Decreased Effective Patellar Tendon Length following Distalization Tibial Tubercle Osteotomy without Patellar Tendon Tenodesis

Tyler J. Uppstrom,*† MD, Connor F. Fletcher,† BS, Daniel W. Green,‡ MD, MS, Andreas H. Gomoll,† MD, and Sabrina M. Strickland,† MD
Investigation performed at the Hospital for Special Surgery, New York, New York, USA

Background: Distalization tibial tubercle osteotomy (TTO) is an effective treatment for improving patellar height in patients with patella alta associated with patellofemoral instability and cartilage lesions. The addition of a patellar tendon tenodesis has been suggested; nonetheless, concerns exist regarding possible increased patellofemoral cartilage stresses.

Purpose: To evaluate pre- and postoperative patellar tendon length and alignment parameters on magnetic resonance imaging (MRI), as well as patient-reported outcome measures (PROMs) after distalization TTO without patellar tendon tenodesis.

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

Methods: Twenty skeletally mature patients who underwent distalization TTO with or without anteromedialization at our institution between December 2014 and August 2021 were included. All patients underwent pre- and postoperative MRIs of the affected knee. The Caton-Deschamps index (CDI), the axial and sagittal tibial tubercle–trochlear groove (TT-TG) distances, the distances from the tibial plateau to the patellar tendon insertion and the tibial tubercle, and the patellar tendon length were assessed. PROMs included the International Knee Documentation Committee Subjective Knee Evaluation Form, the Knee injury and Osteoarthritis Outcome Score–Quality of Life subscale, the Kujala Anterior Knee Pain Scale, and the Veterans RAND 12-Item Health Survey mental and physical component scores.

Results: The mean patient age at surgery was 27.4 years (range, 14-42 years). Radiographic parameters demonstrated improved patellar height (CDI decreased from 1.36 to 1.11; $P < .001$) after distalization TTO. The distance from the tibial plateau to the patellar tendon insertion significantly decreased from 20.1 mm preoperatively to 17.9 mm postoperatively ($P < .020$), and the patellar tendon length decreased from 53.4 mm preoperatively to 46.0 mm postoperatively ($P < .001$). The patellar tendon insertion was not distalized after distalization TTO, likely because of scarring of the patellar tendon proximal to the osteotomy site. Patients demonstrated significant pre- to postoperative improvements on all PROMs ($P \leq .024$ for all). There were 4 (20%) complications—2 cases of arthrofibrosis, 1 postoperative infection, and 1 osteotomy delayed union.

Conclusion: Distalization TTO without patellar tendon tenodesis was associated with improved radiographic outcomes and PROMs. It provides an additional tool for surgical management of patellofemoral pathology with associated patella alta.

Keywords: distalization; patella alta; patellofemoral instability; tibial tubercle osteotomy

Patella alta refers to an abnormally proximal location of the patella within the trochlear groove and is present in nearly 25% of patients with patellofemoral instability and/or patellofemoral cartilage lesions.[10,17,29] Several classification systems have been described to assess patellar height, including the Caton-Deschamps index (CDI), Insall-Salvati index, and Blackburne-Peel index.[2,6,7,11,24,38] As a result of the proximal location of the patella, patients with patella alta require greater knee flexion before the patella is captured within the bony constraints of the trochlear groove, thereby increasing the risk for patellofemoral instability and placing greater strain on soft tissue stabilizers.[11,13] In addition, variations in patellar height produce abnormal forces across the patellofemoral joint,

The Orthopaedic Journal of Sports Medicine, 12(2), 23259671241227201
DOI: 10.1177/23259671241227201

thereby increasing the risk of developing patellofemoral cartilage lesions and patellofemoral osteoarthritis.

As a result, addressing patellar height is widely accepted as an essential component of the effective treatment of patellofemoral instability and patellofemoral cartilage offloading in these patients. Numerous surgical interventions have been described to improve patellar height in patients with patella alta, including distalization tibial tubercle osteotomy (TTO), patellar tendon imbrication, or patellar tendon advancement.[4,12,21,27,33,37] Previous studies have demonstrated distalization TTO to be an effective method to decrease patellar height, although concerns regarding complication rates—including altered patellofemoral contact pressures, fracture risk, and nonunion/malunion—have limited its wider adoption.[§] Moreover, previous studies have proposed that increased patellar tendon length itself is an important risk factor for recurrent patellofemoral instability.[23] To address this issue, the addition of patellar tendon tenodesis via placement of a suture anchor proximal to the distalization TTO has been described and demonstrated to be effective in restoring patellofemoral joint stability and normalization of the patellar tendon length.[21,23,35] However, concerns exist regarding increased patellofemoral cartilage contact forces with the addition of a patellar tendon tenodesis.[40]

This study aimed to investigate radiographic and clinical outcomes after distalization TTO without patellar tendon tenodesis in patients with patella alta for the management of patellofemoral instability or patellofemoral cartilage lesions. We hypothesized that distalization TTO would not result in significant distalization of the patellar tendon insertion and would be associated with significant postoperative improvements in radiographic alignment parameters, functional outcome scores, and patient-reported outcome measures (PROMs).

