

A Systematic Review of 21 Tibial Tubercle Osteotomy Studies and More Than 1000 Knees: Indications, Clinical Outcomes, Complications, and Reoperations

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Abstract

Following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, we searched the literature for tibial tubercle osteotomy (TTO) studies and systematically reviewed them for indications, clinical outcomes, complications, and reoperations. Therapeutic clinical studies that reported TTO indications, operative findings, and outcomes were included. Quality of each study was assessed with the modified Coleman methodology score (MCMS). Twenty-one studies (976 patients, 1055 knees) were included in the analysis.

Better quality studies had a mean (SD) MCMS of 19.8 (8.2), well under the 55-point cutoff. TTO was most commonly performed for isolated patellar instability in the presence of knee pain. The other pathologies addressed were patellofemoral osteoarthritis, patella alta, and patella baja with or without knee pain. TTO significantly improved knee pain and clinical outcome scores, though 21% of patients (>1 in 5) required reoperation for hardware removal. Young women with prior surgery on the affected knee were the primary patient population.

Take-Home Points

- TTO specifics depend on anatomy, radiographic alignment characteristics, and presence of chondral defects.
- Osteotomy and movement of the tibial tubercle can include anteriorization, anteromedialization, proximalization, medialization, or distalization.
- TTO was most commonly performed for isolated patellar instability in the presence of knee pain.
- Young women with prior surgery on the affected knee made up the primary patient population for this procedure.
- While TTO significantly improves knee pain and clinical outcome scores, >1 in 5 patients required reoperation for hardware removal.

Patellofemoral pain and patellofemoral instability are common orthopedic problems.

Studies have found that 30% of patients 13 to 19 years old have patellofemoral pain and that 29 in 100,000 patients 10 to 17 years old have patellofemoral instability.¹⁻³ The reported rate of recurrence after nonoperative management of patellofemoral instability is 33%.⁴ Tibial tubercle osteotomy (TTO), first described by Hauser⁵ in 1938, is an effective treatment option for many patellofemoral disorders.

TTO indications include patellofemoral maltracking or malalignment, patellar instability, patellofemoral arthritis, and focal patellofemoral chondral defects.⁶ With TTO, the goal is to move the tibial tubercle in a direction that will either improve patellar tracking or offload the medial or lateral patellar facet to improve pain and function.^{7,8} This

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action typically involves anterior, medial, lateral, or distal translation of the tibial tubercle, as posteriorization can lead to increased contact forces across the patellofemoral joint, resulting in accelerated patellofemoral wear and increased pain.⁹

We systematically reviewed the TTO literature to identify indications, clinical outcomes, complications, and reoperations. We hypothesized that the overall complication rate and the overall reoperation rate would both be <10%.

Clinical Evaluation of Patellofemoral Pathology

Patients with patellofemoral pain often report anterior knee pain, which typically begins gradually and is often activity related. Several symptoms may be present: pain with prolonged sitting with knees bent; pain on rising from a seated position; pain or crepitus with climbing stairs; and pain during repetitive activity such as running, squatting, or jumping. Location, duration, and onset of symptoms should be elicited. Patellofemoral instability can be described as dislocation events or subluxation events; number of events, mechanisms of injury, and resulting need for reduction should be documented. As age, sex, body mass index, and physical fitness are relevant to risk of recurrence, the physician should ask about general ligamentous laxity, other joint dislocations, and prior surgical intervention. Swelling or mechanical symptoms may indicate patellofemoral joint pathology.^{6,10}

Physical examination of patients with patellofemoral pathology begins with assessment for overall limb alignment (including resting position of patella and corresponding quadriceps angle [Q-angle]), generalized ligamentous laxity (including hypermobile joints, evaluated with Brighton criteria), overall peri-knee muscle tone and strength, effusion, and gait pattern. Knee and hip range of motion should be documented. Apprehension (**Figure 1**) and lack of a firm endpoint on placement of a lateralizing moment on the patella suggest prior dislocation or subluxation. Patella and surrounding anatomy must be palpated for location and severity of tenderness. Finally, patellar tilt, height, mobility, and dynamic tracking, including J-sign, are pertinent to evaluation. The J-sign for patellar tracking is positive when the patella deviates laterally as the knee moves from flexion into extension. Examination of the asymptomatic contralateral side is essential for comparison. Plain radiographs are important first-line imaging. Computed tomography or magnetic resonance imaging can be used to measure tibial



Figure 1. Apprehension testing maneuver for physical examination of patellofemoral instability.

