Tibial Tubercle Osteotomy With Screw Fixation for Total Knee Arthroplasty

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abstract
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This study investigated the efficacy of tibial tubercle osteotomy (TTO) with screw fixation as part of the surgical treatment of primary complicated total knee arthroplasty (TKA) and revision TKA. From January 2000 to April 2011, 15 patients (15 knees) underwent revision TKA and 20 patients (21 knees) underwent primary TKA. The average patient age was 68.7±8.7 years. Patients underwent follow-up at the authors’ institution for an average of 60.6±32.9 months. Comparison of preoperative and postoperative Knee Society Scores and Knee Society Functional Scores showed significant postoperative improvement (P<.05). Moreover, postoperative range of motion of the knee improved from 88.5°±33.8° to 104.3°±18.2° (P<.05). Radiographic assessment showed that the average period to bone union was 59.4±5.9 mm, the average width at the proximal end was 18.9±2.9 mm, and the average thickness at the proximal end of the osteotomy was 10.3±1.2 mm. Tibial tubercle osteotomy provided wide exposure for TKA while protecting the extensor mechanism. Solid bone-to-bone fixation was achieved using TTO with 2 screws, and although the overall complication rate was 8.3%, none of the complications were associated with TTO itself. It is recommended that the bone fragment be 60 mm long, 20 mm wide, and 10 mm thick at the proximal end. Appropriate size of the osteotomized bone and solid screw fixation are essential to prevent complications during this procedure.

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Total knee arthroplasty (TKA) is a commonly performed surgery. Adequate surgical exposure to confirm bony landmarks and ligament balancing is essential to restore knee function and achieve long-term success. Among several surgical methods, the medial parapatellar approach is generally considered the most common and successful; however, occasionally, this approach is not considered the optimal exposure during revision TKA or for fixed valgus knees or stiff or ankylosed knees. Exposure can be difficult during revision TKA because of restricted range of motion (ROM), adhesion of soft tissues, and patella baja. Approximately 10% to 15% of patients who undergo primary TKA present with valgus deformity. TKA exposure in a patient with a fixed valgus deformity might prove difficult.

In these cases, exposure techniques, including quadriceps snip, quadriceps turn-down, and tibial tubercle osteotomy (TTO), are considered among the surgical options. Tibial tubercle osteotomy has several advantages because it provides wide knee joint exposure and can be useful in removing a tibial prosthesis. In addition, TTO allows bone-to-bone healing and maintains the blood supply to the patella and surrounding soft tissue. However, postoperative extensor lag, proximal migration of the tibial tubercle, and tibial fracture are complications associated with TTO, although no large population studies have been conducted on TKA with TTO exposure. The authors use TTO with screws during revision TKA and for fixed valgus deformities. Both screws and cerclage wires are commonly used to fix bone fragments; however, few reports have investigated screw fixation.

The goal of this study was to investigate the clinical results and complications of TKA with TTO along with the efficacy of screw fixation.

**Materials and Methods**

From January 2000 to April 2011, 1774 primary and revision TKA surgeries were performed at the authors’ institution. Of the 1774 knees, 36 knees of 35 patients (2%) who underwent TTO as part of surgical treatment were identified retrospectively from the arthroplasty database. Fifteen patients (15 knees) underwent revision TKA and 20 patients (21 knees) underwent primary TKA; these patients included 9 men and 26 women (mean age, 68.7±8.7 years; range, 46-83 years). Average patient height was 1.5±0.1 m (range, 1.4-1.7 m), and average weight was 59.9±10.1 kg (range, 34-78 kg). Body mass index was defined as weight in kilograms divided by the square of the patient’s height in meters (mean, 26±3.7 kg/m²; range, 14.3-31.2 kg/m²).

