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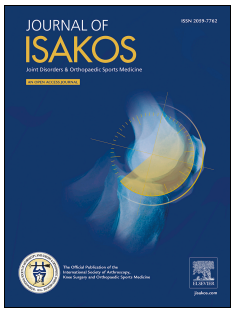

High Incidence of Complication Following Tibial Tubercle Surgery"

Anna Lundeen, MS, MS, ATC, Jeffrey Macalena, MD, Julie Agel, MA, ATC, Elizabeth Arendt, MD

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High Incidence of Complication Following Tibial Tubercle Surgery".

Anna Lundeen, MS3, MS, ATC; Jeffrey Macalena, MD; Julie Agel, MA, ATC; Elizabeth Arendt, MD

University of Minnesota, Minneapolis, MN, USA

Corresponding Author:

Elizabeth A. Arendt, MD
Department of Orthopedic Surgery
University of Minnesota
2450 Riverside Avenue South
Suite R 200
Minneapolis, MN 55454
612-273-1177
arend001@umn.edu

High Incidence of Complication Following Tibial Tubercle Surgery

ABSTRACT

Objectives: Tibial tubercle osteotomy (TTO) is a common procedure that is frequently used in the treatment of recurrent patellar instability and/or patellar chondrosis. Current estimates of TTO complications in the literature vary widely; with complication rates reaching 59 percent. This variability is due, in part, to inconsistent definitions of complication between studies. The purpose of this study was to identify our complication rate following TTO procedures, with sub-analysis of whether the complication rate was affected by:

1. an intra-articular component defined as an additional procedure that altered post-operative rehabilitation, and
2. a distalization of the tubercle translation.

Methods: All patients between May 2009 and May 2015 who underwent a TTO were retrospectively identified. Complications were defined as major (fracture of the tibia, deep infection, nonunion, delayed union, arthrofibrosis, deep vein thrombosis (DVT), loss of screw fixation) versus minor (superficial wound infection, disturbance of cutaneous sensation, delay in wound healing). Subgroup analysis of distalization versus no distalization, and intra- versus extra-articular concomitant procedures were also analyzed.

Results: One hundred and sixty-three TTOs in 150 patients were included in the final cohort with a mean follow-up of 21.3 months. The overall complication rate was 35 major complications (21.5%) and 13 minor complications (8.0%), with a total complication rate

of 29.5%. TTO distalization did not increase the rate of complications. DVT was only seen in the intra-articular procedure cohort (n=3/1.8%). Arthrofibrosis was the most common complication, occurring in 17 knees.

Conclusion: The overall complication rate of tibial tubercle osteotomies was 29.5%, with arthrofibrosis (10.4%) as the largest complication. DVT was increased with concomitant intra-articular procedure. Distalization of the tubercle compared to no distalization had no significant effect on complications.

What Are the New Findings?

- The tibial tubercle osteotomy complication rate was 29.5 percent.
- Arthrofibrosis was the most common complication, affecting 10.4% of the study population.
- Distalization of the tubercle did not significantly affect the complication rate compared to those not distalized.
- The deep vein thrombosis rate was higher when a Tibial Tubercle Osteotomy was combined with an intra-articular procedures.

Level of Evidence: Retrospective Cohort study, level III.

Key Words: Tibial Tubercle Osteotomy, Patella Alta, Patellar Instability, Patellofemoral.

INTRODUCTION

Recurrent lateral instability associated with patella alta, increased lateral tibial tubercle offset, and lateral patellofemoral (PF) arthrosis are indications for tibial tubercle osteotomies (TTOs)[1-5]. Tibial tubercle osteotomies require transferring the tubercle medially, distally, anteriorly, or a combination of these directions guided by the patient's symptoms and osseous anatomy[6,7]. Tibial tubercle osteotomies frequently medialize the tubercle to decrease the lateral vector of the distal extensor mechanism. This is indicated in cases of localized cartilage wear on the lateral and/or inferior patella; and in some cases, to protect cartilage restoration procedures of the PF joint. Tubercle fragment distalization corrects patella alta. Tibial tubercle osteotomies performed for patellar instability are frequently combined with patellar stabilization procedures, such as medial patellofemoral ligament reconstruction, medial retinacular imbrication, lateral retinacular release/lengthening, and trochleoplasty [8,9].