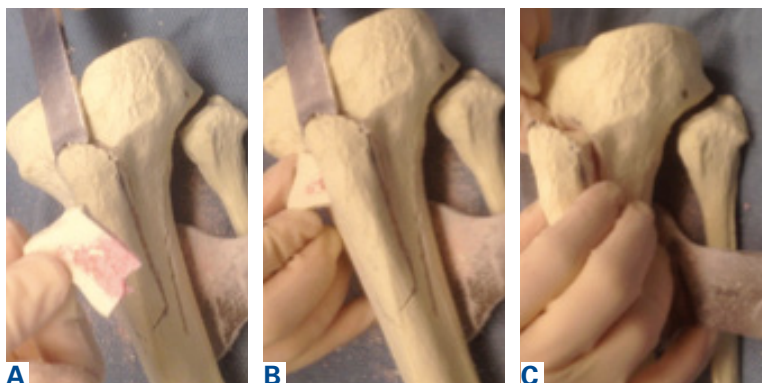


Figure 2. Model demonstration of tibial tubercle osteotomy (TTO) with anteriorization. (A) Osteotomy of the tibial tubercle. (B) Placement of bone posterior to the osteotomy in order to anteriorize the tubercle. (C) Completion of TTO with anteriorization.

tubercle-trochlear groove (TT-TG) distance. TT-TG distance of >15 mm is abnormal, and >20 mm indicates TTO is required. Advanced imaging is additionally valuable in assessing for chondral injury or trochlear dysplasia.^{6,10}

Common TTO Procedures

TTO specifics depend on anatomy, radiographic alignment characteristics, and presence of chondral defects. Essentially, the patella is translated to offload the affected areas. Osteotomy and movement of the tibial tubercle can include anteriorization, anteromedialization, proximalization, medialization, or distalization. Lateralization or anterolateralization may be pertinent to revision if an osteotomy direction results in overcorrection of tuberosity position. Anteriorization (**Figures 2A-2C**) does not have a role

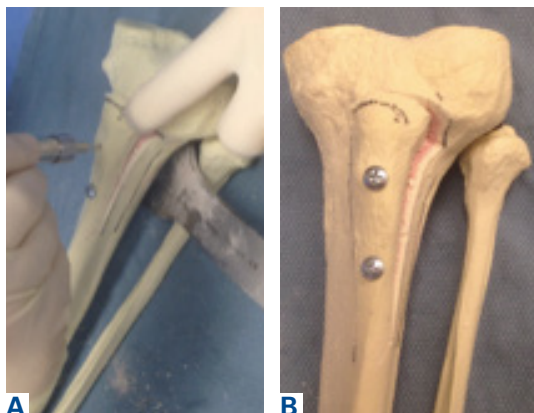


Figure 3. Model demonstration of tibial tubercle osteotomy (TTO) with medialization. (A) Placement of the screw through osteotomized tubercle. (B) Completed TTO with medialization.

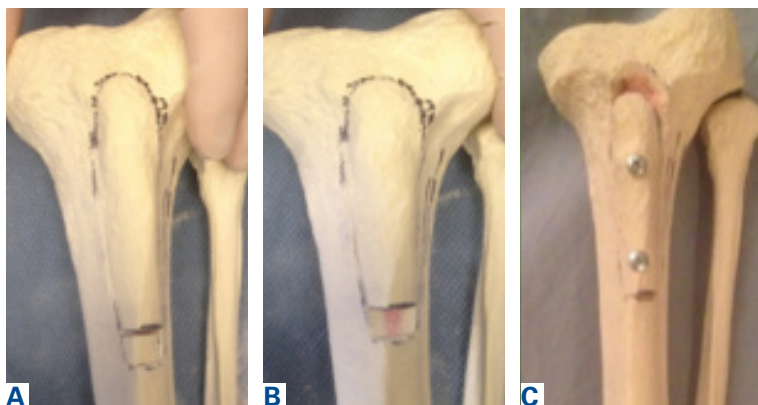


Figure 4. Model demonstration of tibial tubercle osteotomy (TTO) with distalization. (A, B) Osteotomy with marked out distalization. (C) Completion of TTO with distalization.



Figure 5. Model demonstration of tibial tubercle osteotomy with anteromedialization.

in patellofemoral instability, but can unload areas of excessive patellar chondral force concentration at the central or proximal patella by increasing the angle between the patellar and quadriceps tendons and thereby decreasing the joint reaction forces. Straight medialization (**Figures 3A, 3B**) offloads lateral patellar chondral injury and may decrease lateral instability. Distalization (**Figures 4A-4C**) can correct for patella alta in the setting of patellar instability and allows earlier engagement of the patella in the trochlea to increase osseous restraint to lateral translation.⁶