The reasons for revision TKA included infection (8 knees) and aseptic loosening (7 knees). Primary TKA with TTO was performed because of severe fixed valgus deformity of the knee with restricted motion caused by osteoarthritis (11 knees), rheumatoid arthritis (4 knees), and restricted motion and patella baja after high tibial osteotomy (6 knees). All of the surgeries performed for infection were divided into 2 stages. In revision TKA, TTO was used if the patella could not be retracted enough with the knee at 90° flexion. The lateral parapatellar approach with TTO was used for primary TKA with a severely valgus knee if forcing varus stress could not correct these deformities or if knee flexion was severely disturbed, impeding patellar tendon avulsion.

Clinical examination and radiographic findings were evaluated preoperatively and at final follow-up.

The following parameters were investigated: operating time; flexion and degree of knee extension, including ROM; Knee Society Score (KSS); and Knee Society Functional Score (KSFS). Anteroposterior and lateral radiographs with weight bearing (100 mA, 0.05-s exposure at 60 kV, depending on soft tissue thickness) were recorded. In addition, angles of the varus or valgus deformity were evaluated and compared and the coronal mechanical axes of the long leg were recorded preoperatively and postoperatively. Furthermore, the shape and size of the osteotomized tibial tuberosity, the period of bone union, and complications such as tubercle or tibial fracture were investigated with commercially available imaging software (Synapse, Fujifilm, Tokyo, Japan). The digital imaging software has been confirmed to measure the size of the osteotomized bone accurately. In addition, bone union was assessed by lateral radiographs and was determined to have occurred when the osteotomized line disappeared. These evaluations were performed at least 3 times in each patient by 2 authors (N.C. and K.I.) who were blinded to the clinical information. The final judgment was defined on the basis of these data.
All surgeries were performed by experienced arthroplasty surgeons at the authors’ institution. Exposure was first attempted with a medial parapatellar approach except in the case of a valgus knee. However, when adequate exposure could not be achieved, the authors proceeded with TTO.

For revision TKA and TKA after high tibial osteotomy with TTO, all patients underwent medial parapatellar arthroplasty with TTO performed with a powered oscillating saw and an osteotome. Cold saline was applied to prevent heat production, which would lead to devitalization of the TTO site when using the powered oscillating saw. The bone fragments were 60 to 80 mm long, 10 to 20 mm wide, and 10 mm thick at the proximal end. A step cut was made at the proximal end of the osteotomy after the patellar tendon insertion was marked to prevent proximal migration of the bone fragment (Figure 1).

The bone fragment thickness was gradually tapered to reduce the stress at the anterior tibia. When all of the cuts were completed, the bone fragment was elevated from the medial to the lateral side to act as a soft tissue hinge. The lateral periosteum and musculature remained attached to the bone fragment to maintain stability and blood supply favorable for bone union. In addition, the cement around the stem was removed through the osteotomy when removing the tibial implant would be difficult because of rigid fixation of the stem.

After the new prosthesis was implanted, the stability of the osteotomized fragment and patellar tracking were assessed during knee flexion. Thereafter, the authors evaluated the knee ROM and tracking of the patella. All of the bone fragments were reduced to their original position, and it was not necessary for fragments to be moved to improve patellar tracking. The bone fragment was fixed with 2 4.5-mm cortical screws. Lateral release was added in 5 of the 15 knees with revision TKA for further improvement of tracking.

The postoperative rehabilitation protocol was similar to that for standard primary TKA. Continuous passive motion was initiated after the drain was removed on surgical day 2, and weight bearing was allowed as soon as the patients could tolerate it postoperatively. Further, knee flexion exercises were freely allowed. When solid fixation of the tibial tubercle was not achieved because of poor bone quality, a splint was used for 6 weeks.

A lateral parapatellar approach was used with TTO for primary TKA and a fixed valgus knee deformity. Tibial tubercle osteotomy was performed with the same method as used for revision TKA except that the direction of the bone fra-
ment was everted from the lateral to the medial side, leaving the soft tissue attachment intact (Figure 2). The size and shape of the bone fragment were the same, and wide exposure of the knee joint was obtained when it was hinged medially. The bone fragment was fixed with 2 4.5-mm cortical screws after implantation of the prosthesis (Figure 3).

The same postoperative rehabilitation protocol was used as described earlier when rigid fixation was achieved.

