Outcomes of Patellar Stabilization Utilizing a Combined Arthroscopic and Open Technique

A Retrospective Review With 5-Year Follow-up

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Background: Few studies have reported the long-term outcomes of patellar stabilization surgery in an active duty military cohort.

Purpose: To evaluate the long-term results of a combined open and arthroscopic patellar stabilization technique for the treatment of recurrent lateral patellar instability in members of a military population.

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

Methods: We performed a retrospective review of a consecutive series of 63 patients who underwent operative management for patellar instability at a tertiary military medical center between 2003 and 2017. All cases were performed by a single sports medicine fellowship–trained orthopaedic surgeon. Patients with recurrent lateral patellar instability whose nonoperative management failed were included. All patients underwent arthroscopic imbrication of the medial patellar retinaculum, an open lateral retinacular release, and an Elmslie-Trillat tibial tubercle osteotomy. Outcome measures at final follow-up included recurrent instability, need for surgical revision, subjective assessments, and military-specific metrics. We also analyzed anatomic risk factors for failure: patella alta, coronal plane alignment, trochlear dysplasia, and tibial tubercle–trochlear groove distance.

Results: A total of 51 patients were included (34 men, 17 women; mean ± SD age at surgery, 27.2 ± 5.8 years; mean follow-up, 5.3 years). The mean postoperative SANE score (Single Assessment Numeric Evaluation) was 75.0 ± 17.7, and the mean visual analog scale pain score was 2.5 ± 2.1. Four patients (7.8%) reported redislocation events, and 4 underwent revision surgery. Twenty-five patients (49.0%) reported a decrease in activity level as compared with preinjury, while 10 (19.6%) cited restrictions in activities of daily living. Of the 21 patients remaining on active duty, 6 (28.6%) required an activity-limiting medical profile. Of the 48 active duty patients, 12 (25.0%) underwent evaluation by a medical board for separation from the military. Differences in the Caton-Deschamps Index and tibial tubercle–trochlear groove distance between surgical success and failure were not statistically significant.

Conclusion: Surgical management of patellar instability utilizing a multifaceted technique resulted in low recurrence rates and may be independent of predisposing anatomic risk factors for instability. At 5-year follow-up, most patients retained their active duty status, although nearly half experienced a decrease in activity level.

Keywords: knee; patella; ligaments; osteotomy; sports trauma; military training

Traumatic patellofemoral instability results from a failure of the complex interaction between the soft tissue stabilizers and bony restraints of the patellofemoral joint. Patellar dislocations represent the second-most common cause of traumatic knee hemarthroses and account for 2% to 3% of all knee injuries.[45] Dislocation arthropathy can manifest as persistent pain, decreased activity, and patellofemoral arthritis.[20]

After resolution of the acute postinjury phase, patients are usually treated nonoperatively with a physical therapy regimen focused on quadriceps strengthening to improve patellar tracking.[14] For patients with recurrent patellar instability, surgical stabilization may be indicated. Operative techniques may include medial patellofemoral ligament (MPFL) imbrication or reconstruction, a distal realignment procedure such as a tibial tubercle osteotomy, or both.[24,39,41,47] As the origin of patellar instability is multifactorial, previous studies[4,16,27] have suggested that correction of anatomic risk factors, such as patella alta, valgus

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malalignment, and an increased tibial tubercle–trochlear groove (TT-TG) distance, may be paramount to patient outcomes.

Management of patellofemoral instability is particularly challenging in military servicemembers, who are inherently at a higher risk for injury in comparison with their civilian counterparts because of their daily physical demands. The mean load to failure of the medial stabilizers of the patella is only 178 N, which is easily exceeded by many of the high-demand activities within this patient population.[30] Hsiao et al[25] reported that the incidence of patellar dislocation in an active duty military cohort was 77.4 per 100,000 person-years, or 10 times higher than in previous studies within the civilian population. One study outlined the long-term outcomes of patellar stabilization surgery in an active duty cohort of military patients.[6]

The purpose of our study was to report the outcomes of a standardized operative technique in a predominantly active duty population with recurrent patellar instability. Additionally, we evaluated the relative efficacy of our technique against an analysis of radiographic and magnetic resonance imaging (MRI) parameters associated with instability. We hypothesized a low rate of recurrent instability with an association between failure rate and predisposing risk factors, high subjective outcome scores, and expected a high likelihood for patients to meet the physical requirements for military retention.