Anteromedialization (**Figure 5**) is indicated in patients with a normal proximal and medial patellar chondral surface and a laterally positioned

patella leading to alteration of the contact area in the trochlear groove and resulting pain, lateral patellar or trochlear chondral disease, or instability. Osteotomy angle can provide varied medialization through consistent slope and anteriorization. For example, a 60° slope osteotomy provides 9 mm of medialization with 15 mm of anteriorization.⁶ The procedure, similar to the additional TTO operations, begins with a lateral parapatellar incision that is extended distal to the tibial tubercle and anterior over the crest. The soft tissues around the tubercle are released to allow mobilization. Variable osteotomy jigs allow for different slope cuts for more medialization or anteriorization, based on preoperative findings. The osteotomy cuts are started with a thin oscillating blade (**Figure 6**) and finished with an osteotome. The tubercle fragment (**Figure 7**) is shifted and provisionally fixed with a Kirschner wire before being drilled and fixated with two 4.5-mm countersunk cortical screws (**Figures 8, 9A-9B**). Locally harvested corticocancellous bone can help anteriorize the tubercle block. Osteotomy specifics allow for corresponding anatomical translations of the TTO to address the preoperative pathology.

Methods

Search Strategy and Data Collection

We searched the PubMed (Medline) database for all English-language TTO studies published between database inception and April 9, 2015. After PROSPERO registration, and following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, we used the algorithm (“tibial” AND “tubercle” AND “osteotomy”) NOT (“total” AND “knee” AND “arthroplasty”) to search the literature. Inclusion criteria included level I-IV studies on TTO indications, operative findings, and outcomes. Exclusion criteria were non-English studies, unpublished studies, level V evidence, letters to the editor, editorials, review articles, basic science articles, technique articles, revision procedures, articles without clinical outcomes, and conference proceeding abstracts. Studies that reported on duplicate populations were included only with the most recent available clinical outcomes. All abstracts were reviewed in duplicate by Dr. Levy and Dr. Rao and assessed with respect to the criteria outlined. Then the same authors performed full-text reviews of eligible studies before including these studies in the systematic review. They also manually checked the references in study articles to identify additional studies for possible inclusion in the review. A stan-

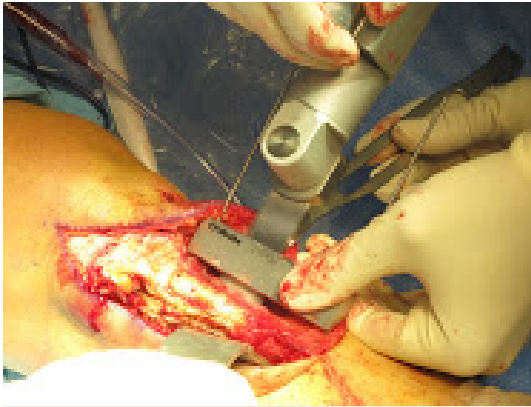


Figure 6. Thin oscillating blade being used to make osteotomy cut for tibial tubercle osteotomy within appropriately placed cutting jig.

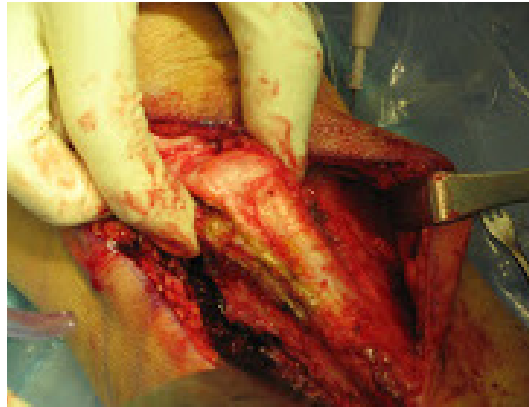


Figure 7. Osteotomized tibial tubercle bone block being translated in the appropriate direction to address patellofemoral pathology being corrected.

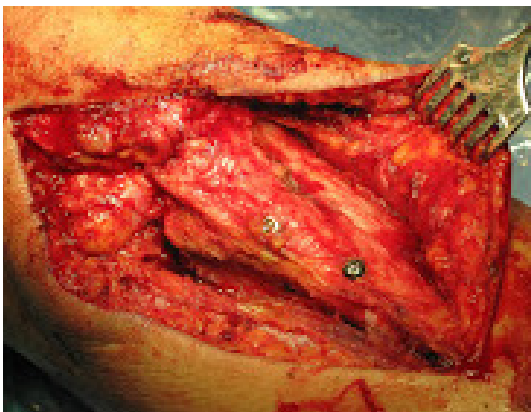


Figure 8. Tibial tubercle bone block being drilled and fixated in translated position with two 4.5-mm countersunk cortical screws.