Statistical Analysis
Statistical analysis was performed with the SPSS package (SPSS, Chicago, Illinois). The paired t test was used, and results were considered significant at $P<.05$. 

RESULTS
Patients were observed for follow-up at the institution for an average period of 60.6±32.9 months (range, 16-116 months). Of the 35 patients, none were lost to follow-up for 1 year after surgery.

The average operating time was 144.8±35.9 minutes (range, 92-235 minutes). Comparison of the preoperative and postoperative knee flexion angles showed significant improvement postoperatively ($P<.05$). Furthermore, comparison of preoperative knee extension angles and ROM showed significant differences compared with postoperative knees ($P<.05$). Both KSS and KSFS improved significantly postoperatively (Table 1).

Postoperative varus and valgus deformity angles improved significantly from those observed preoperatively ($P<.05$; Table 1). The average time for bone union was 10.8±5 weeks (range, 5-28 weeks). The average length of the bone fragment was 59.4±5.9 mm (range, 44-67 mm), the average width at the most proximal end was 18.9±3.9 mm (range, 14-24 mm), and the average thickness at the proximal end of the osteotomy was 10.3±1.2 mm (range, 8-12 mm) (Table 2).

The average operating time for revision TKA was 170.1±28.8 minutes (range, 137-235 minutes). KSS and KSFS improved significantly after surgery ($P<.05$), but the degree of knee flexion, knee extension, and ROM did not improve (Table 3). Moreover, the preoperative deformity toward the coronal mechanical axis improved significantly as well ($P<.05$; Table 3). The length, width, and thickness of the bone fragment were 59.3±1.1 mm (range, 52-67 mm), 18.9±3.6 mm (range, 14-24 mm), and 10.4±1.1 mm (range, 8-12 mm), respectively (Table 2).

The average operating time for primary TKA was 127.9±30.2 minutes (range, 92-216 minutes). Further, the degree of knee flexion, knee extension, ROM, and deformity toward the coronal mechanical axis improved significantly postoperatively ($P<.05$). In addition, KSS and KSFS improved significantly postoperatively ($P<.05$; Table 4). The length, width, and thickness of the bone fragment were 60.5±6.5 mm (range, 44-67 mm), 19.3±2.6 mm (range, 16-24 mm), and 10.3±1.2 mm (range, 8-12 mm), respectively (Table 2).

Complications
No intraoperative or TTO-related complications were observed. However, 3 (8.3%) patients had postoperative compli-

<table>
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<th>Table 1</th>
<th>Comparisons Between Preoperative and Final Follow-up Results of All Cases</th>
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<tr>
<td>Clinical Outcome</td>
<td>Preoperative</td>
</tr>
<tr>
<td>Average knee flexion, ° (range)</td>
<td>97.8±28.1 (30-140)</td>
</tr>
<tr>
<td>Average knee extension, ° (range)</td>
<td>-10.2±12.1 (-35-0)</td>
</tr>
<tr>
<td>Average range of motion, ° (range)</td>
<td>88.5±33.8 (15-140)</td>
</tr>
<tr>
<td>Average KSS, points (range)</td>
<td>37.1±21.1 (0-66)</td>
</tr>
<tr>
<td>Average KSFS, points (range)</td>
<td>36.2±15.8 (0-65)</td>
</tr>
<tr>
<td>Average angles of varus or valgus deformity, ° (range)</td>
<td>11.7±6.9 (0-33)</td>
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$^a$Statistically significant difference $P<.05$.

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<th>Table 2</th>
<th>Comparisons of the Size of Bone Fragment in Tibial Tubercle Osteotomy</th>
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<tr>
<td>Size</td>
<td>Primary Total Knee Arthroplasty</td>
</tr>
<tr>
<td>Average length, mm (range)</td>
<td>60.5±6.5 (44-67)</td>
</tr>
<tr>
<td>Average width, mm (range)</td>
<td>19.3±2.6 (16-24)</td>
</tr>
<tr>
<td>Average thickness at proximal end, mm (range)</td>
<td>10.3±1.2 (9-12)</td>
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cations: infection in a patient with rheumatoid arthritis and severe valgus knee deformity, postoperative hypoxemia as a result of suspected pulmonary embolism in the 2nd patient, and supracondylar fracture of the femur because of a fall in the 3rd patient. All of these complications were resolved during the follow-up period. No patient had extensor lag at final follow-up.