METHODS

After receiving institutional review board approval for the study protocol, we conducted a retrospective review of all patients who underwent distalization TTO by 1 of 3 orthopaedic surgeons (S.M.S, A.H.G, D.W.G.) at a single tertiary-care center between December 2014 and August 2021. All patients provided informed consent. The inclusion criterion was as follows: skeletally mature patients with patella alta (CDI >1.2) associated with a diagnosis of patellofemoral instability and/or patellofemoral cartilage lesions who underwent distalization TTO with or without concurrent anteriorization and/or medialization. All included patients underwent 6 months of preoperative conservative treatment—including focused physical therapy, injections, bracing, etc—and all patients had available pre- and postoperative magnetic resonance imaging (MRI) of the operative knee. Concomitant surgical procedures—including medial patellofemoral ligament (MPFL) reconstruction, lateral release or lateral lengthening, and cartilage restoration procedures—were not exclusion criteria. Patients with a history of previous TTO of the ipsilateral extremity were excluded.

Surgical Procedure

A 6-cm incision over the proximal anterolateral tibia was utilized, extending distally from the proximal aspect of the tibial tubercle. A wedge-shaped osteotomy was performed to create a 5-cm osteotomy fragment. If anteriorization or medialization was also required based on preoperative imaging parameters—that is, axial and/or sagittal tibial tubercle–trochlear groove (TT-TG) distance >15 mm)—the angle of cut was adjusted accordingly to allow for appropriate translation. With the osteotomy mobilized, the shingle was then distalized and anteriorized/medialized if required at a predetermined distance based on preoperative imaging, with a goal CDI of <1.1. An allograft Evans Wedge (MTF Biologics) of the corresponding distalization length was placed proximal to the shingle to provide a buttress for the distalized shingle. Excess bone from the distal aspect of the shingle was removed and used as an autograft to fill the proximal defect. The tubercle was then secured with two 4.5-mm fully threaded cortical screws using the lag technique to achieve compression during osteotomy. Anterior-posterior and lateral fluoroscopy were used to confirm the appropriate length and position of the screws. The knee was then taken through its range of motion (ROM) to ensure that the patella was tracked centrally. If the patient presented with patellar instability or cartilage defect, additional procedures—including chondroplasty, lateral release,

[§]References 9, 16, 19, 21, 23, 29, 30, 34, 39

*Address correspondence to Tyler J. Uppstrom, MD, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA (emails: tyler.j.uppstrom@gmail.com; uppstromt@hss.edu).
[†]Sports Medicine Institute, Hospital for Special Surgery, New York, New York, USA.
[‡]Department of Pediatric Orthopaedics, Hospital for Special Surgery, New York, New York, USA.
Final revision submitted August 15, 2023; accepted August 21, 2023.
One or more of the authors has declared the following potential conflict of interest or source of funding: D.W.G. has received consulting fees from OrthoPediatrics; nonconsulting fees from Arthrex and Synthes; and royalties from Arthrex and Pega Medical. A.H.G. has received research support from JRF Ortho and Vericel; consulting fees from Bioventus, Vericel, Smith & Nephew, Flexion Therapeutics, JRF Ortho, Moximed, and Organogenesis; nonconsulting fees from Pacira Pharmaceuticals and Linvatec; royalties from Organogenesis; and honoraria from Vericel, Fidia Pharma, and JRF Ortho. S.M.S. has received research support from Vericel; consulting fees from Smith & Nephew, Vericel, and Flexion Therapeutics; nonconsulting fees from Smith & Nephew; royalties from Vericel; and honoraria from Vericel and JRF Ortho and has investment holdings in Engage and Stryker. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from the Hospital for Special Surgery (ref No. 2020-0264-AM3).

MPFL reconstruction, or cartilage restoration procedures (ie, matrix autologous chondrocyte implantation [MACI] and osteochondral allograft [OCA])—were then completed as indicated. Full-thickness cartilage defects with underlying subchondral bone involvement (ie, bony edema, subchondral sclerosis, or subchondral cysts) were treated with OCA. Partial-thickness cartilage defects or full-thickness cartilage defects without subchondral bone involvement were treated with MACI.