Until recently, literature described a range of TTO complication rates between 0-12% though these studies were limited by their cohort sizes (ranging from 18-116 knees)[10-15].

One recent retrospective cohort study describes a TTO complication rate of 58% (n = 88) out of 153 TTOs (153 patients), including a 21% (n = 32) painful hardware removal rate[10]. This high complication rate is influenced by their inclusion of painful hardware removal as a complication, not classified as a complication in most publications. Additionally, the concomitant procedures reported in this study are MPFL reconstruction and lateral

retinacular release, with no mention of bony procedures. One study performed TTOs with concomitant patellar tendon tenodesis and reports a total complication rate of 14.8% with a mean follow-up of 9.6 years[16]. Moreover, a 2017 systematic review examined 21 TTO outcomes studies (1055 knees) and found a complication rate of 8% (79 complications), with an additional 21% (219 knees) requiring reoperation (170 of which removed painful hardware)[15].

Tibial tubercle osteotomy complications can be classified as major and minor. Major complications reported in the literature are deep vein thrombosis (DVT), tibia fracture, nonunion, deep infection requiring surgical debridement, arthrofibrosis requiring surgery, and subsequent patellar instability[1,17-26] Minor complications reported in the literature include superficial infection, scar numbness or pain, hardware discomfort, and hematoma[11,13,14,27-34].

The purpose of the present study is to identify the complication rate resulting from tibial tubercle osteotomies, with sub-analysis of whether the complication rate was affected by:

1. an intra-articular component defined as an additional procedure that altered post-operative rehabilitation, and
2. a distalization of the tubercle translation.

METHODS

After IRB approval was obtained (UMN IRB #1609M94383), this study was determined to be exempt from further review under federal guidelines 45 CFR Part 46.101(b) category

2: Surveys and interviews. All ethical standards of maintaining patient confidentiality have been employed, including those in accordance with the US Health Insurance Portability and Accountability Act (HIPAA). A retrospective chart review was performed on 177 tibial tubercle osteotomies. One hundred and sixty-three knees were included in the final study cohort. Demographics and list of procedures are listed in table 1. (Table 1). Three months was chosen as the minimum follow-up as the majority of complications have declared themselves by that time. All TTOs were performed from May 2009 to May 2015 by four fellowship trained orthopaedic surgeons. Surgical technique is elsewhere described[35].

Demographics were collected on all patients and included age at operation, sex, body mass index (BMI), and tobacco use (Table 2). Tobacco pack per day, smoking history, and date of smoking cessation were noted in cases in which the data was available.

Major complications were tibia fractures (fig 1), deep infection requiring surgical debridement, arthrofibrosis defined as knee stiffness requiring surgical intervention, DVT, loss of tibial tubercle fixation (broken screw) with subsequent healing, nonunion, and delayed union. For the purposes of data collection, the definition of nonunion (Fig 2) was absence of bony union necessitating a refixation procedure. Delayed union was defined as delayed bony union after 3 months which resolved with non-operative management. Minor complications included wound dehiscence treated non-operatively, superficial infection, and loss or decrease of cutaneous sensation. Surgeons evaluating patients post-operatively were not blinded to details regarding the procedure. Data was also collected regarding previous, concomitant, and subsequent procedures pertinent to the operative knee.

For the purposes of this study, we sub-classified intra-articular procedures as any intra-articular bony procedure that changed the TTO post-operative protocol in regards to limited motion and/or weight bearing status.

The post-operative protocol employed requires partial weight bearing in a locked knee immobilizer for four weeks, opening the brace when sitting and for exercises. At four weeks, the protocol is advanced to weight bearing as tolerated depending on patient and imaging related factors. This TTO protocol is attached as an appendix. Concomitant intra-articular procedures (49 knees) included: cartilage restoration including autologous chondrocyte implantation (ACI) and osteochondral allograft transplantation (OCA) (N=31/63%), microfracture (n=13/27%), and/or trochleoplasty (n=5/10%). Concomitant extra-articular procedures (114 knees) was largely patellar stabilization including : medial patellofemoral ligament (MPFL) reconstruction with or without lateral retinaculum release/lengthening (n=82/72%), lateral retinaculum release/lengthening (n=20/18%), other soft tissue patellar stabilization (n=12/10%). When a patient had both concomitant intra- and extra-articular procedures, they were placed in the intra-articular subgroup.