**Discussion**

Adequate exposure and protection of the extensor mechanism is essential during TKA. Insufficient exposure leads to several problems, including patellar tendon rupture and inadequate prosthesis position,\(^{13,14}\) which lead to instability and malalignment that are associated with short-term survival of TKA.\(^{15,16}\) Preoperative evaluation and adequate knowledge of specialized surgical techniques are essential for avoiding potentially serious problems, particularly in stiff knees, ankylosing knees, and knees with severe fixed valgus deformities.\(^{12,17,18}\)

If a simple medial parapatellar approach cannot provide sufficient exposure, techniques such as quadriceps snip, quadriceps turn-down, and TTO have been described.\(^{5,6,19,22}\) Occasionally, quadriceps snip does not provide sufficient exposure, and quadriceps turn-down has the disadvantage of devascularizing both the patella and the quadriceps tendon.\(^{17}\) Extension lag might occur with quadriceps turn-down, which suggests that transection of the quadriceps tendon weakens the extensor muscle group. Therefore, quadriceps turn-down would restrict postoperative rehabilitation to a certain degree.

The 1st report of TTO was by Dolin in 1983,\(^{20}\) with modification reported by Whiteside and Ohl\(^{2}\) and Whiteside.\(^{6}\) This technique allows a wide surgical area and bone-to-bone fixation; in addition, TTO can be useful for removing the tibial prosthesis and cement during repetitive operations. However, several complications, such as bone fragment migration, tibial and bone fragment fractures, and nonunion, have been reported.\(^{5,10}\)

Mendes et al\(^{11}\) reported that the rate of complications associated with TTO in 67 revision TKA procedures was 7%, including postoperative extensor lag caused by proximal migration of the tibial tuberosity, tibial metaphyseal fracture, and nonunion. Moreover, Burki et al\(^{12}\) reported 51 patients (61 cases) who underwent primary TKA (valgus knees or knees that had undergone previous nonarthroplasty surgery) using the lateral approach and TTO. In their series, complications associated with the technique included hematomas in 4 patients and compartment syndrome in 1 patient, but no patellar necrosis or tibial fracture occurred.\(^{12}\) In the current study, no complications associated with TTO,

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<th>Table 3</th>
<th>Comparisons Between Preoperative and Final Follow-up Results in Revision Total Knee Arthroplasty</th>
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<tr>
<td>Clinical Outcome</td>
<td>Preoperative</td>
</tr>
<tr>
<td>Average knee flexion, ° (range)</td>
<td>95.5±29.5 (30-130)</td>
</tr>
<tr>
<td>Average knee extension, ° (range)</td>
<td>-1±3.2 (-10-0)</td>
</tr>
<tr>
<td>Average range of motion, ° (range)</td>
<td>96.3±28.3 (30-130)</td>
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<tr>
<td>Average KSS, points (range)</td>
<td>42.3±19 (6-66)</td>
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<tr>
<td>Average KSFS, points (range)</td>
<td>40.9±16.3 (20-65)</td>
</tr>
<tr>
<td>Average angles of varus or valgus deformity, ° (range)</td>
<td>5.1±1.9 (0-14)</td>
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**Abbreviations:** KSFS: Knee Society Functional Score; KSS: Knee Society Score.

*Statistically significant difference P<.05.

