni AS, Tartarone M, Patricola A, Paxton E.W, Fithian DC. Long-term results of lateral retinacular release. *Arthroscopy*. 2005;21(5):526-531.
28. Schottle PB, Scheffler SU, Schwarck A, Weiler A. Arthroscopic medial retinacular repair after patellar dislocation with and without underlying trochlear dysplasia: a preliminary report. *Arthroscopy*. 2006;22(11):1192-1198.
29. Schroeder EL, Lavallee ME. Ehlers-Danlos syndrome in athletes. *Curr Sports Med Rep*. 2006;5(6):327-334.
30. Tanner SM, Garth WP Jr, Soileau R, Lemons JE. A modified test for patellar instability: the biomechanical basis. *Clin J Sport Med*. 2003;13(6):327-338.
31. Teitz CC, Hu SS, Arendt EA. The female athlete: evaluation and treatment of sports-related problems. *J Am Acad Orthop Surg*. 1997;5(2):87-96.
32. von Knoch F, Bohm T, Burgi ML, von Knoch M, Bereiter H. Trochleaplasty for recurrent patellar dislocation in association with trochlear dysplasia: a 4- to 14-year follow-up study. *J Bone Joint Surg Br*. 2006;88(10):1331-1335.