METHODS

Design and Setting

This was an institutional review board–approved retrospective study of a consecutive series of adult patients at a single military medical center. Preliminary data were collected from patients who underwent a primary or revision patellar stabilization procedure from 2003 to 2017 through a review of medical records. Postoperative subjective data at final follow-up were obtained using telephone surveys. The minimum follow-up duration was 2 years. A minimum of 10 contact attempts were made before patients were considered lost to follow-up. All cases were performed by a single sports medicine fellowship–trained orthopaedic surgeon (C.R.B.). A total of 63 patients met our inclusion criteria. Of these, 12 were unable to be contacted for follow-up, leaving a final study population of 51 patients for clinical assessment (follow-up, 81.0%) (Figure 1).

Demographics collected at the time of patient presentation were age at surgery, sex, and active duty status. Laterality and history of ipsilateral knee surgery were documented. Physical examination of each knee included an apprehension test, patellar tilt test, and observation of patellar tracking. Standard anteroposterior and lateral radiographs were obtained for each patient.

Patient Population

Study enrollment was limited to patients within a single tertiary military treatment facility. All patients were aged >18 years. Recurrent instability was defined as a documented history of ≥2 episodes of lateral patellar dislocation or subluxation. All patients underwent a course of physical therapy before undergoing the patellar stabilization procedure. Predetermined exclusion criteria from our series were as follows: concurrent anterior cruciate ligament or meniscal injuries, revision patellar instability cases, open physes, severe genu valgum, and preexisting patellofemoral arthritis.

Surgical Procedure and Rehabilitation

All cases were performed by a senior fellowship-trained orthopaedic sports surgeon (C.R.B.), using an operative technique consisting of arthroscopic imbrication of the medial patellar retinaculum, an open lateral retinacular release, and an Elmslie-Trillat tibial tubercle osteotomy. With the patient in a supine position and the application of a thigh tourniquet, a diagnostic arthroscopy was initially performed. A medial patellar retinaculum imbrication was performed using No. 2 nonabsorbable sutures (FiberWire; Arthrex) inserted with a disposable suture-shuttling instrument (Suture Lasso; Arthrex). Arthroscopic knots were utilized to plicate the medial retinaculum and MPFL. After the arthroscopic plication, an 8-cm incision was made extending distally from the anterolateral arthroscopy portal along the lateral border of the tibial tubercle, and subfascial planes were developed around the tubercle with electrocautery. An open lateral retinacular release was then performed proximally through the same incision with a long electrocautery tip, and it was complete when the patella was able to be everted past neutral. Next, an Elmslie-Trillat tibial tubercle osteotomy was created using an osteotome. The osteotomy measured 7 cm in length, and the distal periosteum and soft tissue hinge were left intact, without distalization of the tubercle. The extent of tubercle medialization was determined via an intraoperative

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Ethical approval for this study was obtained from Tripler Army Medical Center (No. 218079).