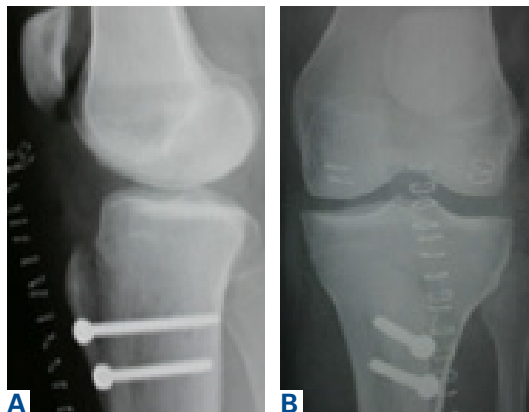


Figure 9. Postoperative (A) lateral and (B) anteroposterior plain radiographs show changes made with tibial tubercle osteotomy with anteromedialization.

standardized form created by the authors at the start of the review was used to extract data (**Table 1**).

Assessment of Study Quality

The quality of each TTO study in the review was assessed with a modified Coleman methodology score (MCMS), which ranges from 0 to 100. A study with an MCMS of <55 points is considered a poor-quality study.¹¹

Data Synthesis and Statistical Analysis

Given that most of the included studies were level IV, a formal meta-analysis was not indicated. In this article, we report categorical data as frequencies with percentages and preoperative and postoperative continuous data as means (SDs), with weighted means based on number of patients in each study, where applicable. We used 2-tailed *t* tests for comparisons made with the free Meta-Analysis Calculator and Grapher (<http://www.healthstrategy.com/meta/meta.pl>).

Statistical significance was set at $P < .05$.

Results

Search Results and Included Studies

Twenty-one studies (976 patients, 1055 knees) were included in the analysis (**Figure 10; Table 2**).¹²⁻³² These studies were published between 1986 and 2013. There were 18 level IV studies (85.7%), 3 level III studies (14%), and no level I or II studies. Better quality studies had a mean (SD) MCMS of 19.8 (8.2), well under the 55-point cutoff. In the 16 studies that reported sex, women accounted for 69% of the population. Weighted mean (SD) age was 27.68 (10.45) years (range, 12-77 years) (18 studies reporting). Only 1 study provided preoperative body mass index (27 kg/m²). There were 55.35% of patients who had prior surgery on the affected knee (6 studies reporting).

Table 1. Data Extracted From Studies Included in Analysis

Study-Specific Variables	Patient-Specific Demographic Variables	Patient-Specific Preoperative Radiographic Variables	Surgical Intervention Specifics	Patient-Specific Postoperative Data
Authors	Number of patients	Insall-Salvati ratio	Osteotomy directions: anteromedialization, anteriorization, medialization, distalization, proximalization "triple", lateral trochlear elevation	Knee range of motion
Publication year	Number of knees	Caton-Deschamps index	Concomitant procedures: femoral trochleoplasty, allograft, patellar chondroplasty, loose body removal, proximal release	Recurrent patellar instability
Journal	Sex	Blackburne-Peel ratio		Recurrent patellar dislocation
Publication date	Age	Outerbridge osteoarthritis grade		Recurrent patellar subluxation
Study design	Body mass index	Tibial tubercle-trochlear groove distance		Quadriceps angle
Level of evidence	Patellofemoral arthritis			Insall-Salvati ratio
Conflict of interest	Patellar dislocation			Caton-Deschamps index
Single or multiple centers	Patellofemoral pain			Blackburne-Peel ratio
Enrollment dates	Patellar subluxation			Patellar tilt
Inclusion criteria	Prior knee surgery (lateral release)			Visual analog scale score
Exclusion criteria	Quadriceps angle			Lysholm score
Modified Colman methodology score	Visual analog scale score			Kujala score
Follow-up (clinical, radiographic, complications) period	Lysholm score			Shelbourne-Trumper score
	Kujala score			Cox-Insall score
	Shelbourne-Trumper score			Overall clinical outcome rating
	Cox-Insall score			Patient satisfaction
				Complications: total, wound complication, tibial tubercle fracture, proximal tibia fracture, hardware removal, anterior knee pain, neuropraxia, infection
				Requirement for additional surgery or reoperation: revision tibial tubercle osteotomy, high tibial osteotomy, patellofemoral arthroplasty, total knee arthroplasty

