Effectiveness of an Accelerated Rehabilitation Protocol After Tibial Tubercle Osteotomy

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Background: Patients with recurrent patellar dislocations with trochlear dysplasia are commonly treated surgically with a tibial tubercle osteotomy (TTO). Recovery and rehabilitation processes are often nonoperative out of concern for fixation failure or fracture. A more accelerated rehabilitation protocol allowing for early weightbearing and quadriceps strengthening may help to improve patient outcomes as long as complications are not increased.

Purpose: To evaluate the safety and effectiveness of an accelerated weightbearing and early strengthening postoperative rehabilitation program for patients who undergo TTO.

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

Methods: Included were patients who underwent unilateral/staged bilateral TTO performed by a single surgeon between August 2013 and February 2018 with ≥6 months of follow-up. The surgical indication was primarily for patients with recurrent patellar instability. In all cases, a diagnostic arthroscopy was performed to evaluate the cartilage surfaces and document patellar tracking. The TTO was performed using a freehand technique and two 3.5-mm fully threaded screws for fixation. Patients underwent an accelerated postoperative rehabilitation program that allowed for weightbearing and lower extremity strengthening starting at 4 weeks. Objective and subjective outcome measures included any postoperative complications, knee range of motion, and patient-reported outcome scores (Kujala Anterior Knee Pain Scale [AKPS] and Knee injury and Osteoarthritis Outcome Score composite [(KOOS5]).

Results: A total of 51 knees in 50 patients (38 female, 12 male) with a mean age of 31.24 ± 12.57 years were included in the final analysis. Compared with preoperative values, postoperative maximum knee flexion was significantly improved (117.67 ± 32.65° vs 131.12 ± 9.02°, respectively; P = .022). Postoperative complications included 6 patients with arthrofibrosis requiring manipulation under anesthesia, 4 with removal of symptomatic hardware, 1 tibial fracture (due to a fall), and 1 conversion to patellofemoral arthroplasty. The mean postoperative AKPS and KOOS5 scores were 72.98 ± 21.51 and 75.05 ± 16.02, respectively.

Conclusion: Accelerated postoperative rehabilitation in TTO patients was an effective means of treatment with good subjective and objective outcomes and complication rates lower than traditional rehabilitation protocols.

Keywords: tibial tubercle osteotomy; accelerated rehabilitation; patient outcomes; patellar instability

Tibial tubercle osteotomy (TTO) is one of the many procedures utilized in the treatment of recurrent patellar instability, painful extensor mechanism maltracking, and patellofemoral chondrosis, alongside a concomitant cartilage procedure in patients who fail nonoperative treatment options. The ultimate goal of a TTO is to correct the underlying malalignment and dynamic patellar tracking that can reduce patellofemoral contact forces. An underlying malalignment, which is expressed as an increased quadriceps angle and quantified by the tibial tubercle–trochlear groove distance, is a known risk factor for recurrent patellofemoral joint instability, especially in the presence of trochlear dysplasia. Osteotomies can also be used to treat unbalanced patellofemoral cartilage loading and knee pain and reduce the risk of both recurrent dislocations and patellofemoral osteoarthritis (OA). While there are multiple techniques and modifications described in the literature for TTO surgery, such as the classic Fullkerson procedure (utilized in this study cohort), Maquet procedure, and Elmslie–Trillat procedure, the rehabilitation protocols for TTO surgeries have not changed over the years and remain relatively nonoperative.
Classically, rehabilitation protocols after TTO procedures have included brief hospitalizations, extended non-weightbearing status, bracing the involved knee in extension, and limiting early weightbearing with assistive devices (ie, crutches) for a period of 6 to 8 weeks to reduce the risk of fixature failure or tibial fracture. After this period of immobilization, patients are allowed to resume weightbearing as tolerated, increase knee range of motion exercises, and begin gradual quads and lower extremity strengthening. Progression to sports-specific activities during rehabilitation commonly occurs once quads strength and range of motion of the surgical limb are regained compared with the contralateral limb. Typically, the timeline for full return to play is around 6 months.7,9,10,12,16,40,44,50