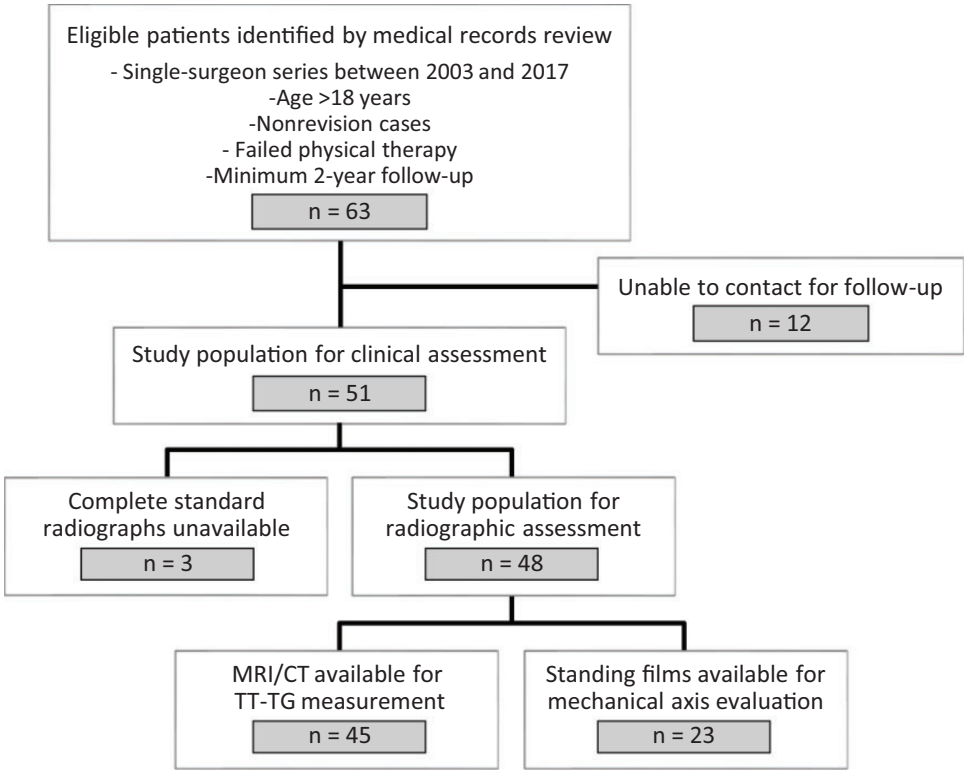

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flowchart. CT, computed tomography; MRI, magnetic resonance imaging; TT-TG, tibial tubercle–trochlear groove.

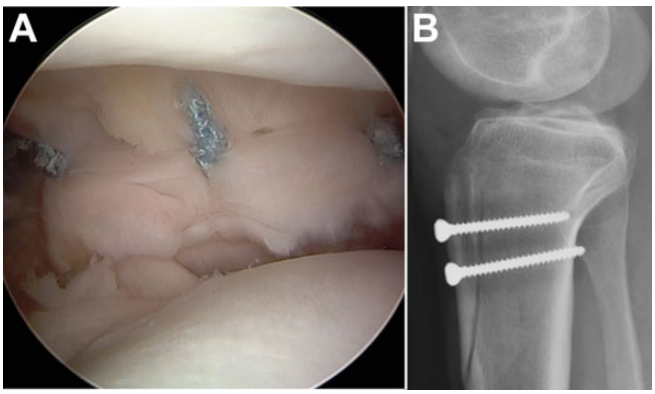

Figure 2. (A) Arthroscopic medial patellofemoral ligament imbrication. The No. 2 nonabsorbable sutures were tied using arthroscopic knots. (B) Postoperative lateral radiograph demonstrating tibial tubercle osteotomy with cortical screws (2 × 4.5 mm).

patellar tracking examination demonstrating centralized engagement of the patella within the trochlea beginning at 30° of flexion as seen arthroscopically and clinically. Bicortical fixation of the tubercle was achieved with fully threaded cortical screws (2 × 4.5 mm) in a lag-by-technique fashion (Figure 2).

All patients underwent a standardized postoperative rehabilitation protocol. Immediately postoperatively, patients were placed in a hinged knee brace. Patients were restricted to flat-foot weightbearing and knee flexion to 90° for 2 weeks. All patients then began a directed physical therapy program at 2 weeks. Range of motion was advanced as tolerated, while advancement of weightbearing and brace discontinuation were based on quadriceps function and control. All patients were full weightbearing by 6 weeks. Return to full activities was typically permitted at 6 months but was contingent on radiographic evidence of union of the osteotomy and patient-specific factors.

Variables of Interest and Data Analysis

Our primary outcome measure was the rate of recurrent patellar instability, defined as patellar dislocation or subluxation after operative intervention. Standardized secondary outcome measures included pre- and postoperative assessment using the visual analog scale for pain as well as postoperative Single Assessment Numeric Evaluation (SANE) score.[29,49] We asked patients to categorize their functional status as not restricted, minimally restricted, or restricted. We also asked patients to categorize their postoperative activity level as same as preinjury or decreased compared to preinjury. We categorized each patient's occupational demand level at the time of data collection as office, light manual, and heavy manual. Persistent symptoms (eg, swelling or limping) were documented. The timing of initial dislocation was categorized as before or during the period of active duty service. The frequency,