Statistical Analysis –

All variables were evaluated by Chi-square analysis to determine statistical significance between cohorts. Level of significance was set at $P<0.05$.

RESULTS

The final study cohort represents 163 knees in 150 patients, with a mean follow-up of 21.3 months (range: 3 months to 6.8 years). The minimum follow-up was 3 months. Ninety

percent had at least 6 months of follow-up. Fourteen patients were excluded due to lack of sufficient follow-up; no complications were recorded in the excluded patients. Ninety-one of 163 TTOs (55.8%) had a primary diagnosis of patellar instability and 32 knees (19.6%) had a primary diagnosis of patellofemoral chondral damage. Forty knees (24.5%) carried a combined diagnosis of patellar instability and cartilage wear.

The overall complication rate for tibial tubercle osteotomy was 29.5%: major complication rate 21.5%, minor complication rate 8.0% (Table 3). The most common complication was knee arthrofibrosis in seventeen knees (10.4%).

Out of those with arthrofibrosis in the intra-articular subgroup (n=5), one patient developed ‘catching’ in the operative knee and required further surgery. Of those with arthrofibrosis in the extra-articular subgroup (n=12), one patient had a non-union following treatment for arthrofibrosis resulting in reoperation with bone grafting. Fifteen out of seventeen arthrofibrosis cases achieved functional motion, comparable to the other side.

For the sub-analysis, there was no significant differences between the overall complication rate of TTOs with or without concomitant intra-articular procedure. Of the 49 osteotomies that underwent a concomitant intra-articular procedure, there were 12 complications (24.5%) in 9 knees. Of the 114 osteotomies with a concomitant extra-articular procedure, there were 36 complications (31.6%) in 27 knees (Table 3).

153 The rate of DVT was very low (n=3/1.8%) and was present only in the intra-articular
154 procedure cohort (p = 0.03, Table 3). None of the DVTs had a subsequent pulmonary
155 embolism; all were treated with greater than or equal to three months of anticoagulation.
156
157 In the sub-analysis between distalized and nondistalized subgroups, there were no
158 significant differences in overall complication rates (p = 0.39, Table 4).
159
160 When total bony complication rates (delayed union, nonunion, tibia fracture (Fig. 2), and
161 loss of screw fixation) were grouped, complication rates did not differ significantly when
162 comparing intra- (n=3, 6.1%) versus extra-articular (n=12, 10.5%) subgroups (p = 0.56,
163 Table 3), or between distalization (n=10, 10.3%) versus no distalization (n=5, 7.6%)
164 subgroups (p = 0.60, Table 4). There were 2 delayed unions; both healed with use of a
165 bone stimulator. All non-unions required reoperation with bone grafting (n=1) or revision
166 fixation (n=3); all were healed by last follow-up.
167
168 There were no predictors of complications in our demographic variables (BMI/age/sex;
169 Table 2). Notably, previous surgery and smoking status (prior or current) was not
170 associated with an increased rate of complication, though this sub-grouping was too small
171 to make meaningful comparisons. Seventy-eight percent of our cohort were ‘never
172 smokers’. It is the current practice of the authors to require smoking cessation prior to
173 proceeding with TTO surgery.
174

Elective hardware removal was completed in 19 knees (11.7%). The majority of screws used in our patients were 3.5 mm in diameter.

DISCUSSION

The most important finding of this study is the complication rate of tibial tubercle osteotomies is high (29.5%), most of them being major complications. Arthrofibrosis was the most common complication (10.4%) and affected patients regardless of TTO distalization or a concommittant intra-articular procedure.

Past literature reports TTO arthrofibrosis rates of up to 2.8 percent[14,36]. One recent study reports an arthrofibrosis rate of 22%, though all patients in this study underwent concomitant cartilage restoration procedures such as autologous chondrocyte implantation or osteochondral allograft[37]. In another recent study of a cohort of patients undergoing distalization TTO with no secondary intra-articular procedures, the rate of arthrofibrosis (8.8%), was associated with the length of the distalization [38]. In our study, we compare complications of TTO paired with intra-articular (includes ACI, OCA, microfracture, trochleoplasty) versus TTO with associated soft tissue extra-articular procedures and no concomitant bony procedures. No significant difference was found between these groups.