To date, there have only been a few studies that have implemented an accelerated rehabilitation protocol after TTO.5,24,27,43 An accelerated rehabilitation protocol, which has been widely implemented in other knee surgeries,20,39,45 is defined as (1) immediate weightbearing as tolerated in a brace locked in full extension and no restriction of passive range of motion in the early postoperative period, (2) progressive unlocking of the brace as quads function initiates, (3) closed-chain strengthening exercises at 4 weeks, (4) open-chain strengthening by 8 weeks, and (5) noncontact sports participation at 3 months with a gait mechanics–focused rehabilitation program. An accelerated rehabilitation protocol is thought to lead to less knee stiffness, an increase in quads function, shorter recovery times, and possibly earlier resumption of sports, daily activities, and improved outcomes.20,39,45 Nevertheless, researchers and surgeons have suggested that early postoperative weightbearing is associated with proximal tibial fractures6,7,20,21,42,47 because patients reach a higher degree of activity and confidence sooner with a “vulnerable tibia” in the postoperative rehabilitation stage.20,21,24,42

While accelerated rehabilitation protocols have been implemented in TTO surgeries throughout the years,5,24,27,43 little to no research has been completed looking specifically at the outcome measures of accelerated rehabilitation protocols. The purpose of this study was to report on the outcomes of an accelerated postoperative rehabilitation protocol in a cohort of patients after TTO. We hypothesized that patients who undergo a TTO procedure with an accelerated postoperative rehabilitation protocol will have no increase in postoperative complications compared with historical data of the classic rehabilitation protocols. We also hypothesized that patient perceptions of their knee function after the accelerated program would be similar to outcomes of traditional programs.

METHODS

After institutional review board approval, a query of a single surgeon’s (C.M.E.) surgical log was performed to identify patients who underwent TTO (Current Procedure Terminology code 27418) between August 2013 and February 2018. The initial query returned 78 TTO procedures in 74 patients, of which 51 procedures in 50 patients had ≥6 months of follow-up data (Figure 1). Six months was used as a minimum follow-up, as major postsurgical complications are expected to occur more acutely after surgery, and most patients have been discharged from formal rehabilitative therapy by this time.

Surgical Technique

Patients were positioned in the supine position and placed under general anesthesia utilizing a low-concentration femoral nerve block for regional pain control.30 In all cases, diagnostic arthroscopy was carried out to examine for cartilage lesions and qualify trochlear morphology and patellar tracking from a superolateral portal with a 70° arthroscope.5 In some cases, this guided the treatment decision to include or exclude the TTO. The arthroscope was withdrawn once the patient was deemed an adequate candidate for osteotomy.

![Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flowchart. CPT, Current Procedure Terminology; TTO, tibial tubercle osteotomy.](image-url)
The leg was then exsanguinated using an Esmarch bandage, and the tourniquet was inflated. An incision 1 cm proximal to the tibial tubercle was extended distally, typically 5 to 8 cm, over the lateral edge of the tibial crest. Full-thickness skin flaps were created, patellar tendon insertion was developed and protected, anterior compartment fascia was elevated off the tibia, and a shelf osteotomy was created medial to lateral. The angle of the cut was made based on the perceived amount of anterior and medial translation necessary to correct the patellar tracking based on preoperative planning, observed patellar tracking during the diagnostic arthroscopy, and clinical examination. The osteotomy was first made on the medial aspect of the tibia with an oscillating saw, and care was taken to leave a distal periosteal hinge. The osteotomy was completed using an osteotome on the proximal and proximal/lateral aspects of the tubercle. The osteotomy was slowly translated medially to allow for plastic deformation at the distal tibial attachment (the typical translation is approximately 0.8-1.3 cm) and fixed using ≥2 countersunk small-fragment (3.5-mm) stainless steel cortical screws placed perpendicular to the osteotomy in compression mode. Precise measurements were taken to determine the length of the screw in order to avoid prominent implants on the posterior tibia and were verified with mini C-arm fluoroscopy intraoperatively. The tourniquet was dropped before closure. The incision in the anterior compartment fascia was left open, and the original surgical incision was closed. A hinged knee brace was placed intraoperatively with a cooling unit for the leg and locked in extension until initial clinic follow-up at 5 to 6 days.