TABLE 1
Characteristics of the Study Patients (N = 51)

Variable	Value[a]
Follow-up, y	
Mean ± SD	5.3 ± 4.0
Median (range)	3.3 (2.1-16.6)
Age at surgery, y	
Mean ± SD	27.2 ± 5.8
Median (range)	26.1 (19.0-41.4)
Laterality	
Left	30 (58.8)
Right	21 (41.1)
Sex	
Male	34 (66.7)
Female	17 (33.3)
Duty status	
Military	48 (94.1)
Dependent	3 (5.9)
Time of first dislocation	
Before active duty service	20 (41.7)
During active duty	28 (58.3)

[a]Data are reported as No. (%) unless noted otherwise.

TABLE 2
Clinical Outcomes[a]

Variable	Value[b]
Postoperative patellar stability	
Stable	47 (92.2)
Unstable	4 (7.8)
Postoperative SANE score	
Mean ± SD	75.0 ± 17.7
Median (range)	80 (40-100)
Functional status	
No limitations	16 (31.4)
Minimal restrictions	25 (49.0)
Restricted	10 (19.6)
Postoperative activity level	
Same as preinjury	26 (51.0)
Decreased	25 (49.0)
Persistent symptoms	
None	23 (45.1)
Knee swelling only	19 (37.3)
Limp only	2 (3.9)
Swelling and limp	7 (13.7)
Underwent revision	
Yes	4 (7.8)
No	47 (92.2)
Time to revision, mo	
Mean ± SD	64.8 ± 57.8
Median (range)	64.8 (23.9-105.7)
Current occupational demands	
Office	22 (43.1)
Light manual	18 (33.3)
Heavy manual	12 (23.5)

[a]SANE, Single Assessment Numeric Evaluation.
[b]Data are reported as No. (%) unless noted otherwise.

timing, and nature of revision procedures were recorded. Military-specific metrics were current duty status and prevalence of medical profiles limiting activity level. Additionally, we calculated the incidence of a medical evaluation board (MEB) referral, which is typically initiated when a servicemember is unable to meet physical retention standards.

Additional secondary outcome measures included comparative assessments of anatomic risk factors for patellar instability. Lateral knee radiographs were utilized to measure patella alta via the Caton-Deschamps Index (CDI), while trochlear dysplasia was evaluated using the Dejour classification.[12,16] Coronal plane alignment was classified by zones on mechanical axis films as described by Stevens et al.[46] Assessment of the TT-TG distance was performed using MRI: specifically, the distance between (1) a line drawn through the deepest point of the trochlear groove tangential to the posterior condyle and (2) a line through the most anterior portion of the tibial tubercle parallel to the trochlear line, with >20 mm considered abnormal.[16,50] All measurements were performed by a sports medicine fellowship–trained orthopaedic surgeon (L.Z.). Statistical analyses involving quantitative variables were evaluated with a 2-tailed Student *t* test ($\alpha = 0.05$).

RESULTS

Demographics

The 51 study patients consisted of 34 men and 17 women, with a mean ± SD age at surgery of 27.2 ± 5.8 years (range, 19.0-41.4). Two patients previously underwent partial meniscectomies. One patient had a remote history of anterior cruciate ligament reconstruction, from which he had fully recovered before his patellar instability event. Most patients (94.1%) were active duty, while 3 dependents (spouse or child) meeting the inclusion criteria were also surveyed. The mean follow-up duration was 5.3 years (range, 2.1-16.6 years). Of the 48 active duty patients, 28 (58.3%) sustained their first instability episode while on active duty. Descriptive analyses of our study cohort are summarized in Table 1.

Recurrent Instability

Four patients (7.8%) reported at least 1 repeat instability episode (Table 2). Among this subset of patients, the mean number of repeat events was 3.0 (range, 1-5). Chondroplasty was performed in 18 of 24 patients with documented chondral injury and in all 15 patients with Outerbridge grade 3 or 4 lesions. After the index procedure, 4 patients (7.8%) underwent revision patellar stabilization: 3 for continued instability and 1 for a painful osteotomy nonunion. Additional procedures unrelated to patellar instability and not in the primary outcome analysis were as follows: removal of symptomatic hardware in 2 patients, partial meniscectomy in 1, and total knee