The rate of arthrofibrosis requiring surgical intervention is high in the present study and may indicate the importance of adherence to post-operative physical therapy and early mobility following TTO, despite concomitant procedures. Adequate pain control and rigid fixation are additional strategies that support early motion.

All three DVT in this study were in the intra-articular subgroup (Table 3), resulting a significant difference compared to the extra-articular subgroup. This finding may be the result of a possible longer operating time with the addition of an intra-articular procedure. Each patient should receive an individualized and risk stratified decision regarding DVT prophylaxis.

One purpose of our study was to see if distalization was an independent risk factor for having a complication given the potential higher forces experienced at the site of the tubercle following distalization, the loss of a periosteal hinge, and with the inferior osteotomy site being closer to diaphyseal bone. Our data did not support this hypothesis (Table 4). The rate of complication in the distalization group did not differ significantly from the nondistalized group (p = 0.39), though one publication reports significantly increased rates of delayed union among TTOs that are distalized[10]. Post-operative management, specifically time on crutches and progression to full weightbearing, likely plays a role in this variable; granularity of post-operative management could not be ascertained from current and past literature. Our post-operative protocol is conservative in that we keep the patient partial weight bearing until radiographic evidence of complete or near complete union is demonstrated with pain-free ambulation.

The rate of hardware removal in our study (11.7%) represents a lower rate than the current literature, which reports a symptomatic hardware removal rate of up to 59 percent[13,15,39]. If the present study had a greater average time to final follow-up, we may have detected a higher hardware removal rate. Additionally, current literature shows that a screw size of 4.5 mm is associated with a higher rate of post-operative discomfort and

subsequent hardware removal when compared to the predominant screw size used in our patient population (3.5 mm)[10].

The literature reports a reduction in cutaneous nerve sensation at a rate of up to 0.4% [13,15], lower than the present study. The literature's definition of neurologic complications includes both saphenous neuromas and temporary peroneal nerve palsies, while our study focused on superficial nerve paresthesia and dysesthesias from the infrapatellar branch of the saphenous nerve. No neurologic motor dysfunction specific to the peroneal nerve was recorded in our study. This differed from prior literature's definition of neurologic deficit and may account for the variability found between values in the literature and this present study.

The uniqueness of this study is the evaluation of post-operative TTO complications between concomitant intra- versus extra-articular procedures, and between TTO with and without distalization. This data may better inform the patient-physician conversation surrounding this operation and its risks, especially when additional intra-articular procedures are performed with the TTO.

Limitations –

Limitations of the study include the retrospective design. However, this is somewhat offset by the sample size as well as a 90% follow-up rate at 6 months. Additional limitations include the heterogeneity of concomitant procedures and variations in the degree of tibial tubercle translation, both of which may result in a heterogenous population and may

negatively impact the power of our study. A description of indications for each procedure is not within the scope of this paper, and therefore not included.

CONCLUSION

Tibial tubercle osteotomies are associated with a high rate of complications. Arthrofibrosis was the most highly reported complication in our study. Deep vein thrombosis was the only complication significantly affected by concomitant intra-articular procedures. There were no significant differences when comparing complications of distalized and nondistalized subgroups. This study provides insight into the rate and types of complications associated with TTO procedures.

References

[1] Ding DY, Kanevsky R, Strauss EJ, Jazrawi LM. Anteromedialisation tibial tubercle osteotomy for recurrent patellar instability in young active patients: A retrospective case series. Injury. 2016;47(3):737-741.10.1016/j.injury.2015.10.005

[2] Brown DE, Alexander AH, Lichtman DM. The Elmslie-Trillat procedure: evaluation in patellar dislocation and subluxation. Am J Sports Med. 1984;12(2):104-109.10.1177/036354658401200203

[3] Caton JH, Dejour D. Tibial tubercle osteotomy in patello-femoral instability and in patellar height abnormality. Int Orthop. 2010;34(2):305-309.10.1007/s00264-009-0929-4

