The Results of Tibial Tubercle Osteotomy for Revision Total Knee Arthroplasty

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Abstract: Tibial tubercle osteotomy was used in the surgical exposure of 67 knees in 64 patients undergoing revision total knee arthroplasty. The clinical and radiographic results were reviewed retrospectively. The mean follow-up time was 30 months (range, 5–60 months). Knee Society scores (KSS) confirmed good or excellent results in 87% of the knees, and the mean KSS was 86. The procedure was particularly effective in 2-stage exchanges for infected total knee arthroplasty, in which infection was eradicated in 9 of 10 cases, with a mean KSS of 82. In this series, no patellofemoral complications, no component malalignments, and no avulsions of the patellar tendon occurred. Serious complications directly related to the tibial tubercle osteotomy occurred in 5 patients (7%). **Key words:** revision, total knee arthroplasty, exposure, osteotomy, complications.

The incidence of revision total knee arthroplasty (TKA) continues to increase, with problems such as arthrofibrosis, metallosis, and osteolysis making the revision surgery more challenging. Conventional surgical exposures are usually inadequate for situations in which deformity, peripatellar contracture, and capsular inflammation that result from implant failure and deep infection are present. These revision cases require a much greater degree of exposure, and the integrity of the extensor mechanism is at risk.

Extensor mechanism rupture has been reported to occur in 0.17% to 1.4% of primary TKAs [1,2]. The incidence in revision cases has not been clearly defined, but it is believed to be much higher. Consequently, exposures have been developed to protect the extensor mechanism, particularly the patellar tendon insertion. Proximal release of the extensor mechanism was first described by Coonse and Adams [3] and is called the VY quadricepsplasty. Unfortunately, this technique typically requires postoperative immobilization and is associated with a high incidence of extensor lag [4,5]. Insall [6] subsequently modified the technique by extending the medial parapatellar approach into the vastus lateralis and preserving the inferior lateral geniculate vessels. He called it the patellar turndown procedure. In situations in which only a small additional increase in soft tissue release is necessary, the "quadriceps snip" developed and popularized by Garvin, Scuderi, and Insall [7], has been used with great effectiveness. The method of tibial tubercle osteotomy (TTO) was first applied to TKA surgery by Dolin [8,9]. Whiteside subsequently reported excellent results [10,11], although Wolff and Hungerford et al. [12] and Barrack and Smith et al. [13] reported an unacceptably high incidence of complications. Considerable controversy remains over the indications for the VY quadricepsplasty versus the TTO, and the technical de-

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Table 1. Indications

Indication for Revision Surgery	Patients (n)
Aseptic loosening	25
Painful component malposition	14
Polyethylene component wear	13
Arthrofibrosis, peripatellar contracture	12
Flexion instability/PCL insufficiency	11
Active infection	10
Metallosis	7
Patellar malalignment	5
Nonunion periprosthetic fracture	1
Polyethylene locking pin failure	1

tails of these procedures have not been perfected. The goal of this study is to report our experience with a TTO technique used in a series of difficult revision TKAs, and to compare our results with those of previously reported series. Our surgical technique has been mechanically tested in a cadaver model [14] and is a modification of that described by Whiteside and Ohl [10].

Materials and Methods

Patient Characteristics

This is a retrospective case study of 97 revision TKAs performed by the senior author (W.A.J.) between 1992 and 2001, in which failed components were removed and replaced. The preoperative and postoperative records and radiographs of these patients were reviewed. Of these, 67 knees in 64 patients underwent TTO for adequate and safe exposure. Patients included 39 women and 25 men, and knees treated were 35 right and 32 left knees. The patients ranged in age from 35 to 93 years (average, 65.6). The 67 knees had undergone an average of 1.76 prior operative procedures on the index knee (range, 1–5 procedures). Indications for the revision procedure are listed in Table 1. Some patients had more than one indication.