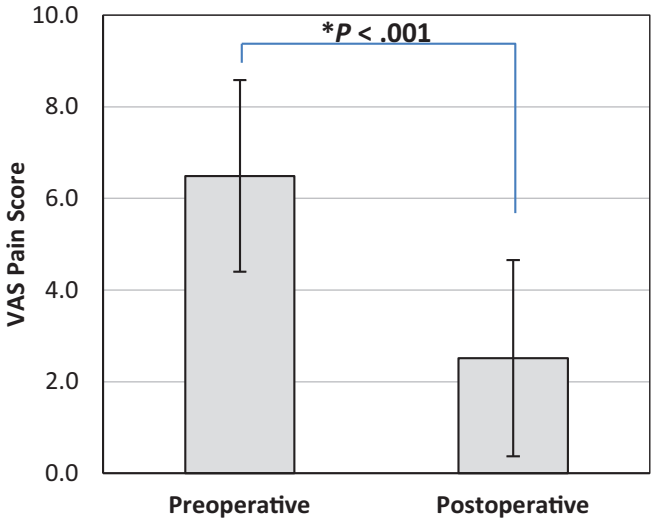

Figure 3. Pre- and postoperative visual analog scale pain scores. Error bars indicate standard deviations.

arthroplasty in 1 with progressive patellofemoral arthritis at 46 years of age.

Subjective Outcome Measures

Notably, pain levels decreased significantly after surgery (Figure 3). The mean score on the visual analog scale was 6.5 ± 2.2 preoperatively, which improved to 2.5 ± 2.1 postoperatively ($P < .001$). The mean postoperative SANE score was 75.0 ± 17.7 (Table 2).

Overall, 80.4% of patients indicated no restrictions or minimal restrictions with regard to their functional status. However, 25 (49.0%) reported a decrease in activity level as compared with the preinjury level, and all attributed their knee as the primary cause of decreased activity. Of the 12 patients whose level of occupational demand was heavy manual at the conclusion of the study, 3 (25.0%) experienced a decrease in their activity levels. Most patients (82.4%) stated that they had either no persistent symptoms or intermittent swelling episodes alone, while the remaining patients (17.6%) cited onset of a limp after prolonged activity. Patient occupational demand level at the time of survey was recorded, with 43.1% indicating office duty work, 33.3% participating in light manual duties, and 23.5% performing heavy manual duties.

Military Readiness

Our military cohort consisted of 48 servicemembers (men and women), totaling 94.1% of our study population. Among these patients, 21 (43.8%) had remained on active duty at the time of final follow-up (Table 3). Of these 21 patients, 5 (23.8%) described their jobs as heavy manual labor. For soldiers with a condition that permanently precludes their ability to meet defined physical standards, a medical profile may be issued for recommendation of alternative exercises. Of the 21 patients, 6 (28.6%) remaining on active duty required a medical profile after patellar stabilization because of continued knee symptoms.

TABLE 3
Military Readiness Outcomes (n = 48 Active Duty Patients)

Variable	No. (%)
Duty status at final follow-up	
Remained active duty	21 (43.8)
Retired	27 (56.3)
Medical profile issued	
Yes	6 (28.6)
No	18 (71.4)
Referred to medical evaluation board	
Yes	12 (25.0)
No	36 (75.0)

TABLE 4
Radiographic/MRI Analysis (n = 48 Patients)[a]

Variable	Surgical Success	Surgical Failure	*P*
Caton-Deschamps Index			
Mean ± SD	1.06 ± 0.14	1.01 ± 0.13	.439
Median (range)	1.06 (0.83-1.35)	0.97 (0.9-1.19)	
Dejour classification			
Nondysplastic	21	2	
A	15	1	
B	4	1	
C	1	0	
D	3	0	
Mechanical axis zone			
–3	0	0	
–2	2	0	
–1	13	1	
+1	7	0	
+2	1	0	
+3	0	0	
MRI available			
Yes	43	2	
No	6	0	
TT-TG distance, mm			
Mean ± SD	16.60 ± 4.54	17.95 ± 3.12	.568
Median (range)	16.06 (5.7-27.85)	16.93 (15.47-21.45)	

[a]Data are reported as No. unless noted otherwise. MRI, magnetic resonance imaging; TT-TG, tibial tubercle–trochlear groove.