[4] Fulkerson JP. Anteromedialization of the tibial tuberosity for patellofemoral malalignment. Clin Orthop Relat Res. 1983(177):176-181

[5] Trillat A, Dejour H, Couette A. [DIAGNOSIS AND TREATMENT OF RECURRENT DISLOCATIONS OF THE PATELLA]. Rev Chir Orthop Reparatrice Appar Mot. 1964;50:813-824

[6] Middleton KK, Gruber S, Shubin Stein BE. Why and Where to Move the Tibial Tubercle: Indications and Techniques for Tibial Tubercle Osteotomy. Sports Med Arthrosc Rev. 2019;27(4):154-160.10.1097/jsa.0000000000000270

[7] Servien E, Verdonk PC, Neyret P. Tibial tuberosity transfer for episodic patellar dislocation. Sports Med Arthrosc Rev. 2007;15(2):61-67.10.1097/JSA.0b013e3180479464

[8] Arendt EA, Donell ST, Silanpaa PJ, Feller JA. The management of lateral patellar dislocation: state of the art

. Journal of ISAKOS. 2017;2(4):205-212.10.1136/jisakos-2015-000011.

277 [9] Post WR, Fithian DC. Patellofemoral Instability: A Consensus Statement From the
278 AOSSM/PFF Patellofemoral Instability Workshop. Orthop J Sports Med.
279 2018;6(1):2325967117750352.10.1177/2325967117750352
280 [10] Johnson AA, Wolfe EL, Mintz DN, Demehri S, Shubin Stein BE, Cosgarea AJ.
281 Complications After Tibial Tuberosity Osteotomy: Association With Screw Size and
282 Concomitant Distalization. Orthop J Sports Med.
283 2018;6(10):2325967118803614.10.1177/2325967118803614
284 [11] Longo UG, Rizzello G, Ciuffreda M, et al. Elmslie-Trillat, Maquet, Fulkerson, Roux
285 Goldthwait, and Other Distal Realignment Procedures for the Management of Patellar
286 Dislocation: Systematic Review and Quantitative Synthesis of the Literature. Arthroscopy.
287 2016;32(5):929-943.10.1016/j.arthro.2015.10.019
288 [12] Parikh SN, Nathan ST, Wall EJ, Eismann EA. Complications of medial patellofemoral
289 ligament reconstruction in young patients. Am J Sports Med. 2013;41(5):1030-
290 1038.10.1177/0363546513482085
291 [13] Payne J, Rimmke N, Schmitt LC, Flanigan DC, Magnussen RA. The Incidence of
292 Complications of Tibial Tubercle Osteotomy: A Systematic Review. Arthroscopy.
293 2015;31(9):1819-1825.10.1016/j.arthro.2015.03.028
294 [14] Pidoriano AJ, Weinstein RN, Buuck DA, Fulkerson JP. Correlation of patellar articular
295 lesions with results from anteromedial tibial tubercle transfer. Am J Sports Med. 1997;25(4):533-
296 537.10.1177/036354659702500417
297 [15] Saltzman BM, Rao A, Erickson BJ, et al. A Systematic Review of 21 Tibial Tubercle
298 Osteotomy Studies and More Than 1000 Knees: Indications, Clinical Outcomes, Complications,
299 and Reoperations. Am J Orthop (Belle Mead NJ). 2017;46(6):E396-e407

[16] 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):346-351.10.1177/0363546511427117

[17] Atkinson HD, Bailey CA, Anand S, Johal P, Oakeshott RD. Tibial tubercle advancement osteotomy with bone allograft for patellofemoral arthritis: a retrospective cohort study of 50 knees. Arch Orthop Trauma Surg. 2012;132(4):437-445.10.1007/s00402-011-1433-z

[18] Jack CM, Rajaratnam SS, Khan HO, Keast-Butler O, Butler-Manuel PA, Heatley FW. The modified tibial tubercle osteotomy for anterior knee pain due to chondromalacia patellae in adults: A five-year prospective study. Bone Joint Res. 2012;1(8):167-173.10.1302/2046-3758.18.2000083