Preoperative Data

Preoperative pathologic, radiographic, and clinical scoring data were scarcely reported and nonuniform (Table 2). The most common pathology treated with TTO was isolated patellofemoral instability (746/1055 patients, 70.7%). The other pathologies addressed were isolated patellofemoral osteoarthritis/chondromalacia patellae (143, 13.6%), patellofemoral instability with patella alta (61, 5.8%), patellofemoral instability with patellofemoral osteoarthritis (45, 4.3%), isolated patella baja (41, 3.9%), isolated patella alta (19, 1.8%), and patellofemoral osteoarthritis with patella baja (2, 0.2%). Five hundred fifty-five patients (53%) had a preoperative complaint that included knee pain, and 809 (77%) reported preoperative patellar laxity or instability events. The imaging data reported were Q-angle, Insall-Salvati ratio, Caton-Deschamps index, Blackburne-Peel ratio, Outerbridge osteoarthritis grade, and TT-TG distance. Preoperative clinical scoring data most prominently included a visual analog scale (VAS) score of 70.50 (4 studies reporting), a Lysholm score of 59.19 (5 studies), and a Kujala score of 41.16 (4 studies). Shelbourne-Trumper and Cox-Insall scores were reported in 1 and 2 studies, respectively.

Operative Characteristics

Of the 21 studies, 12 reported only on patients who had TTO performed in isolation; in the other 9 studies, cohorts included patients who underwent concurrent procedures. In the 17 studies (856 patients) that listed numbers of patients who underwent specific concomitant procedures, 715 patients (83.5%) underwent an isolated TTO procedure, and the other 141 (16.5%) underwent either concomitant lateral femoral trochleoplasty, arthroscopic drilling of chondral lesions, patellar shaving chondroplasty, partial meniscectomy or concomitant meniscal repair, intra-articular loose body removal, and/or lateral release with or without medial plication.

Twenty studies reported specifics on the intraoperative direction of the tibial bone block osteotomy (Table 3). In most cases (50.8%), anteromedial

translation (anteromedialization) was performed; anteriorization was performed in 18.7% of cases, medialization in 9.6%, medial and distal translation in 7.2%, a “triple” (anteriorization, medialization, proximalization) in 6%, isolated distalization in 2.8%, and proximalization in 1.6%. The remaining 2.8% of procedure specifics were not identified.

Postoperative Data

Table 4 lists the overall cohort’s postoperative radiographic, clinical outcome scoring, and complications data. Fifteen studies reported follow-up of >2 years. As with the preoperative data, radiographic and clinical scoring data were relatively nonuniform; some numeric data, however, should be highlighted. Statistical analysis allowed for comparison of preoperative-postoperative VAS, Lysholm, and Kujala scores, each of which was significantly higher after surgery ($P < .001$). Seven studies reported an overall clinical outcome rating, with the cumulative majority of patients reporting good (37.9%) or excellent (39.2%) results.

There was a cumulative total of 79 complications (8% of cohort): 17 recurrent patellar dislocations (1.9%), 4 recurrent patellar subluxations (0.4%), 10 wound complications (1.0%), 2 intraoperative complications (0.2%), 14 tibial tubercle fractures (1.3%), 19 proximal tibia fractures (1.8%),

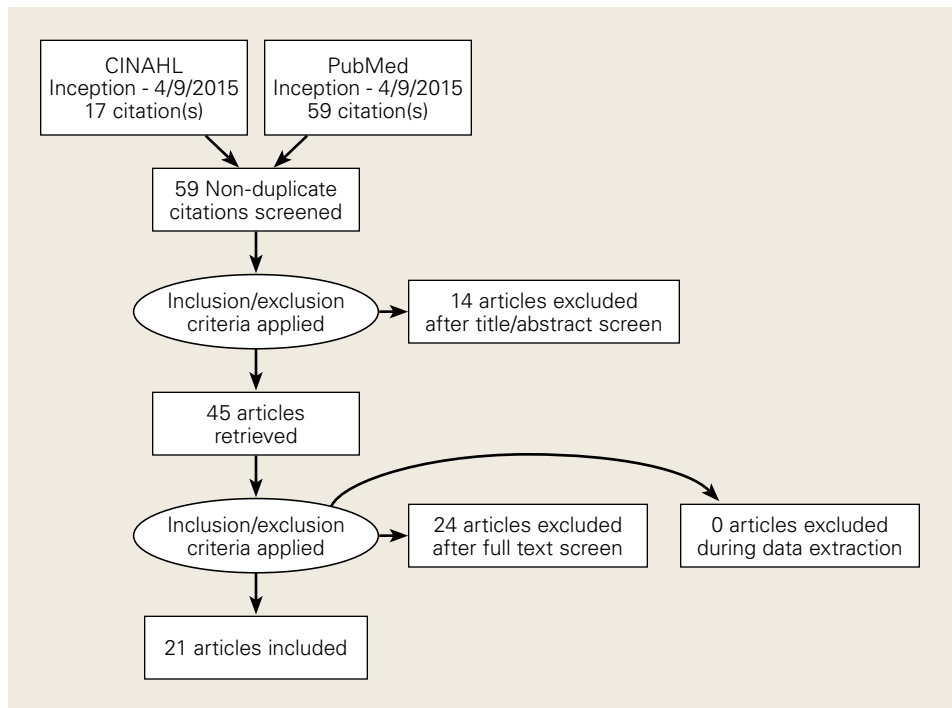


Figure 10. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart.