The decision to use a TTO for exposure was made intraoperatively if the patella could not be retracted with the knee at 90° of flexion without risking patellar tendon avulsion. TTO was reserved for use in only the most difficult cases, in which the patellar tendon was at actual risk of avulsion during the exposure of the tibial component in preparation for its removal. Medial parapatellar or midvastus approaches alone were used in 30 cases in which less contracture of the extensor mechanism was present.

Preoperatively, the patients were assessed by clinical examination and radiographs. Postoperatively, follow-up evaluations were performed at 4 weeks, 3 months, 6 months, and then yearly. Records from these evaluations were reviewed for the occurrence of local complications, and Knee Society clinical scores [15] were retrospectively assigned. Radiographs including standing anteroposterior, nonstanding lateral, and sunrise views, were examined for the presence of union or displacement of the osteotomy site, integrity of the wire fixation, presence of tubercle or tibial metaphyseal fracture, and patellofemoral congruity and tracking.

Surgical Technique

The most lateral skin incision scar from previous surgery was used. The initial capsular approach was the midvastus in 40 patients, medial parapatellar in 19, subvastus in 4, and not noted in 4. Intraoperatively, the decision to use a TTO for exposure was made if the patella could not be retracted with the knee at 90° of flexion without risking patellar tendon avulsion. The skin incision was then extended along the medial side of the tubercle to expose a 10-cm length. Using a powered oscillating saw irrigated with cold saline, an 8 to 10 cm long, 1.0 to 1.5 cm thick (at the thickest point) osteotomy was made from medial to lateral, just scoring the inner side of the lateral cortex.

A step cut at the proximal end of the osteotomy was made with a thin osteotome before the saw cut, as shown in Fig. 1, to provide resistance against proximal displacement. If, because of osteolysis or component subsidence, insufficient tibial bone stock exists proximal to the patellar tendon insertion to form this step of bone, then the osteotomy fragment is reduced against the anterior edge of the

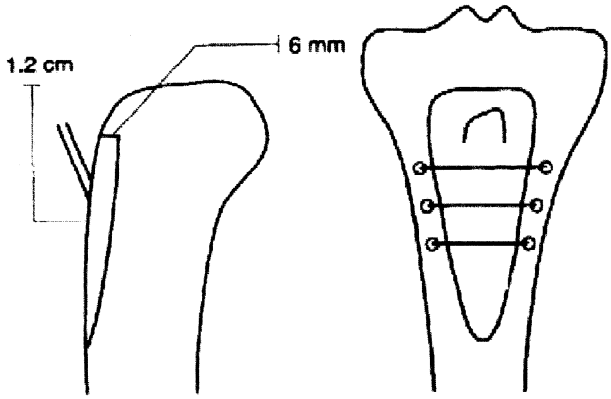

Fig. 1. Surgical technique is shown.

tibial component tray to provide resistance to proximal displacement.

The saw cut at the distal end of the osteotomy was gradually angled out of the anterior cortex (Fig. 1), so that the stress riser effect was reduced in the remaining tibial metaphysis. This was done to lower the risk of postoperative tibial stress fracture. The shape and length of the osteotomy are similar to that in Whiteside's descriptions [10,11]. Two osteotomes were used to open the osteotomy, hinging it on the intact lateral soft tissue attachments of the periosteum, crural fascia, and anterior compartment muscles. The anterior fat pad and associated soft tissue was released from the lateral tibial rim to complete the tibial component exposure. The tibial intramedullary canal was accessed through the osteotomy in 4 of the surgeries to facilitate removal of the implant and retained cement.

All 3 components (femoral, tibial, patellar) were revised in 47 cases, and a well-fixed patellar component with minimal poly wear was left in place in 20. Extended modular tibial stems (115 mm from the tibial base plate) were used in 65 of the 67 knees, and standard primary tibial components were used in 2. Cerclage wire fixation was used in all but one tubercle repair to avoid the difficulties of placing screws around intramedullary stems. Drill holes were made across the base of the osteotomy, then 3 to 6 18-gauge monofilament stainless steel wires were passed first through the holes and then through the lateral soft tissues with the aid of a 14-gauge cannulated needle.