[19] Karamehmetoglu M, Ozturkmen Y, Azboy I, Caniklioglu M. [Fulkerson osteotomy for the treatment of chronic patellofemoral malalignment]. Acta Orthop Traumatol Turc. 2007;41(1):21-30

[20] Koëter S, Diks MJ, Anderson PG, Wymenga AB. A modified tibial tubercle osteotomy for patellar maltracking: results at two years. J Bone Joint Surg Br. 2007;89(2):180-185.10.1302/0301-620x.89b2.18358

[21] 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):19-26.10.1007/s11832-010-0311-5

[22] Pritsch T, Haim A, Arbel R, Snir N, Shasha N, Dekel S. Tailored tibial tubercle transfer for patellofemoral malalignment: analysis of clinical outcomes. Knee Surg Sports Traumatol Arthrosc. 2007;15(8):994-1002.10.1007/s00167-007-0325-9

[23] Tanaka MJ, Munch JL, Slater AJ, Nguyen JT, Shubin Stein BE. Incidence of Deep Venous Thrombosis After Tibial Tubercle Osteotomy: A Single Case Series Study. Orthop J Sports Med. 2014;2(8):2325967114544457.10.1177/2325967114544457

[24] Tjoumakaris FP, Forsythe B, Bradley JP. Patellofemoral instability in athletes: treatment via modified Fulkerson osteotomy and lateral release. Am J Sports Med. 2010;38(5):992-999.10.1177/0363546509357682

[25] Wang CJ, Chan YS, Chen HH, Wu ST. Factors affecting the outcome of distal realignment for patellofemoral disorders of the knee. Knee. 2005;12(3):195-200.10.1016/j.knee.2004.08.006

[26] Wang CJ, Wong T, Ko JY, Siu KK. Triple positioning of tibial tubercle osteotomy for patellofemoral disorders. Knee. 2014;21(1):133-137.10.1016/j.knee.2012.10.027

[27] Bellemans J, Cauwenberghs F, Witvrouw E, Brys P, Victor J. Anteromedial tibial tubercle transfer in patients with chronic anterior knee pain and a subluxation-type patellar malalignment. Am J Sports Med. 1997;25(3):375-381.10.1177/036354659702500318

[28] Dantas P, Nunes C, Moreira J, Amaral LB. Antero-medialisation of the tibial tubercle for patellar instability. Int Orthop. 2005;29(6):390-391.10.1007/s00264-005-0015-5

[29] Endres S, Wilke A. A 10 year follow-up study after Roux-Elmslie-Trillat treatment for cases of patellar instability. BMC Musculoskelet Disord. 2011;12:48.10.1186/1471-2474-12-48

[30] Karataglis D, Green MA, Learmonth DJ. Functional outcome following modified Elmslie-Trillat procedure. Knee. 2006;13(6):464-468.10.1016/j.knee.2006.08.004

[31] Kumar A, Jones S, Bickerstaff DR, Smith TW. Functional evaluation of the modified Elmslie-Trillat procedure for patello-femoral dysfunction. Knee. 2001;8(4):287-292.10.1016/s0968-0160(01)00105-3

[32] Naveed MA, Ackroyd CE, Porteous AJ. Long-term (ten- to 15-year) outcome of arthroscopically assisted Elmslie-Trillat tibial tubercle osteotomy. Bone Joint J. 2013;95-b(4):478-485.10.1302/0301-620x.95b4.29681

[33] Rantanen J, Paananen M. Modified Hauser operation for patellar instability. Immediate mobilization of 35 knees, a 5-8 year follow-up study. Acta Orthop Scand. 1996;67(5):455-458.10.3109/17453679608996667

[34] Rillmann P, Dutly A, Kieser C, Berbig R. Modified Elmslie-Trillat procedure for instability of the patella. Knee Surg Sports Traumatol Arthrosc. 1998;6(1):31-35.10.1007/s001670050069

[35] Ridley TJ, Baer M, Macalena JA. Revisiting Fulkerson's Original Technique for Tibial Tubercle Transfer: Easing Technical Demand and Improving Versatility. Arthrosc Tech. 2017;6(4):e1211-e1214.10.1016/j.eats.2017.04.013