Postoperative Rehabilitation Protocol

Patients began using a hinged knee brace immediately after the procedure. For the first 6 weeks postoperatively, patients were toe-touch weightbearing on the operative extremity, with the hinged knee brace locked in full extension for ambulation. Patients were allowed to begin ROM exercises on the first postoperative day. ROM was restricted to within 0° to 90° for the first 2 weeks, followed by unrestricted ROM. Formal physical therapy was initiated 1 week postoperatively, emphasizing quadriceps strengthening, ROM, and gait training. At 6 weeks postoperatively, patients were encouraged to transition to full weightbearing, assuming recovery of adequate muscle control, and progressed to closed chain strengthening exercises at physical therapy. Patients were allowed to return to full activities at 4 to 6 months postoperatively unless concomitant cartilage procedures necessitated a slower rehabilitation progression. This decision was based on restoration of full motion, no swelling, and strength within 20% of the contralateral limb.

Descriptive, Perioperative, and Follow-up Data

Descriptive data—including age, sex, smoking status, and body mass index (BMI)—were obtained from the patients' medical records. Perioperative data included preoperative physical examination, previous procedures, tourniquet time, and concomitant procedures. Clinical follow-up data included a postoperative physical examination, subsequent surgery, and complications.

Radiographic Assessment

All patients had undergone preoperative MRI within 1 year of the index procedure. Postoperative MRI was performed at least 6 months after the index procedure. The pre- and postoperative MRI scans were independently reviewed by 2 fellowship-trained orthopaedic surgeons (S.M.S. and A.H.G.), and the following radiographic parameters were measured according to previously published literature: the CDI, axial TT-TG (aTT-TG) distance, and sagittal TT-TG (sTT-TG) distance.[‖] All knee MRI scans were obtained using a knee coil and with the knee in full extension.

[‖]References 2, 5, 8, 15, 18, 24, 28, 36, 38

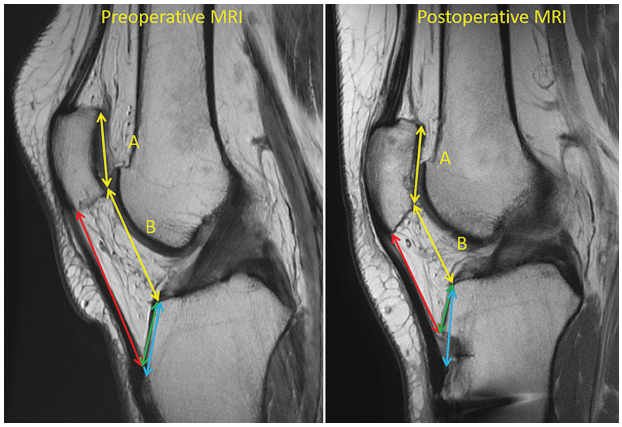

Figure 1. A schematic diagram demonstrating measurement of the CDI (yellow arrows; the ratio of A/B), the patellar tendon length (red arrows), the distance from the tibial plateau to the proximal patellar tendon insertion (green arrows), and the distance from the tibial plateau to the proximal aspect of the tibial tubercle (blue arrows) on pre- and postoperative MRI. CDI, Caton-Deschamps index; MRI, magnetic resonance imaging.

The CDI was measured on the sagittal MRI slice with the greatest length of the patella, through the central aspect of the patellar facets, in accordance with previous literature.[5,28] The distance from the tibial plateau to the tibial tubercle was measured on sagittal MRI pre- and postoperatively (blue arrows in Figure 1), with the difference reflecting the length of distalization. Last, the effective patellar tendon length—defined as the distance between the inferior patellar pole to either the tibial tubercle (preoperatively) or to the most proximal aspect of the tendon and connected to the tibia by fibrous tissue (postoperatively) (red arrows in Figure 1)—was measured on sagittal MRI.

Patient-Reported Outcome Measures

PROMs were administered preoperatively within 9 months of the index procedure and at each clinical follow-up postoperatively. The PROMs included in this study included the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, the Knee injury and Osteoarthritis Outcome Score–Quality of Life subscale (KOOS-QOL), the Kujala Anterior Knee Pain Scale, and the Veterans RAND 12-Item Health Survey mental (VR12-MH) and physical (VR12-PH) component scores.