Table 2. **Characteristics of Included Studies, Patient Demographic Data, and Preoperative Information**

	Data	Studies Reporting (Out of 21), n
Characteristics of Included Studies		
N	21	—
Level of evidence	—	21
I	0 (0%)	—
II	0 (0%)	—
III	3 (14.3%)	—
IV	18 (85.7%)	—
Conflict of interest	—	5
Present	0 (0%)	—
Absent	5 (23.8%)	—
Not reported	16 (76.2%)	—
Studies with modified Coleman methodology score of <55 (poor quality)	21 (100%)	—
Mean (SD) modified Coleman methodology score	19.8 (8.2)	—
Patient Demographic Data		
Patients, N	976	21
Male, n	163	16
Female, n	366	16
Knees, n	1055	21
Mean (SD) age, y	27.68 (10.45)	16
Age range, y	12-77	18
Mean body mass index, kg/m ²	27	1
Prior knee surgery	55.35%	6
Patient Preoperative Indication for Surgery		
	—	21
Patella alta	19 (1.8%)	—
Patella baja	41 (3.9%)	—
Patellofemoral osteoarthritis/chondromalacia patellae	143 (13.6%)	—
Patellofemoral osteoarthritis & patella baja	2 (0.2%)	—
Patellofemoral instability	746 (70.7%)	—
Patellofemoral instability & patella alta	61 (5.8%)	—
Patellofemoral instability & patellofemoral osteoarthritis	45 (4.3%)	—
Patient Preoperative Radiographic Data		
Quadriceps angle, degrees	20.24	2
Insall-Salvati ratio	1.098	2
Caton-Deschamps index	1.15	2
Blackburne-Peel ratio	0.4	1
Outerbridge osteoarthritis grade	2.56	4
Tibial tubercle-trochlear groove distance, mm	17.85	1
Patient Preoperative Clinical Scoring Data		
Visual analog scale score	70.50	4
Mean (SD) Lysholm score	59.19 (14.0)	5
Mean (SD) Kujala score	41.16 (12.54)	4
Shelbourne-Trumper score	36.7	1
Cox-Insall score	36 poor (58.1%) 26 fair (41.9%) 0 good (0%) 0 excellent (0%)	2

4 cases of anterior knee pain (0.4%), 4 cases of neuropraxia (0.4%), and 5 infections (0.5%). Of note, 219 knees (21%) required reoperation, but 170 (16.3%) of these were for painful hardware removal. Sixteen knees (1.5%) required revision TTO, 1 (0.1%) required subsequent high tibial osteotomy, 2 (0.2%) underwent patellofemoral arthroplasty for advanced arthritic changes, and 5 (0.5%) underwent total knee arthroplasty for advanced arthritic changes.

Studies With TTO Performed in Isolation

Twelve studies reported outcomes of isolated TTO procedures. In the 638 patients who underwent isolated TTO, the pathologies addressed were instability/laxity (429 patients, 67%), patellofemoral osteoarthritis (74, 12%), patella alta with instability (61, 10%), patellofemoral osteoarthritis with instability (31, 5%), patella baja (24, 4%), and patella alta (19, 3%). Pain was a preoperative issue in 289 (45%) of these patients and instability in 472 (74%).

Only 2.8% of patients experienced postoperative patellar dislocation events. Of the 12 studies, 2 reported VAS scores (34-point weighted mean improvement, 65 points before surgery to 31 after surgery), 3 reported Lysholm scores (30-point improvement, from 60 to 90), and 2 reported Kujala scores (21-point improvement, from 46 to 67).

Complication rates for this isolated-TTO pooled cohort of patients were 1.2% for revision TTOs, 0.5% for wound complications, 0.8% for tibial tubercle fractures, and 1.9% for proximal tibia fractures. In total, 16% of patients required hardware removal after surgery.

Discussion

This study found that TTO improved patient pain and clinical outcome scores despite having a high (16%) rate of reoperation for painful hardware in patients with preoperative pain or instability, or with patellofemoral osteoarthritis or aberrant patellar anatomy. This reoperation rate and the overall complication rate both exceeded our hypothesized 10% cumulative rate. However, <1% of patients required conversion to a definitive end-stage surgery (patellofemoral arthroplasty or total knee arthroplasty) by final follow-up, and the rates of comorbidities (anterior knee pain, wound infection, recurrent patellar subluxation/dislocation, tibial fracture) were relatively low.