[36] Servien E, Aït Si Selmi T, Neyret P. [Subjective evaluation of surgical treatment for patellar instability]. Rev Chir Orthop Reparatrice Appar Mot. 2004;90(2):137-142.10.1016/s0035-1040(04)70035-5

[37] Merkely G, Ackermann J, Sheehy E, Gomoll AH. Does Flipping the Tubercle for Improved Cartilage Repair Exposure Increase the Risk for Arthrofibrosis? Cartilage. 2020:1947603520968209.10.1177/1947603520968209

[38] Schmiesing A, Engelking M, Agel J, Arendt EAA. Distalization of the Tibial Tubercle for Patellar Stabilization combined with Medial Patellofemoral Ligament Reconstruction. Am J Sports Med. 2022;50(6):1627-1634.10.1177.03535465221089979

[39] Klinge SA, Fulkerson JP. Fifteen-Year Minimum Follow-Up of Anteromedial Tibial Tubercle Transfer for Lateral and/or Distal Patellofemoral Arthrosis. Arthroscopy. 2019;35(7):2146-2151.10.1016/j.arthro.2019.02.030

Figures:

Figure 2: Sagittal view of the tibia four months after surgical distalization tibial tubercle osteotomy. The bent distal screw, migration of the osteotomy block and the wide gap between osseous surfaces indicate a non-union.

Figure 1: Sagittal view of the tibia with a fracture emanating from the anterior cortex of the tibia, at the distal aspect of the osteotomy bone segment. Interval healing is present.

388 **Tables:**

Table 1: Study Cohort

Total Knees Reviewed	*177*
Excluded:	**14**
Final follow-up <3 months with no complication	
Included:	**163**
Knees with complication or final follow-up ≥ 3 months	

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Table 2: Patient Demographics & Characteristics

Gender:	Male - 41 (25%)
	Female - 122 (75%)
Mean Age:	24.6 years (13-48)
Mean Body Mass Index:	28 (17-44)
Smoking Status:	Current - 17 (10%)
	Prior - 16 (10%)
	None - 127 (78%)
	Unknown - 3 (2%)
Previous Surgery:	Yes - 46 (28%)
	No - 117 (72%)

391

392 **Table 3: Tibial Tubercle Osteotomy Complication Rates between**

393 **Intra- versus Extra-articular Procedure**

	Intra-articular 49/163 (30.1%)	Extra-articular 114/163 (69.9%)	*p* value	Complication Frequency
Overall Complications	12 (24.5%)	36 (31.6%)		48 (29.5%)
Major	**11 total**	**24 total**		**35 (21.5%)**
All Bony Complications	(n=3, 6.1%)	(n=12, 10.5%)	0.56	
Fracture of Tibia	0	6	0.18	6 (3.7%)
Loss of Fixation	2	1	0.22	3 (1.8%)
Nonunion	0	4	0.32	4 (2.5%)
Delayed Union	1	1	0.51	2 (1.2%)
Deep Vein Thrombosis	3	0	0.03**	3 (1.8%)
Arthrofibrosis, requiring surgery	5	12	1.0	17 (10.4%)
Deep Infection	0	0	1.0	0
Minor	**1 total**	**12 total**		**13 (8.0%)**
Superficial Infection	1	2	1.0	3 (1.8%)
Decrease in Cutaneous Sensation	0	9	0.06	9 (5.5%)
Wound Dehiscence	0	1	1.0	1 (0.6%)

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398 **Table 4: Complications Following Distalization vs. No Distalization**

	Distalization (97, 59.5%)	No Distalization (66 40.5%)	*p* value
Overall Complications	26 (26.8%)	22 (33.3%)	0.39
Major	19 total	16 total	
All Bony Complications	(n=10, 10.3%)	(n=5, 7.6%)	0.60
Fracture Tibia	4	2	1.0
Loss of Fixation	2	1	1.0
Nonunion	4	0	0.15
Delayed Union	0	2	0.16
Deep Vein Thrombosis	0	3	0.06
Arthrofibrosis	9	8	0.56
Deep Infection	0	0	1.0
Minor	7 total	6 total	
Superficial Infection	2	1	1.0
Decrease in Cutaneous Sensation	5	4	1.0
Wound Dehiscence	0	1	0.40

399

400