**Rehabilitation Protocol**

An accelerated rehabilitation protocol was implemented, with immediate active rehabilitative therapy, after the TTO procedure (Figure 2). All rehabilitation details were subject to slight variations based on patient progression and timing of transitions between phases after surgery and were at the discretion of the treating therapist and physician. The outlined rehabilitation program reported here is the foundation of what was provided to the treating therapists and patients. All patients generally followed the accelerated rehabilitation program, which is described in detail in the Appendix. Fixation was checked during the early postoperative phase for healing (Figure 3).
Data Collection

Patient identifiers, including name, medical registration number, date of service, and follow-up date, were stored in a separate file that was linked to a data file by an assigned study identification number. A retrospective chart review of the confirmed TTO cases was performed to obtain patient information including age, operative side, sex, body mass index, pre- and postoperative maximum knee flexion angles, and indications for surgery and concomitant procedures to the ipsilateral knee. Complications of interest included tibial fracture, nonunion, superficial and deep infection, implant failure, arthrofibrosis, recurrence of symptoms (instability), painful implants, deep vein thrombosis or pulmonary embolism, chronic regional pain syndrome, neurovascular injury, and wound dehiscence.

Patient-reported outcome (PRO) scores collected included the Kujala Anterior Knee Pain Scale (AKPS) and the Knee injury and Osteoarthritis Outcome Score composite (KOOS5). The Kujala AKPS scale is a 13-item screening instrument designed to assess patellofemoral pain.19 The KOOS is an instrument that was developed to assess patellofemoral pain.1 It has been used to evaluate both short- and long-term patient’s opinion about their knee and associated problems; it has been used to evaluate both short- and long-term consequences after myriad knee injuries and conditions. The KOOS5 is the mean of the 5 KOOS subscale scores (Pain, Symptoms, Sport/Recreation, Activities of Daily Living, and Quality of Life), providing a single overall score ranging from 0 (worst) to 100 (best). Both outcome measures provide valuable information about patient perceptions regarding their knee function after TTO procedures. These surveys were completed in the clinic or via a telephone interview at a minimum of 6 months postoperatively and recorded in the patients’ data file. At this time, the patients were also verbally asked whether they had returned to their preinjury level of activity (yes/no response), and their response was recorded in their medical record.

Statistical Analysis

Descriptive statistics were calculated for all variables (Table 1). Paired t tests were used to compare maximum knee flexion range of motion between pre- and postoperative time points. Statistical analyses were completed using SPSS Version 27.0 (IBM). An alpha level of .05 was set a priori.

RESULTS

The 50 study patients (51 knees) had a mean age of 31.24 ± 12.57 years (range, 14-56 years). The mean follow-up interval was 16.82 ± 10.19 months. Additional patient information can be found in Table 1.

The most common diagnoses leading to indication for surgical intervention were patellar instability (n = 37) and extensor mechanism malalignment (n = 21). A complete list of surgical indications can be found in Table 2.

Two 3.5-mm cortical screws were used in 47 knees, three 3.5-mm screws in 1 knee, a combination of a 3.5-mm and a larger (4.0- or 4.5-mm) screw in 1 knee, and two 4.5-mm cortical screws in 2 knees. Table 3 shows postoperative complications and procedures. There were 6 knees with arthrofibrosis requiring lysis of adhesions with manipulation and 12 knees who reported symptomatic implants, of whom 4 underwent implant removal. One patient underwent a patellofemoral arthroplasty 4 years 2 months after TTO.