The wires were then looped over the tubercle fragment and were twisted and tightened medially, as shown in Fig. 1. This loop cerclage wire configuration was our main technical modification of the Whiteside technique, in which the wires are passed through drill holes in the tubercle fragment. In our series, 5 wires were used in 41 knees, 4 wires in 15, 6 wires in 4, and 3 wires in 3 knees. Two wires combined with a single screw were used in one patient. In 3 knees, the number of wires could not be clearly determined.

After fixation was completed, the knee was taken through a full range of motion, and tracking of the patellofemoral joint was examined. A lateral release was used in 13 of the 67 knees to improve central tracking. In 64 knees, the tubercle was reduced anatomically. One tubercle was translated medially to improve tracking in a patient with chronic lateral patellar dislocation preoperatively. Two tubercles were intentionally reduced proximally 1 to 2 cm to address preoperative severe patella baja.

Postoperative management included a standardized protocol of immediate full weight bearing as tolerated, immediate supervised passive range of motion, and the use of an extension knee immobilizer. At the sixth postoperative week, the immobilizer was discontinued, and active extension and resistance exercises were begun.

Results

The average follow-up period was 30 months (range, 5–60 months). Three patients died of unrelated causes less than 6 months after surgery. Three patients were lost to follow-up time less than 1 year after surgery. Preoperative and postoperative Knee Society scores (KSS) could be assigned to 56 of the patients in the series. The average preoperative clinical score was 56, and the average postoperative score was 86. Only 4 patients had a lower score postoperatively, 2 related to pain not associated with the TTO. One patient developed a nonunion of the osteotomy and then a secondary infection that resulted in a lower score. The mean loss in these 4 patients was 9 points. According to the criteria of Stern and Insall [16], we had 36 (59%) excellent, 17 (27.9%) good, 5 (8.2%) fair, and 3 (4.9%) poor results.

The mean preoperative flexion arc for the whole group was 101°, which was increased to an average of 107° postoperatively. Four patients lost flexion over the preoperative values, but none had tubercle complications. Eleven patients gained more than 30° of flexion over preoperative values.

A total of 3 patients in this study (4.5%) who had no lag before the surgery developed a lag postoperatively, all related to proximal displacement of the osteotomy. The lag measured 5° in two patients. A 15° lag accompanied a nonunion with proximal displacement of the fragment in the third. Four of the 5 patients (80%) with an extensor lag preoperatively were improved and had no lag at follow-up evaluation. Neither of the patients with an intentional proximal reduction of the tubercle (for preoperative patella baja) had an extensor lag postoperatively.

Nine knees (13.4%) underwent postoperative closed manipulation under anesthesia to improve range of motion. The indication for manipulation was a maximum flexion of less than 80° and failure to progress with supervised physical therapy. Manipulation was performed between the eighth and sixteenth postoperative week. The mean final flexion achieved in this manipulated group was 99.4° (range, 90–120), and the mean KSS was 87 (range, 73–94). One fracture of the proximal tibia occurred

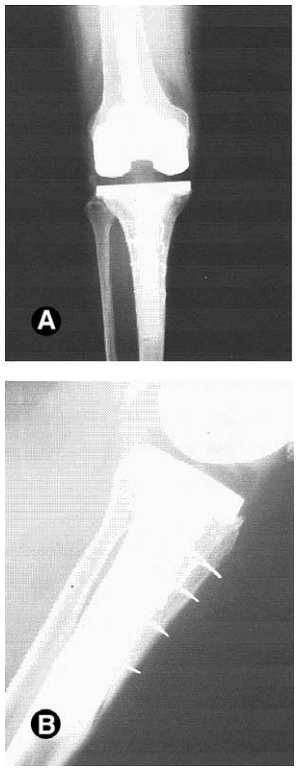

Fig. 2. Example of a healed tibial tubercle osteotomy (patient #35).

during manipulation and healed with closed treatment.