Patellofemoral disorders are common in the general population and a frequent primary com-

Table 3. Patient Surgical Intervention Specifics (20 of 21 Studies Reporting)

Osteotomy Direction	%
Anterior/medial (anteromedialization)	50.8
Anterior	18.7
Medial	9.6
Distal	2.8
Medial/distal	7.2
Proximal	1.6
“Triple”: anterior, medial, proximal	6.0
Not specified	2.8

plaint on presentation to orthopedic offices. Having a thorough understanding of knee joint biomechanics is imperative when trying to determine whether surgery is appropriate for these complaints and how to proceed. Extensor mechanism abnormalities, including high lateral force vectors (or larger TT-TG distances) and excessive patellar tilt, can affect alignment and increase the risk for patellofemoral dislocations, patellofemoral anterior-based knee pains, and chondral lesions. Patella alta, an elevated patella, risks increased contact stresses between the patella and the trochlear groove³³ and decreases the osseous constraints that inhibit dislocation of the patella with physiologic flexion of the joint.³⁴ With TTO, the change in tuberosity position can alter angles in the extensor mechanism and thereby decrease joint reaction forces and patellofemoral contact area forces.^{35,36}

Although its use began as an option for combating patellar instability events in patients with predisposed patellofemoral kinematics,⁵ TTO has evolved in its therapeutic uses to include offloading patellar and trochlear focal chondral lesions and slowing progression of patellofemoral arthritis. Multiple iterations and modifications of the procedure have involved distal and medial transfer of the tibial tuberosity, medialization alone, concurrent anterior and medial elevation of the tuberosity, and proximal or distal transfers, depending on the pathology being corrected. Although TTO is highly versatile in treating multiple patellofemoral joint pathologies, this study found that its primary indication continues to be patellar instability, with anteromedialization as the most common direction of tubercle transfer in support

Table 4. Patient Postoperative Characteristics

Characteristic	Data	Studies Reporting (Out of 21), n	Preoperative-Postoperative Comparison, P
General Clinical Data			
Weighted mean physical examination follow-up, mo	92.45	7	N/A
Patient Radiographic Data			
Weighted mean radiographic examination follow-up, mo	133.67	2	N/A
Quadriceps angle, degrees	14.2	2	NR
Insall-Salvati ratio	0.91	2	NR
Caton-Deschamps index	1.045	1	NR
Blackburne-Peel ratio	1.0	1	NR
Patellar tilt, degrees	5.39	2	NR
Patient Clinical Outcome Scoring Data			
Weighted mean clinical outcome scoring follow-up, mo	77.22	12	N/A
Mean (SD) visual analog scale score	32.61 (19.49)	4	<.001 ^a
Mean (SD) Lysholm score	90.01 (11.61)	5	<.001 ^a
Mean (SD) Kujala score	77.13 (15.92)	4	<.001 ^a
Shelbourne-Trumper score	76.5	1	NR
Cox-Insall score	10 poor (19.2%) 10 fair (19.2%) 27 good (51.9%) 5 excellent (9.6%)	2	NR
Overall clinical outcome rating	19 poor (8.2%) 34 fair (14.7%) 88 good (37.9%) 91 excellent (39.2%)	7	N/A
Patient satisfaction score	79.2	1	N/A

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of the medial structures providing the medial force vector that keeps the patella in place. These medial structures include the medial patellofemoral ligament, the vastus medialis obliquus, the medial patellotibial ligament, and the medial retinaculum.

Also notable was the relatively high rate of reoperation after TTO. However, >75% of reoperations were performed to remove painful hardware, and the need for reoperation seemed to have no effect on the statistically significant overall preoperative-to-postoperative improvement in VAS, Lysholm, and Kujala scores. Rates of definitive surgery for end-stage patellofemoral changes, including patellofemoral arthroplasty and total knee arthroplasty, were quite low at the weighted mean follow-up of several years after surgery, suggesting a role for TTO in avoiding arthroplasty. Although the infection rate was <1%, the rate of tibial tubercle or proximal tibia fractures was a cumulative 3.1%. Patients should be counseled on this complication risk, as treatment can require cast immobilization and weight-bearing limitations.²⁴

The 69% proportion of women in the overall cohort and the mean (SD) age of 27.68 (10.45) years highlight the primary patient population that undergoes TTO. Compared with men, young women are more likely to have aberrant patellofemoral biomechanics, owing to their native anatomy, including their relatively larger Q-angle and TT-TG distance and thus increased lateral translational force vectors on the patella.³⁷ In addition, more than half of patients who are having TTO underwent previous surgery on the affected knee—an indication that TTO is still not universally considered first-line in addressing patellofemoral pathology.