Under exceptional circumstances in which a condition permanently interferes with a soldier's ability to serve on active duty, an MEB may review the case for whether the soldier meets retention standards.[32] Among our total military cohort, 12 (25.0%) patients were referred to the MEB and medically separated thereafter. The remaining 36 (75.0%) patients did not require MEB referral or separation from the military owing to functional limitations related to their knees.

Anatomic Risk Factor Analysis

Of the 51 patients with clinical follow-up, 48 (94.1%) had a complete set of standard radiographs available for review,

including lateral radiographs. As shown in Table 4, there were no statistically significant differences in the mean CDI between surgical success and failure (1.06 ± 0.14 vs 1.01 ± 0.13, respectively; $P = .439$). Of the 48 patients with lateral radiographs, 27 (56.3%) had evidence of trochlear dysplasia, with the majority of these cases classified as Dejour type A. Among the failures, 1 case was Dejour A, 1 was Dejour B, and 2 were nondysplastic. Mechanical axis films were available for 23 (47.9%) patients, and most demonstrated zone 1 valgus alignment, including the 1 case of failure with available imaging. MRI studies were available for 45 (88.2%) patients. There was no statistically significant difference in TT-TG distance between surgical success and failure (16.60 ± 4.54 vs 17.95 ± 3.12 mm; $P = .568$).

DISCUSSION

Management of recurrent patellofemoral instability remains a complex pathological process, with a wide range of treatment options and a lack of standardized surgical protocols.[2,9,11,17,22,34] Hawkins et al[23] reported on its natural history, with persistent instability and anterior knee pain manifesting in 30% to 50% of patients treated nonoperatively. Surgical stabilization of the patella has been shown to improve outcomes in selected patients; however, the interpretation of results may be limited given the wide range of treatment modalities available.[7,19,43] While MPFL reconstruction is a well-established technique, imbrication of the MPFL has been described with good results.[1,3,44] Lateral retinacular release may be combined with concomitant soft tissue and bony realignment procedures to address a tight lateral patellar retinaculum and to restore patellar tilt. Iatrogenic medial patellar instability is a known complication of lateral release when performed in isolation, although no instances were noted in our study.[21,26,38,40] In our single-surgeon series utilizing a previously unreported standardized operative technique of medial imbrication, lateral release, and tibial tubercle osteotomy, we noted several important findings.

First, our incidence of recurrent patellar instability was 7.8% at a mean follow-up of 5.3 years. This finding is comparable to that of Carney et al,[10] whose review of 18 patients who underwent the Roux-Elmslie-Trillat procedure revealed a failure rate of 7% at a mean 26-year follow-up. The authors reported an unchanged percentage of failures as compared with previous results at 3-year follow-up within the same cohort.[15] Notably, according to defined exclusion criteria, only 18% of patients from the 3-year follow-up group were ultimately evaluated. Our investigation yielded a follow-up rate of 81.0% and a similar rate of recurrent instability.

Functional status of the knee after surgery is a salient consideration, and few studies have been published on long-term subjective outcomes after a patellar stabilization procedure. Nakagawa et al[35] noted excellent/good results in 91% of patients at a mean follow-up of 45 months; however, at 13-year follow-up within the same cohort, a deterioration of outcomes was noted, as results were sustained in just 64% of patients. The authors postulated these results to be reflective of worsening patellofemoral joint pain, rather than instability. Nomura et al[36] demonstrated excellent/good results at a mean follow-up of 11.9 years in 21 of 24 patients who underwent proximal realignment procedures alone, although follow-up was limited to 61.5%. In the study by Carney et al,[10] only 54% of patients rated their knees as excellent/good, in contrast to 73% within the larger 3-year cohort. Our postoperative SANE score of 75.0 ± 17.7 is comparable to a prior study of 13 patients by Morrissey et al[33] (79.5 ± 18.6), although follow-up in their cohort was limited to 16 months. It should be emphasized that at final-follow-up, our study cohort was not a uniformly high-demand population, with 43.1% of patients indicating office-level duties. We attribute this finding to expected declines in age-related and occupational activity levels, given the corresponding proportion of patients (56.3%) who had since retired from the military at the time of data collection. It is therefore unsurprising that 49% of patients reported a decrease in activity level. Yet, with respect to their functional demands, 80.4% of patients in our study stated that they had no limitations or minimal restrictions at final follow-up, and just 25% of patients who held a heavy manual occupation cited a decrease in their activity levels.