Preoperatively, 13 patients had either clinical or radiographic evidence of patellar malalignment, ranging from frank dislocation to mild tilting of the patella on the sunrise radiographic view. No patients had patellar complications postoperatively, and only one had a mild tilt on the postoperative radiograph, unchanged from his preoperative view. This patient's postoperative KSS was 100.

Ten patients with deep infection presented at a mean of 66 months (range, 12–240 months) after a previous primary TKA (8 patients) or a revision TKA (2 patients). We used a TTO during the surgical care of these patients. They were treated with a standardized protocol of 2-stage exchange arthroplasty, with interval intravenous antibiotics and antibiotic-impregnated static cement spacer. Five of these knees required TTO at both the implant removal and reimplantation procedures, with limited wire fixation of the tubercle osteotomy during the resection phase. The average time interval between the 2 procedures was 4.9 months (range, 3–16 months). The average postoperative KSS of these 10 was 82.5, and the average postoperative range of motion was 102°. These 5 patients remain free of infection at latest follow-up evaluation, with an average KSS of 79. One of the 5 had a 5° extensor lag.

Five other patients with deep infection required a TTO only for the reimplantation procedure. Four have remained infection free, with a mean KSS of 85. One patient initially recovered well, but subsequently developed a recurrent infection and was lost to follow-up evaluation. In summary, 9 of 10 (90%) deep infections were successfully managed using this protocol, all without significant extensor mechanism complications.

Postoperative radiographs in all patients showed stable position and appropriate alignment of the tibial, femoral, and patellar arthroplasty components. No progressive radiolucencies were noted.

Complications

Satisfactory healing of the osteotomy without nonunion, postoperative extensor lag, or tibial metaphyseal stress fracture occurred in 62 of the 67 knees (93%). No cases of patellar tendon avulsion were found. An example of a healed TTO is shown in Fig. 2. Minor complications that did not affect the final clinical result occurred in 20 knees (30%). These minor complications responded to simple nonoperative measures and are listed in Table 2. The average KSS of this group was 86. The osteotomy was purposely repaired proximally less than 2 cm (2 patients) or inadvertantly slipped proximally a distance of less than 2 cm postoperatively (13 patients). None of these patients had an extensor lag or weakness of extension. Eleven patients complained of mild tenderness when the tubercle fixation wires were palpated, and 2 required removal of the wires with resolution of the symptoms.

Serious complications related to the TTO occurred in 5 patients (7%). Symptomatic nonunion

Table 2. Minor Complications

Minor Complications	Knees (n)*	Knees (%)*
Proximal slippage of osteotomy <2 cm	13	22
Local tenderness	11	16
Delayed wound healing	5	7
Transient peroneal nerve palsy	3	4
Nondisplaced tibial stress fracture	2	3
Stable fibrous union of osteotomy	1	1.5

*More than one minor complication was present in some knees.

of the osteotomy occurred in 2 patients (3%). One was managed with open reduction, autologous bone grafting, and angled screw fixation. The osteotomy went on to heal, but the patient had continued chronic pain syndrome and a final KSS of 42. Another patient developed nonunion after the tubercle fragment slid proximally under the 5 looped wires. He underwent open reduction, bone grafting, and repeat wire fixation, but went on to recurrent nonunion when the fragment fractured through the drill hole for the distal bridle wire and migrated under the other 4 looped wires. The patient declined further surgery and developed a fibrous union, 4.0 cm of proximal migration of the osteotomy, a 15° extensor lag, and a final KSS of 80. No further treatment is planned for these patients.

Two patients (3%) developed an extensor lag postoperatively that could be attributed to loss of fixation and proximal slipping of the osteotomy. Neither of these patients had a knee flexion contracture or an infrapatellar tendon contracture (patella infera) preoperatively. The intraoperative and postoperative course for these patients was unremarkable, so we have no clear explanation for these technical failures. For comparison, 4 patients who had an extensor lag preoperatively did not have a lag on the final postoperative visit.