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<th>Table 4</th>
<th>Comparisons Between Preoperative and Final Follow-up Results in Primary Total Knee Arthroplasty</th>
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<tr>
<td>Clinical Outcome</td>
<td>Preoperative</td>
</tr>
<tr>
<td>Average knee flexion, ° (range)</td>
<td>99.1±26.8 (45-140)</td>
</tr>
<tr>
<td>Average knee extension, ° (range)</td>
<td>-14.1±12.1 (-35-0)</td>
</tr>
<tr>
<td>Average range of motion, ° (range)</td>
<td>85±34.8 (15-140)</td>
</tr>
<tr>
<td>Average KSS, points (range)</td>
<td>33.5±21.1 (0-70)</td>
</tr>
<tr>
<td>Average KSFS, points (range)</td>
<td>31.7±15.9 (0-65)</td>
</tr>
<tr>
<td>Angles of varus or valgus deformity, ° (range)</td>
<td>12.3±8.4 (0-33)</td>
</tr>
</tbody>
</table>

**Abbreviations:** KSFS, Knee Society Functional Score; KSS, Knee Society Score.

*Statistically significant difference P<.05.
such as fracture of the tibial tuberosity or tibia, occurred.

It is important to obtain the optimum TTO size to decrease TTO-related complications. In previous reports, TTO length varied from 70 to 100 mm, width varied from 10 to 20 mm, and thickness at the proximal tibia varied from 10 to 20 mm.6-7,11,18,23,24 In addition, several surgeons reported that if the TTO was too large, it could lead to tibial fractures, and if it was too small, the risk of fracture or migration of the bone fragment increased.\(^5,6,11\) Wolff et al\(^17\) reported 3 cases of migration of a bone fragment in 26 knees and concluded that either a bone fragment less than 30 mm or fixation with 1 screw or staple led to this complication. In addition, it is important to obtain proper shape of the bone fragment. A step cut at the proximal end of the osteotomy and a tapered cut at the distal end are recommended. The former is used to prevent proximal migration of TTO, and the latter is used to reduce the stress riser effect.\(^11\) In the current study, all of the bone fragments were of optimal size and appropriate shape. The authors believe that this was one of the reasons for the lack of TTO-related complications.

Screws and cerclage wires are the commonly used fixators.\(^7,10-12\) Wire fixation seems to be more common because of a concern about obstacles to the tibial prostheses.\(^7\) However, some reports have suggested that the use of screws allows for much stronger fixation.\(^25,26\) For these reasons, the authors selected screw fixation and consider this a simple technique if care is taken to avoid screw interference with the stem of the tibial prosthesis. As a result, strong fixation of the bone fragment with 2 screws enables good bone union. The authors believe that the direction and position of the screws and the size and shape of the bone fragment are equally important for the success of this procedure.

A lateral parapatellar approach with TTO was used in primary TKA in severely valgus knees. The advantage of the lateral parapatellar approach is that no lateral retinacular release needs to be added, as reported by Keblish,\(^22\) and lateral contractions of the knee can be corrected more easily. By evertting the tibial tubercle with TTO, wide exposure of the knee joint is obtained. Another advantage is that medial parapatellar soft tissue and medial patellar blood supply can be maintained. In addition, if necessary, the tibial tubercle can be transferred to improve patellar tracking. These are particularly important considerations in severely valgus knees. In revision TKA with patella baja, the tibial tubercle can be transferred to the proximal position when the extensor mechanism is too stiff to bend the knee joint.

A limitation of this study was the lack of comparison with another exposure method. Therefore, it is impossible to conclude that TTO with screw fixation is superior to other exposure techniques. However, the authors believe that the strength of this study is the relatively large intensive series with this exposure technique for relatively rare conditions such as infection and severely valgus knees.

**CONCLUSION**

This study used TTO for primary TKA in severely valgus and ankylosing knees along with revision TKA. The findings showed solid bone-to-bone fixation during TTO using 2 screws, with significantly improved clinical results and the lowest ever complication rate compared with previous reports. The bone fragment should be 60 mm long, 20 mm wide, and 10 mm thick at the proximal end to avoid complications. Use of an appropriately sized osteotomized bone with solid screw fixation is important to prevent complications. The authors concluded that TTO provides wide exposure that affords protection of the extensor mechanism and that fixation of TTO with 2 screws was a key to the success of this procedure.

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