Statistical Analysis

Means and standard deviations were reported for descriptive statistics for continuous variables. Paired t tests were utilized to compare pre- and postoperative PROM scores, and independent-samples t tests were used to compare pre- and postoperative radiographic parameters. The

TABLE 1
Preoperative and Postoperative Radiographic Parameters[a]

Parameter	Preoperative		Postoperative		
	Mean ± SD	ICC	Mean ± SD	ICC	*P*
CDI	1.36 ± 0.1	0.57	1.11 ± 0.1	0.58	**<.001**
aTT-TG distance, mm	14.3 ± 4.1	0.93	11.1 ± 4.1	0.97	**.018**
sTT-TG distance,[b] mm	–4.3 ± 3.9	0.96	–1.4 ± 4.3	0.98	**.037**
Plateau to TT distance, mm	20.1 ± 2.9	0.81	26.5 ± 3.7	0.77	**<.001**
Plateau to PT insertion, mm	20.1 ± 2.9	0.81	17.9 ± 2.9	0.84	**<.020**
PT length, mm	53.4 ± 5.3	0.88	46.0 ± 5	0.74	**<.001**

[a]Bold *P* values indicate statistically significant differences between pre- and postoperative values ($P < .05$). aTT-TG, axial tibial tubercle–trochlear groove; CDI, Caton-Deschamps index; ICC, intraclass correlation coefficient; PT, patellar tendon; sTT-TG, sagittal axial tibial tubercle–trochlear groove; TT, tibial tubercle.

[b]Measured as the anteroposterior position of the anterior most aspect of the tibial tubercle relative to the floor of the trochlear groove. Negative values indicate the tibial tubercle is located posterior to the trochlear groove, and positive values indicate the tibial tubercle is located anterior to the trochlear groove.

interrater reliability for pre- and postoperative radiographic parameters was evaluated using the intraclass correlation coefficient. Statistical significance was defined as $P < .05$ for all variables. Statistical analyses were conducted using SPSS statistical software Version 28.0.0 (IBM Corp).

RESULTS

A total of 20 patients were included in the study, with a mean clinical follow-up of 1.3 years. The mean age at the time of surgery was 27.4 years (range, 14-42 years), and all patients were women. The mean BMI was 24.9 ± 4.4 kg/m^2. Nine patients (45%) were diagnosed with isolated patellofemoral cartilage lesions, 7 patients (35%) were diagnosed with both instability and cartilage lesions, and 4 patients (20%) were diagnosed with patellofemoral instability without associated cartilage lesions. At the time of TTO distalization, 11 patients (55%) underwent MACI, 9 patients (45%) underwent MPFL reconstruction, 4 patients (20%) underwent lateral release/lengthening, and 3 patients (15%) underwent OCA implantation. Fourteen patients (70%) underwent anteromedialization of the tibial tubercle in addition to distalization. The mean planned distalization of the tibial tubercle was 8.6 ± 1.2 mm. Ten patients (50%) underwent elective removal of hardware of TTO screws at a mean of 10.7 months. There were no cases of recurrent instability in this cohort.

Pre- and postoperative radiographic parameters are shown in Table 1. Preoperative MRI was performed at a mean of 6 months before surgery, and postoperative MRI was performed at a mean of 9.6 months after surgery. Radiographic parameters demonstrated improved patellar height (mean CDI decreased from 1.36 to 1.11 [$P < .001$]), improved patellofemoral alignment (mean aTT-TG decreased from 14.3 to 11.1 mm [$P = .018$]), and anteriorization of the tibial tubercle (mean sTT-TG increased from −4.3 to −1.4 mm [$P = .037$]) after TTO. The mean distance from the tibial plateau to the patellar tendon insertion decreased from 20.1 mm preoperatively to 17.9 mm postoperatively ($P < .020$), and the mean effective patellar tendon length decreased from 53.4 mm preoperatively to 46.0 mm postoperative ($P < .001$). The mean distalization was 6.4 mm. No patients met the criteria for patella baja (CDI <0.9) postoperatively.

TABLE 2
Preoperative and Postoperative PROMs[a]

PROM	Preoperative	Postoperative	*P*
IKDC	37.1 ± 14.3	60.5 ± 21.7	**.011**
KOOS-QOL	19.5 ± 17.7	42.1 ± 24.4	**<.001**
Kujala	50.9 ± 19.3	70.6 ± 21.1	**.018**
VR12-MH	52.7 ± 11.6	59.2 ± 8.1	**.024**
VR12-PH	35.1 ± 8	41.7 ± 10.5	**.009**

[a]Data are reported as mean ± SD. Bold *P* values indicate statistically significant differences between pre- and postoperative values ($P < .05$). IKDC, International Knee Documentation Committee; KOOS-QOL, Knee injury and Osteoarthritis Outcome Score-Quality of Life; PROM, patient-reported outcome measure; VR12-MH, Veterans RAND 12-Item Health Survey mental component score; VR12-PH, Veterans RAND 12-Item Health Survey physical component score.