One tibial fracture occurred during closed manipulation under anesthesia, performed for postoperative stiffness. It appeared that this fracture occurred through a screw hole in the tibia. This screw was used to supplement the wire fixation of the osteotomy, and was the only screw used in the study group for this purpose. This fracture healed satisfactorily with closed management.

Discussion

Achieving wide exposure while protecting the extensor mechanism is the key to difficult revision knee arthroplasty. Many studies of revision TKA from excellent surgeons have reported significant complication rates. Rand, Morrey, and Bryan [17] reported only 50% good and excellent results in their series, with a 33% complication rate, and Haas and Insall et al. [18] reported 84% good to excellent results in their series, with an 8% revision rate. We report clinical results that are equal to or better than these series. We believe this is partly because of the improved exposure provided by the TTO. Although we report a significant complication rate attributed to the TTO, we believe that our complications would have been even higher without the exposure.

Simple retraction of a contracted patellar tendon can lead to inadvertant avulsion, a serious complication that is difficult to repair and that can sometimes lead to disastrous loss of function for the patient [19–24]. The incidence of patellar tendon avulsion has been reported to range from 0.17% to 1.4% in primary arthroplasty [1,2]. This is probably significantly higher in revision arthroplasty, although it has not been specifically reported. Extensor mechanism dysfunction in the form of quadriceps muscle weakness or knee extension lag is another potential complication of any anterior approach to the knee. In TTO techniques, the distal release is performed through bone, mobilization of the anterior structures is excellent, and repair can be secured by bone to bone fixation, permitting early rehabilitation and restoration of quadriceps excursion and strength. In contrast, with proximal exposures through soft tissue, such as the VY quadricepsplasty or turndown, range of motion and resistance exercises are delayed and extensor lag can occur. This osteotomy has been used successfully in the treatment of severe fractures of the distal femur, proximal tibia, and the patella [25,26], and has gained even wider use in the management of patellar malalignment conditions, in which the tubercle can be elevated or medialized to improve patellofemoral congruence and tracking [27–29].

Whiteside [10,11,30] has described a technique using an 8 to 10 cm long osteotomy with careful preservation of the lateral soft tissue attachments and fixed with obliquely oriented wires placed through drill holes in the fragment [10]. This TTO has been used specifically in the revision TKA patient with excellent results [10,11,31,32], but Wolf and Hungerford et al. [12] describe a serious complication rate of 23% in their series of TTO in complex TKA. Complications including nonunion, tubercle fragment fracture and displacement, and tibial metaphyseal fracture, have persisted. In view of the infrequent but serious risk of mechanical fixation failures, Davis and Caldwell et al. [14] modified the wire configuration to penetrate both cortices in the base of the osteotomy, then loop around the tubercle fragment, thus avoiding the stress riser effect of drill holes for either the wire or screw constructs previously described. This modification was mechanically tested in a cadaver model, and found to be very stable, though not quite as strong as a 2-screw technique [14]. This loop cerclage technique was used in all of the patients in this series.

Complications that responded to minimal, noninvasive treatments were carefully and rigorously reported in 30% of our patients, as noted in Table 2,

and were classified as minor because they did not affect the final outcome. The final outcome was good or excellent in all, with an average KSS of 86. We do not believe that the occurrence of these complications detracts from the utility or safety of the TTO, particularly in this group of difficult revision exposures.

Extensor lag is an important indicator of the loss of quadriceps mechanism function, and is severe when the patellar tendon is ruptured. Lesser degrees of lag reflect changes in length of the mechanism or loss of quadriceps muscle strength. Three patients in this study (4.5%) who had no lag before the surgery developed a lag, measuring 5° in 2 of them. A 15° lag accompanied a nonunion with proximal displacement of the fragment in the third. Four of the 5 patients (80%) with an extensor lag preoperatively were improved and had no lag at follow-up evaluation. These results confirm that the TTO, combined with early rehabilitation, is protective of extensor mechanism function, though formal quantitative strength testing was not performed. Trousdale and Hanssen et al. [5] studied the strength of knee extension after VY turndown in a series of TKA patients but did not report on the incidence of lag, making direct comparisons difficult. Barrack and Smith et al. [13] reported a trend toward more lag in a VY turndown group than with TTO.