Anatomic risk factors such as trochlear dysplasia, patella alta, coronal plane alignment, and increased TT-TG interval have been frequently cited as risk factors for patellar instability, although recommendations for soft tissue realignment procedures alone versus those with a concomitant bony procedure remain controversial.[5,8,13,18,28] In our series, a comprehensive evaluation of all patients was performed preoperatively, without utilization of these factors as sole criteria for proceeding with a tibial tubercle osteotomy. We performed a retrospective review of the CDI and TT-TG distance and found comparable measurements to a case series by Sappey-Marinier et al,[39] although fewer patients in our study had evidence of trochlear dysplasia. While valgus deformity of the leg axis has been proven to significantly influence patellar tracking, no studies to our knowledge have directly assessed whether a correlation exists with redislocation after a patellar stabilization procedure.[31] We found that 15 of 23 (65.2%) patients with alignment films had evidence of zones –1 and –2 valgus, including 1 clinical failure. Notably, our series comprised no patients with severe genu valgum (identified clinically or by zone –3 alignment), as this identifiable risk factor was a predetermined exclusion for our described technique. Future studies with greater sample sizes are needed to clarify the association between valgus malalignment and lateral patellar instability. Overall, our comparative analysis between surgical failure and success did not demonstrate a significant difference in any of the risk factors for instability.

Finally, military service significantly increases a patient's risk for patellofemoral instability and likelihood of failure after surgical management, adding to the complexity of management within this unique demographic.[25,42] Visuri and Mäenpää noted, in a population of 119 Finnish conscripts, a redislocation rate of 19% at 6-year mean follow-up.[48] Only 35% of patients returned to unrestricted duty, while the retention rate was 48%. Belmont et al[6] reported a case series of 51 military servicemembers who underwent an anteromedializing tibial tubercle osteotomy. However,

operative technique was not standardized, as proximal realignment procedures were utilized in just 48% of patients. The authors demonstrated an 80% return-to-duty rate and 21% recurrent instability rate at a mean follow-up of 3 years. We report a single-surgeon series utilizing a standardized operative technique for all cases and had a retention rate of 75.0% at 5.3-year follow-up. Additionally, the majority of our patients who remained on active duty (71.4%) were able to continue their service without the need for a medical profile to limit physical activity.

Our study is not without limitations. This was a retrospective review, which carries the inherent biases associated with this level of evidence. While our study encompasses long-term follow-up for patients presenting early within the collection period, the wide range of follow-up precluded a standardized method for collection of telephone surveys. Although our review of anatomic risk factors failed to show differences in the measured variables, our interpretations are limited by the significant portion of patients who lacked mechanical axis films (52.1%) and MRI studies (11.8%) and the small number of failures with available imaging studies for comparative analysis. A recent comparative study[37] demonstrated significantly higher failure rates in patients who underwent MPFL repair and/or imbrication as compared with MPFL reconstruction (36.9% vs 6.3%). While we recognize that MPFL reconstruction is considered by many surgeons to be the mainstay of patellar stabilization, the purpose of our study was to independently report clinical results of a novel procedure incorporating a plication technique. Future prospective studies on addressing medial soft tissue constraints are needed to fully evaluate their comparative efficacy. Additionally, while the predictability of our results is aided by the nature of a single-surgeon series within a strict patient cohort, these same factors may limit the reproducibility of the data in more heterogeneous populations.

CONCLUSION

Patellar instability remains problematic for high-demand patients. Nearly half (49%) of all patients in our study reported a decrease in activity as compared with preoperative levels. Retention rate for active duty personnel was 75.0%, among which 28.6% required activity restrictions to complete their service requirements. However, patellar stabilization using our described, standardized technique yielded a low redislocation rate (7.8%) at 5.3-year mean follow-up, with 80.4% of patients citing minimal or no functional limitations. While no association between clinical failure and presence of anatomic risk factors was determined, interpretation was limited by sample size. Future studies are needed to determine the optimal management of this condition.

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