Pre- and postoperative PROMs are shown in Table 2. Preoperative PROMs were administered at a mean of 3.5 months before surgery and postoperative PROMs were administered at a mean of 18 months postoperatively. Sixteen of 20 patients (80%) completed postoperative PROMs. IKDC scores increased from 37.1 to 60.5 ($P = .011$), KOOS-QOL scores increased from 19.5 to 42.1 ($P < .001$), Kujala scores increased from 50.9 to 70.6 ($P = .018$), VR12-MH scores increased from 52.7 to 59.2 ($P = .024$), and VR12-PH scores increased from 35.1 to 41.7 ($P = .009$). No cases of postoperative recurrent instability were observed in patients with preoperative patellofemoral instability.

There were 4 (20%) complications in this cohort. Two patients (10%) developed postoperative arthrofibrosis requiring arthroscopic lysis of adhesions (LOA) and

manipulation under anesthesia (MUA), with 1 patient undergoing MPFL reconstruction with a hamstring allograft and MACI at the index procedure and undergoing LOA with MUA at 2 months postoperatively and 1 patient undergoing MPFL reconstruction with a hamstring allograft and requiring LOA and MUA at 4 months postoperatively. Both patients obtained full ROM at the most recent clinical follow-up. One patient (5%) developed postoperative MPFL graft methicillin-resistant *Staphylococcus aureus* (MRSA) infection at the patellar attachment, which did not involve the TTO surgical site and was treated with irrigation and debridement with removal of the MPFL graft. Finally, 1 patient (5%) developed a delayed union at the distal aspect of the osteotomy at 4 months postoperatively. The patient underwent an exchange of the distal screw and the delayed union site was augmented with bone marrow aspirate concentration and iliac crest bone graft. The patient demonstrated complete healing at 9 months after this procedure and underwent removal of hardware at that time.

DISCUSSION

Our results suggest that distalization TTO is an effective technique for improving patellar height in patients with patella alta associated with patellofemoral instability and/or patellofemoral cartilage lesions, with significant pre- to postoperative improvements in the CDI. However, the position of the proximal insertion of the patellar tendon was not significantly distalized after distalization TTO because of scarring of the patellar tendon to the tibia proximal to the osteotomy site. Additional findings included statistically significant improvements in all radiographic patellofemoral alignment parameters, including axial (ie, aTT-TG distance) and sagittal (ie, sTT-TG distance) parameters related to concomitant anteriorization and medialization of the TTO. Our results also demonstrated significant pre- to postoperative improvements on the IKDC, KOOS-QOL, Kujala, VR12-MH, and VR12-PH ($P \leq .024$ for all). There were 4 (20%) complications in this cohort—2 cases of arthrofibrosis (10%), 1 case of infection (5%), and 1 case of tibial tubercle delayed union (5%).

Neyret et al[25] reported an association between patellar tendon length and patellar instability, demonstrating that patients with patellar instability were more likely to demonstrate longer patellar tendon lengths, as measured on lateral radiographs and MRI, than normal controls. The authors suggested that patella alta was associated with a long patellar tendon rather than an abnormally proximal tibial insertion of the patellar tendon, as the elongated patellar tendon may allow greater coronal plane movement of the patella.[14] As a result, patellar tendon tenodesis to the proximal tibia in conjunction with distalization TTO has been suggested as a preferred treatment in these patients, thereby effectively shortening the patellar tendon.[14,35] Mayer et al[23] demonstrated improved mean patellar tendon length and CDI on lateral knee radiographs after distalization TTO and patellar tendon tenodesis via a suture anchor proximal to the osteotomy site, with no recurrent instability episodes and good functional scores postoperatively. Our present study utilized pre- and postoperative MRI in all patients for radiographic measurements, including measurements of the patellar tendon length and insertion position. Based on our results, the patellar tendon insertion does not appear to be significantly distalized after distalization TTO, likely because of an "autotenodesis" effect via scarring of the tendon to the bony bed vacated by the distalized TTO fragment. Similar to the previously described patellar tendon tenodesis via suture anchor, this also effectively creates a shortened patellar tendon, which may contribute to improved patellofemoral stability.