Fracture of the proximal tibial metaphysis at the level of the distal extent of the osteotomy has been previously reported as a complication of TTO. It is a rare occurrence for TTO used in either revision TKA or for patellar realignment [11,33–36], and is likely a result of the mechanical weakening of the cortex at that point, the stress riser effect. Three of our patients (4.5%) sustained this complication, despite careful beveling of the distal end of the osteotomy. In 2, the presentation was shin pain in the postoperative period, associated with periosteal new bone in the region of the end of the osteotomy, consistent with nondisplaced stress fractures. These healed uneventfully with a period of protected weight bearing. The third tibia fractured acutely during a closed manipulation for postoperative stiffness, performed 7 weeks after revision surgery. This patient had chronic steroid-dependent rheumatoid arthritis and osteopenia, and the fracture occurred through the only screwhole used for tubercle fixation in the study, occurring below the level of the tibial intramedullary stem. The fracture was treated nonoperatively and healed in mild varus alignment. A 6- to 8-week period of limited weight bearing has been recommended by some researchers [33–35] for prevention of this complication after TTO in the patellar realignment patient. This recommendation should be considered in the revision TKA population as well.

In 4 of our patients, access to the endosteal proximal tibia was enhanced by the TTO, and permitted safe and efficient removal of retained implants and cement. This capability is unique to the TTO.

Barrack [37], Stiehl and Anouchi et al. [38], and Insall, Thompson, and Brause [39] have reported concerns regarding extensor lag when repeated exposures are made through the quadriceps snip or turndown. Although our sample size of 10 patients with deep infection as the indication for revision surgery is small, it is evident that TTO can be safely and effectively used in the particularly difficult setting of revision using the 2-stage strategy. We confirm that it can be used during both stages, which has been reported by Whiteside [11]. The extensive capsular inflammation, fibrosis, and edema in these patients make the initial exposure risky for tendon avulsion. More significantly, the interval of from 3 to 16 months in our patients, during which the knees were immobilized with the antibiotic impregnated spacer in place, can result in considerable stiffness and capsular contracture. Nonetheless, safe and adequate exposure was achieved in all 10 using the TTO technique described. Nine of the 10 infections were eradicated, and satisfactory function was restored. We agree with Barrack [37] that repeating exposure through a patellar turndown is risky for the development of extensor lag. We believe that 2-stage revision TKA for infection may be the best indication for TTO.

In summary, we report a single surgeon's experience with tibial tubercle osteotomy used in revision knee arthroplasty. We report a functional outcome that is consistent with that reported by Whiteside [11], but we found an incidence of complications that was closer to that reported by Wolfe and Hungerford et al. [12]. We believe that the absence of patellar tendon avulsions, patellofemoral tracking problems, or mechanical failure of the implants was caused by the unequivocally improved exposure afforded by the technique. The complications of TTO are mostly related to fixation of the osteotomy and can be minimized by careful surgical technique and postoperative supervision. The narrow and thin dimensions of the mostly cortical bone of the osteotomy, the proximity of the revision tibial stem with cement mantle, and the need for immediate repetitive cyclic loading during postoperative rehabilitation all place unique demands on the fixation construct. Although several methods of fixation of the osteotomy have previously been described [11,30,31,40,41], the optimal technique

has not yet been determined. This is the focus of our continued study using a biomechanical testing model [14]. Until the ideal method is determined, we recommend that fixation should be tested thoroughly before leaving the operating room, and, wherever possible, the tubercle fragment should have a barrier against proximal migration, whether this is a bone shelf from a step-cut or the anterior portion of the tibial tray. Special care should be given to rehabilitation considerations in the noncompliant or large patient who requires TTO.

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