The mean preoperative and postoperative maximum knee flexions of the surgical limb were 117.67 ± 32.65° and 131.12° ± 9.02°, respectively, indicating a significant improvement in flexion range of motion (P = .022). The mean postoperative Kujala score was 72.98 ± 21.51, and the mean postoperative KOOS5 was 75.05 ± 16.02. At the 6-month follow up, 27 of the 50 patients had returned to their preinjury activity level.
TABLE 3
Postoperative Complications After TTO (N = 51 knees)*

| Complication                        | Value   |
|-------------------------------------|---------|
| Total reoperations                  | 7 (13.7)|
| Arthrofibrosis                      | 6 (11.8)|
| Hardware removal                    | 4 (7.8)*|
| Conversion to PFA                   | 1 (1.7) |
| Tibial fracture (due to fall)       | 1 (1.7) |
| Recurrent instability               | 0 (0)   |
| Nonunion                            | 0 (0)   |
| Infection (superficial, deep)       | 0 (0)   |
| Deep vein thrombosis, pulmonary embolism | 0 (0) |
| Chronic regional pain syndrome      | 0 (0)   |
| Neurovascular injury                | 0 (0)   |
| Wound dehiscence                    | 0 (0)   |

*Data are presented as n (%). PFA, patellofemoral arthroplasty; TTO, tibial tubercle osteotomy.

DISCUSSION

The purpose of this study was to report on the outcomes of an accelerated postoperative rehabilitation protocol in a cohort of patients after TTO. We hypothesized that patients who underwent a TTO procedure with an accelerated postoperative rehabilitation protocol would have no increase in postoperative complications compared with historical data of the classic rehabilitation protocol. Additionally, we hypothesized that patient perceptions of their knee function after the accelerated program would also be similar to outcomes of traditional programs and other knee surgical interventions. Overall, the findings of this study demonstrate that, generally, an accelerated rehabilitation (including early weightbearing and strengthening) program did not increase or exacerbate postoperative complications or negatively affect patient outcomes after a TTO procedure for patellar instability.

In this series of 50 patients who underwent TTO, primarily for recurrent instability, there were no major postoperative complications (Table 3). Patients in this study undergoing an accelerated rehabilitation program did not have any episodes of recurrent instability, nonunion, infections, deep vein thromboses, or other neurological injuries or symptoms. A small percentage (13.7%) did require subsequent surgical intervention to address joint stiffness and painful hardware. Overall, the results of this study demonstrate that an accelerated rehabilitation program after TTO does not exacerbate postoperative complications compared with the historical rate of perioperative complications.

Reoperation rates of 25% after TTO have been reported in past research, with multiple complications occurring in 43% of patients.23 Of the complications that arose within our study, issues requiring reoperation (arthrofibrosis, hardware removal) were the most common, occurring in 13% of the surgeries. Arthrofibrosis occurred in 12% of the cases in this cohort, which falls within previously reported incidence ranges of 5% to 22%.29,34,38,42 Although it may be expected that there would be reduced cases of arthrofibrosis with an accelerated rehabilitation program, there are many factors that can predispose a patient to restricted joint motion, such as past joint injury, limited presuppression range of motion, and early-onset OA. In the current study, 3 of the 6 patients who developed arthrofibrosis were undergoing TTO because of an OA diagnosis and had limited presuppression knee motion. This may have placed them at an increased risk for developing arthrofibrosis after surgery.

There was 1 postoperative tibial fracture at the site of the inferior screw secondary to a traumatic event (fall down the stairs) in this cohort. Past work has also reported a similar frequency of tibial fracture among TTO patients, occurring 8 weeks postoperatively after a fall.23 The tibial fracture within this series was managed nonoperatively with immobilization and went on to heal in slight varus alignment. This patient also had a previous diagnosis of Charcot-Marie-Tooth disease, which increased the patient’s risk for falls secondary to sensory dysfunction and anterior compartment motor weakness. As physical rehabilitative therapy can help improve muscle function in these patients, excluding individuals with these concomitant neurological diseases from certain aspects of rehabilitation post surgery may further limit their muscular function. Thus, it would seem prudent to protect patients with similar neurologic issues and modify accelerated postoperative rehabilitation programming as needed in this setting. The findings of this present study are in contrast to previous studies that recommend protected weightbearing immediately after surgery secondary to the risk of tibial fracture.20,21,42 The majority of fractures that occurred in those reports were secondary to unusual circumstances (such as a fall), as opposed to early initiation of weightbearing.