Several studies have demonstrated improved radiographic and patient-reported outcomes after distalization TTO without patellar tendon tenodesis. A recent study by Leite et al[19] evaluated radiographic and clinical parameters after distalization TTO in 31 knees with patellofemoral instability, demonstrating statistically significant improvements in Kujala (from 52 to 77) and Tegner (from 3 to 4) scores at a mean follow-up of 2.6 years. These results were consistent with previous studies demonstrating improvements in PROMs after distalization TTO.[3,22,23,26] Furthermore, a recent systematic review and meta-analysis by Knapik et al[17] reported on 8 studies with clinical, radiographic, and patient-reported outcomes after TTO for patella alta treatment. The authors demonstrated statistically significant improvements in the Insall-Salvati index (from 1.40 to 0.98), CDI (from 1.26 to 0.97), and TT-TG distance (from 18.3 mm to 10.7 mm). Our results corroborate these previous reports, with significant improvements in postoperative sagittal and rotational parameters postoperatively without the use of patellar tendon tenodesis. Our study also demonstrated significant postoperative improvements on all included PROMs, with no episodes of recurrent patellar instability, providing further evidence that distalization TTO is associated with significant improvements in clinical and patient-reported outcomes across a large number of domains.[3,17,19,22,23,26]

Although previous studies have demonstrated distalization TTO to be an effective method to decrease patellar height, controversy exists regarding the rate of complications. Rates of bony complications—including tibial shaft and tibial tubercle fractures, nonunion, malunion, and delayed union—have been reported[20,29,31] at 1% to 11%. Rood et al[31] reported on the largest cohort of patients undergoing distalization TTO, demonstrating a major bony complication risk of 4.9%, with a 0.75% risk of fracture and a 1.9% risk of nonunion or delayed union. In the present study, our preferred technique for distalization involves the creation of a V-shaped tibial tubercle shingle without a step cut, with proximal allograft bone block and repair of the distal periosteal sleeve. We prefer this technique, as it limits vascular disruption distally and may avoid the increased fracture risk previously reported with step cut osteotomies.[20,31] In the present study, 1 patient (5%) demonstrated delayed union postoperatively, which was successfully treated with bone grafting and revision open reduction and internal fixation. Importantly, there were no cases of tibial fracture in our cohort.

Reoperation rates after distalization TTO have been reported to be between 8% and 44%, with the vast majority of reoperations for symptomatic hardware.[17,22,31] In our study, 10 patients (50%) underwent hardware removal. Two patients (10%) underwent MUA and LOA for arthrofibrosis, all associated with an intra-articular procedure (MACI); 1 patient (5%) underwent irrigation and debridement for localized MRSA infection; and 1 patient (5%) underwent bone grafting for tibial tubercle delayed union. Few studies have reported a rate of postoperative arthrofibrosis after distalization TTO. Schmiesing et al[32] reported on 68 patients who underwent distalization TTO with combined MPFL reconstruction and demonstrated a rate of arthrofibrosis of 8.8%. Similarly, Ahmad et al[1] reported stiffness in 12.5% of patients after distalization TTO. In our study, the rate of arthrofibrosis requiring MUA and LOA (10%) was consistent with that in the published literature.

Limitations

This study has several limitations. First, the small sample size in this case series may preclude achieving statistical significance. Moreover, these procedures were performed by 3 orthopaedic surgeons who specialized in the treatment of patellofemoral disorders at a tertiary care center via a single distalization TTO technique, which may limit the generalizability of the study results. Third, all patients in this cohort were women, which limits the generalizability of the results to male patients; however, the high proportion of female patients is common in previously published reports on distalization TTO and likely reflects the higher prevalence of patellofemoral instability and/or cartilage lesions in this population. In addition, there was heterogeneity in the clinical presentations of the patients included in this cohort, including patients with patellofemoral instability with or without cartilage defects and isolated cartilage defects without patellofemoral instability, which may limit the generalizability of the study findings. Similarly, a high proportion of patients underwent concomitant surgical procedures at the time of distalization TTO, and the improvement in postoperative PROMs seen in this cohort may also be attributed to these concomitant procedures. Finally, complication data are limited to follow-ups at our institution, preventing data collection on those patients treated at outside facilities for their complications. However, given the high volume of patellofemoral procedures performed at our institution and the common practice for complications to be treated by the index surgeon, there is a low likelihood that a significant number of complications were treated at outside facilities.

CONCLUSION

Distalization TTO without patellar tendon tenodesis is an effective surgical technique for improving patellar height in patients with patella alta and patellofemoral instability and/or patellofemoral cartilage lesions, with improvements in radiographic parameters and PROMs postoperatively. There were no cases of recurrent instability in this cohort. The patellar tendon insertion does not appear to be significantly distalized after distalization TTO, which may be related to scarring of the patellar tendon just proximal to the osteotomy site postoperatively. Given the complexity of risk factors associated with patellofemoral instability and patellofemoral cartilage lesions, distalization TTO provides an additional tool for patient-specific surgical management, with no need for patellar tendon tenodesis.