Limitations of the Analysis

The limitations of this analysis derive from the limitations of the included studies, which were mostly retrospective case series with relatively short follow-up. The low MCMS (<55) of all 21 studies highlights their low quality as well. These studies showed considerable heterogeneity in their reporting of specific preoperative, intraoperative, and postoperative radiographic, physical examina-

Table 4. **Patient Postoperative Characteristics (continued)**

Characteristic	Data	Studies Reporting (Out of 21), n	Preoperative-Postoperative Comparison, P
Patient Nonoperative Complications			
Cumulative total complications	85 (8.2%)	21	N/A
Cumulative total recurrent patellar dislocations	17 (1.9%)	21 (10 definitively reported presence or absence; the other 11 did not report dislocations but did not definitively say absence of repeat dislocation)	N/A
Cumulative total recurrent patellar subluxations	4 (0.4%)	21 (10 definitively reported presence or absence; the other 11 did not report subluxations but did not definitively say absence of repeat subluxations)	N/A
Wound complications	10 (1.0%)	21 (7 definitively reported presence or absence; the other 14 did not report complications but did not definitively say absence of repeat complication)	N/A
Intraoperative complications	2 (0.2%)	21 (1 definitively reported presence or absence; the other 20 did not report complications but did not definitively say absence of repeat complication)	N/A
Tibial tubercle fractures	14 (1.3%)	21 (6 definitively reported presence or absence; the other 15 did not report fractures but did not definitively say absence of repeat fracture)	N/A
Proximal tibia fractures	19 (1.8%)	21 (6 definitively reported presence or absence; the other 15 did not report fractures but did not definitively say absence of repeat fracture)	N/A
Anterior knee pain	4 (0.4%)	21 (2 definitively reported presence or absence; the other 19 did not report pain but did not definitively say absence of repeat pain)	N/A
Neuropraxia	4 (0.4%)	21 (4 definitively reported presence or absence; the other 17 did not report neuropraxia but did not definitively say absence of repeat neuropraxia)	N/A
Infection	5 (0.5%)	21 (10 definitively reported presence or absence; the other 11 did not report infections but did not definitively say absence of repeat infection)	N/A

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tion, and clinical outcome scores, which may be indicative of the relatively low rate of use of TTO, a procedure originally described decades ago. These studies also showed ample heterogeneity in the specific radiographic parameters or outcome scales they used to present their data. We were therefore

limited in our ability to cohesively summarize and provide cumulative data points from the patients as a unified cohort. There was substantial variety in the procedures performed, surgical techniques used, concomitant pathologies addressed at time of surgery, and diagnoses treated—indicating a

Table 4. Patient Postoperative Characteristics (continued)

Characteristic	Data	Studies Reporting (Out of 21), n	Preoperative-Postoperative Comparison, P
Reoperations			
Cumulative total reoperations	219 (21.0%)	21	N/A
Removal of painful hardware	170 (16.3%)	21 (14 definitively reported presence or absence; the other 7 did not report removal of hardware but did not definitively say absence of repeat removal of hardware)	N/A
Revision tibial tubercle osteotomy	16 (1.5%)	21 (11 definitively reported presence or absence; the other 10 did not report revision but did not definitively say absence of repeat revision)	N/A
High tibial osteotomy	1 (0.1%)	21 (1 definitively reported presence or absence; the other 20 did not report high tibial osteotomy but did not definitively say absence of repeat high tibial osteotomy)	N/A
Patellofemoral arthroplasty	2 (0.2%)	21 (1 definitively reported presence or absence; the other 20 did not report arthroplasty but did not definitively say absence of repeat arthroplasty)	N/A
Total knee arthroplasty	5 (0.5%)	21 (3 definitively reported presence or absence; the other 18 did not report arthroplasty but did not definitively say absence of repeat arthroplasty)	N/A
Other	14 (1.3%)	21 (4 definitively reported presence or absence; the other 17 did not report reoperation but did not definitively say absence of repeat reoperation)	N/A

*Statistically significant ($P < .05$).
Abbreviations: N/A, not applicable; NR, not reported.

performance bias. This additionally precluded any significant meta-analysis within the patient cohort. A higher quality study, a randomized controlled trial, is needed to answer more definitively and completely the questions we left unanswered, including the effect on radiographic parameters, additional clinical outcomes, and patient satisfaction.

Conclusion

TTO is most commonly performed for isolated patellar instability in the presence of knee pain. Other pathologies addressed are patellofemoral osteoarthritis, and patella alta and patella baja with and without associated knee pain. TTO significantly improves knee pain and clinical outcome scores, though 21% of patients (>1 in 5) require reoperation for hardware removal. Young women with

prior surgery on the affected knee are the primary patient population.

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This paper will be judged for the Resident Writer's Award.