The overwhelming majority of patients in this study (92%) had their osteotomies secured with small-fragment implants. There were no cases of nonunion or implant failure. Contrary to the traditional method of fixation with 2 large-fragment implants, small-fragment implants have the advantage of a much lower profile and thus decreased risk of implant-related complaints.23,50 This was confirmed in this patient cohort, in which only 12 patients complained of implant-related pain, of whom only 4 had their implants removed, a rate of 7.8%. Previous studies suggest that on average, 3.5-mm screws are removed in 16% of cases,43 4.0-mm screws are removed in 30% of cases,32 and 4.5-mm screws are removed in 52% of cases.25,35,46 Although finite element analyses4 have been published on the effect of fragment shape and screw configuration, there have not been quality biomechanical studies performed on the effect of screw size. Based on the results of past23,32,35 and current work, the use of small-fragment implants appears to be a safe practice and leads to a decreased rate of implant-related complaints postoperatively, despite the implementation of an accelerated rehabilitation program.

Accelerated rehabilitation programs have been implemented after other lower extremity surgical interventions with the overall goal of reducing joint stiffness and persistent muscle weakness and improving patient outcomes. After ACL reconstruction,35,41 a large goal of rehabilitation...
has been to combat the effects of arthrogenic muscle inhibition and begin early neuromuscular reeducation to preserve quadriceps muscle health and function. Similarly, after total knee arthroplasty, it has been demonstrated that accelerated rehabilitation results in improvements in pain, muscle strength, and range of motion. The findings of this study corroborate past work done on accelerated rehabilitation programs, in which patients who immediately focused on early weightbearing and muscle strengthening/reeducation after TTO experienced full knee range of motion restoration.

In addition to physical improvements, evidence suggests that accelerated rehabilitation programs improve PRO scores during the early rehabilitation phase. Improved patient perceptions regarding function early in the rehabilitation phase have been previously associated with improved long-term physical function. At a minimum of 6 months postoperatively, patients within this cohort reported similar Kujala and KOOS5 scores to previous work in other realignment surgeries. Hodax et al. reported a mean Kujala score of 81.3 at 3.8 years after TTO and medial patellofemoral ligament (MPFL) procedures, which is slightly higher than the mean score of our study patients (72.98). These differences are likely a result of a longer postoperative follow-up time of 3.8 years in past work compared with 1.4 years for the current patients. Reports have demonstrated continued improvements in PROs in the years after surgical intervention, and this pattern holds true for our patients, who are further removed from surgery. Similarly, the mean KOOS5 score among patients in our cohort (75.05) indicates that after the early weightbearing and strengthening program, patients in our cohort were satisfied with their knee function with regard to pain, symptoms, activities of daily living, sports function, and quality of life. These results are in line with work from Vivod et al., who reported a KOOS mean of 66.68 in patients after MPFL reconstruction and tibial tuberosity transfer and a Kujala score mean of 68, which are lower than the patient scores in our cohort. Mulliez et al. also reported a lower KOOS (mean 67.4) in patients with patellofemoral realignment surgeries; however, the Kujala score (mean 74.7) reported in their work were comparable with the current study. Together, these findings demonstrate that completion of an accelerated rehabilitation program after TTO does not compromise patient satisfaction and perceived function.

Limitations

There are several limitations to this study. First, this study is a cross-sectional retrospective study capturing a single time point postoperatively of a single surgeon’s caseload, and thus, no additional comparisons could be made for surgical outcomes or subjective outcomes between patients’ over time or to a control group. Although we did not compare outcomes with a control group, normative data on PROs such as the KOOS have been reported, which allows for a comparison regarding perceived knee function. Compared with healthy controls, our patient population reported about 20 points lower on the KOOS5, but this is to be expected at a minimum of 6 months after TTO and should likely improve with time. Similarly, although we did evaluate outcomes in patients who participated in an accelerated rehabilitation program, no comparison was performed to a traditional, nonaccelerated program. Future research should evaluate whether an accelerated approach is more effective than traditional rehabilitation programs. We were also unable to capture enough presurgery PROs to make a strong comparison between improvements in KOOS5 and Kujalas scores over time, but as previously stated, our results for postoperative patient PROs are in line with past work.