Author's Note

Presented at the AOSSM 2023 Annual Meeting, Washington, DC, July 13-16, 2023.

REFERENCES

1. Ahmad R, Calciu M, Jayasekera N, Schranz P, Mandalia V. Combined medial patellofemoral ligament reconstruction and tibial tubercle transfer results at a follow-up of 2 years. *J Knee Surg*. 2017;30(1):42-46.
2. Ali SA, Helmer R, Terk MR. Patella alta: lack of correlation between patellotrochlear cartilage congruence and commonly used patellar height ratios. *AJR Am J Roentgenol*. 2009;193(5):1361-1366.
3. Allen MM, Krych AJ, Johnson NR, et al. Combined tibial tubercle osteotomy and medial patellofemoral ligament reconstruction for recurrent lateral patellar instability in patients with multiple anatomic risk factors. *Arthroscopy*. 2018;34(8):2420-2426.e2423.
4. Ambra LF, Phan A, Gomoll AH. A new technique for distalization of the tibial tubercle that allows preservation of the proximal buttress. *Orthop J Sports Med*. 2018;6(9):2325967118798621.
5. Askenberger M, Bengtsson Mostrom E, Ekstrom W, et al. Operative repair of medial patellofemoral ligament injury versus knee brace in children with an acute first-time traumatic patellar dislocation: a randomized controlled trial. *Am J Sports Med*. 2018;46(10):2328-2340.
6. Biedert RM. Patella alta: when to correct and impact on other anatomic risk factors for patellofemoral instability. *Clin Sports Med*. 2022;41(1):65-76.
7. Blackburne JS, Peel TE. A new method of measuring patellar height. *J Bone Joint Surg Br*. 1977;59(2):241-242.
8. Caton J, Deschamps G, Chambat P, Lerat JL, Dejour H. Patella infera. Apropos of 128 cases [Article in French]. *Rev Chir Orthop Reparatrice Appar Mot*. 1982;68(5):317-325.
9. Caton J, Mironneau A, Walch G, Levigne C, Michel CR. Idiopathic high patella in adolescents. Apropos of 61 surgical cases [Article in French]. *Rev Chir Orthop Reparatrice Appar Mot*. 1990;76(4):253-260.
10. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: an anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc*. 1994;2(1):19-26.
11. Elias JJ, Soehnlen NT, Guseila LM, Cosgarea AJ. Dynamic tracking influenced by anatomy in patellar instability. *Knee*. 2016;23(3):450-455.
12. Enea D, Canè PP, Fravisini M, Gigante A, Dei Giudici L. Distalization and medialization of tibial tuberosity for the treatment of potential patellar instability with patella alta. *Joints*. 2018;6(2):80-84.
13. Fabricant PD, Ladenhauf HN, Salvati EA, Green DW. Medial patellofemoral ligament (MPFL) reconstruction improves radiographic measures of patella alta in children. *Knee*. 2014;21(6):1180-1184.
14. Fiquet C, White N, Gaillard R, et al. Partial extensor mechanism allograft reconstruction for chronic patellar tendon disruption shows superior outcomes in native knees when compared to same technique following total arthroplasty. *Int Orthop*. 2018;42(11):2591-2599.

15. Insall J, Salvati E. Patella position in the normal knee joint. *Radiology*. 1971;101(1):101-104.
16. Johnson AA, Wolfe EL, Mintz DN, et al. Complications after tibial tuberosity osteotomy: association with screw size and concomitant distalization. *Orthop J Sports Med*. 2018;6(10):2325967118803614.
17. Knapik DM, Kunze KN, Azua E, et al. Radiographic and clinical outcomes after tibial tubercle osteotomy for the treatment of patella alta: a systematic review and meta-analysis. *Am J Sports Med*. 2022;50(7):2042-2051.
18. Lansdown DA, Christian D, Madden B, et al. The sagittal tibial tubercle-trochlear groove distance as a measurement of sagittal imbalance in patients with symptomatic patellofemoral chondral lesions. *Cartilage*. 2021;13(suppl 1):S449-S455.
19. Leite CBG, Santos TP, Giglio PN, et al. Tibial tubercle osteotomy with distalization is a safe and effective procedure for patients with patella alta and patellar instability. *Orthop J Sports Med*. 2021;9(1):2325967120975101.
20. Luhmann SJ, Fuhrhop S, O'Donnell JC, Gordon JE. Tibial fractures after tibial tubercle osteotomies for patellar instability: a comparison of three osteotomy configurations. *J Child Orthop*. 2011;5(1):19-26.
21. Magnussen RA, De Simone V, Lustig S, Neyret P, Flanigan DC. Treatment of patella alta in patients with episodic patellar dislocation: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(10):2545-2550.
22. Marteau E, Burdin P, Brilhault JM. Gracilis tendon transfer associated with distal alignment for patella alta with recurrent dislocations: an original surgical technique. *Orthop Traumatol Surg Res*. 2011;97(suppl 4):S5-S11.
23. Mayer C, Magnussen RA, Servien E, et al. Patellar tendon tenodesis in association with tibial tubercle distalization for the treatment of episodic patellar dislocation with patella alta. *Am J Sports Med*. 2012;40(2):346-351.
24. Munch JL, Sullivan JP, Nguyen JT, et al. Patellar articular overlap on MRI is a simple alternative to conventional measurements of patellar height. *Orthop J Sports Med*. 2016;4(7):2325967116656328.
25. Neyret P, Robinson AH, Le Coultre B, Lapra C, Chambat P. Patellar tendon length—the factor in patellar instability? *Knee*. 2002;9(1):3-6.
26. Otsuki S, Nakajima M, Fujiwara K, et al. Influence of age on clinical outcomes of three-dimensional transfer of the tibial tuberosity for patellar instability with patella alta. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(8):2392-2396.
27. Patel RM, Gombosh M, Polster J, Andrish J. Patellar tendon imbrication is a safe and efficacious technique to shorten the patellar tendon in patients with patella alta. *Orthop J Sports Med*. 2020;8(10):2325967120959318.
28. Paul RW, Brutico JM, Wright ML, et al. Strong agreement between magnetic resonance imaging and radiographs for Caton-Deschamps index in patients with patellofemoral instability. *Arthrosc Sports Med Rehabil*. 2021;3(6):e1621-e1628.
29. Payne J, Rimmke N, Schmitt LC, Flanigan DC, Magnussen RA. The incidence of complications of tibial tubercle osteotomy: a systematic review. *Arthroscopy*. 2015;31(9):1819-1825.
30. Pritsch T, Haim A, Arbel R, et al. Tailored tibial tubercle transfer for patellofemoral malalignment: analysis of clinical outcomes. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(8):994-1002.
31. Rood A, van Sambeeck J, Koëter S, van Kampen A, van de Groes SAW. A detaching, V-shaped tibial tubercle osteotomy is a safe procedure with a low complication rate. *Arch Orthop Trauma Surg*. 2020;140(12):1867-1872.
32. Schmiesing A, Engelking M, Agel J, Arendt EA. Distalization of the tibial tubercle for patellar stabilization combined with medial patellofemoral ligament reconstruction: length of distalization or residual patella alta and its affect on outcome. *Am J Sports Med*. 2022;50(6):1627-1634.
33. Shih SSW, Kuo CL, Lee DYH. MPFL reconstruction corrects patella alta: a cohort study. *Eur J Orthop Surg Traumatol*. 2022;32(5):883-889.
34. Simmons E, Cameron JC. Patella alta and recurrent dislocation of the patella. *Clin Orthop Relat Res*. 1992;(274):265-269.
35. Tad L SE, Ait Si Selmi T, Neyret P. La ''tenodese'' du tendon rotulien. In: Chambat P NP, Bonnin M, ed. *Le Genou du Sportif*. ALRM; 2002:49-53.
36. Tanaka MJ, D'Amore T, Elias JJ, et al. Anteroposterior distance between the tibial tuberosity and trochlear groove in patients with patellar instability. *Knee*. 2019;26(6):1278-1285.
37. Temperato J, Nuelle CW. Tibial tubercle osteotomy with anteriorization and distalization for treatment of patellar instability with patella alta. *Arthrosc Tech*. 2022;11(6):e1045-e1051.
38. Verhulst FV, van Sambeeck JDP, Olthuis GS, van der Ree J, Koëter S. Patellar height measurements: Insall-Salvati ratio is most reliable method. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(3):869-875.
39. Yang JS, Fulkerson JP, Obopilwe E, et al. Patellofemoral contact pressures after patellar distalization: a biomechanical study. *Arthroscopy*. 2017;33(11):2038-2044.
40. Yin L, Liao TC, Yang L, Powers CM. Does patella tendon tenodesis improve tibial tubercle distalization in treating patella alta? A computational study. *Clin Orthop Relat Res*. 2016;474(11):2451-2461.