A third limitation is that because of our sample size, we were not able to compare PRO scores between surgery types. This has the potential to influence our results, as undergoing concomitant surgical procedures may affect perceived function. Future work in larger patient populations, across various ages, should determine whether the indication for surgery, extent of surgical intervention, and accelerated rehabilitation programming affect patient-perceived function. Last, it is possible that some patients who underwent TTO did not complete the series of PROs at their 6-month follow-up and therefore were not included in this analysis. Thus, it is possible that the outcome scores may not be reflective of all patients undergoing this procedure. Future research should analyze patients further out from surgery to potentially capture these patients.

CONCLUSION

The accelerated rehabilitation program utilized in this cohort, incorporating early weightbearing, joint motion, and lower extremity strengthening after TTO, seems to be comparable with traditional rehabilitation protocols with regard to safety and resulted in no adverse short-term complications attributable to a more accelerated rehabilitation program. Patients may be allowed to bear weight as tolerated immediately after surgery, even with the osteotomy secured with small-fragment implants.

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APPENDIX

DETAILS OF THE ACCELERATED REHABILITATION PROGRAM

Early Motion Phase (weeks 1 and 2)

At the first postoperative visit, the patient’s brace is adjusted, and the hinged knee brace is unlocked to accommodate motion from 0° to 30° of knee flexion. During these first 2 weeks, patients are allowed to fully bear weight on their surgical limb as tolerated (with the use of crutches). In addition to enrollment in a typical rehabilitative program, patients are encouraged to begin home quadriceps activation exercises such as straight-leg raises, and quadriceps isometric contractions with electrical stimulation to encourage muscle activation/neuromuscular reeducation. Patients are encouraged to work through several sets of knee range of motion exercises daily with the brace off, focusing on achieving passive knee extension to 0° and knee flexion to at least 90° using the nonsurgical limb for support/motion.

Progressive Strengthening and Neuromuscular Control Phase (weeks 3-10)

Once satisfactory quadriceps activation and control is observed (typically by week 3), the hinged knee brace is unlocked to allow for knee range of motion between 0° and 70° of knee flexion. During weeks 4 and 5, the patient is transitioned out of the hinged knee brace as confidence, gait mechanics, and quadriceps control improve. Patients who received concomitant MPFL reconstructions are transitioned into an isolated small knee lateral buttress brace at this time. Strengthening of the quadriceps and hip musculature continues to be a focus of rehabilitation. Gait training/retraining may occur at this time to avoid/correct any compensatory ambulatory strategies that may have developed because of lower extremity musculature weakness postoperatively. At this time, patients may begin integration of an exercise bike as tolerated. During weeks 6 and 7, patients continue lower extremity strengthening of the lower extremity musculature focusing primarily on the hip musculature, with continued quadriceps strengthening. Closed-chain strengthening exercises are implemented at 4 weeks, and open-chain strengthening begins at approximately 8 weeks. Additionally, they begin to integrate balance/proprioception exercises and are progressed to pool running. Weeks 8 and 9 are centered on progression to more advanced proprioception training, introducing perturbation training, further endurance training, and continued lower extremity isometric and isokinetic strengthening exercises.

Advanced Activity Phase (weeks 11-16)

During this phase of rehabilitation, patients progress through a return to running program and/or light sports program (with the use of a lateral buttress brace for MPFL patients) as tolerated. Throughout this period, patients are instructed to continue with lower extremity strengthening exercises and neuromuscular training to support reintegration into running and functional activities.

Return to Functional Activity Phase (weeks 16-22)

Patients continue to perform lower extremity strengthening and neuromuscular training exercises, continuing to focus on the hip and quadriceps musculature. Integration into noncontact sports participation begins at this stage and is individualized based on a patient’s quadriceps function, gait mechanics, and readiness/confidence. At this time (progress depending), patients are cleared by the treating physician for noncontact practice/functional activities and continue to progress through running program and agility/sport-specific training as necessary dependent on their individual desires and/or preinjury activity level. Implants remain in place for a minimum of 4 months before the possibility of implant removal is entertained.