Original article

Tibial tubercle osteotomy hinged on the tibialis anterior muscle and fixed by circumferential cable cerclage in revision total knee arthroplasty

Y.P. Le Moulec\textsuperscript{a,} T. Bauer\textsuperscript{a,}\textsuperscript{b}, S. Klouche\textsuperscript{a,}*, P. Hardy\textsuperscript{a,}\textsuperscript{b}

\textsuperscript{a} Hôpitaux universitaires Paris Île-de-France Ouest, AP–HP, 9, avenue Charles-de-Gaulle, 92100 Boulogne-Billancourt, France
\textsuperscript{b} Université de Versailles Saint-Quentin-en-Yvelines, UFR des Sciences de la santé, 78035 Versailles, France

\begin{abstract}
Background: Difficulties in knee exposure during revision total knee arthroplasty (RTKA) may require tibial tubercle osteotomy (TTO). The main objective of this study was to assess union after TTO hinged on the lateral soft tissues and fixed using circumferential cable cerclage during RTKA.

Hypothesis: Non-union is uncommon with this technique.

Patients and methods: We retrospectively included consecutive patients who underwent RTKA between 2008 and 2010 with TTO. Chevron osteotomy was performed and the fragment was left hinged laterally on the tibialis anterior muscle then fixed using circumferential cerclage with one or two steel cables. The primary evaluation criterion was TTO union as assessed on radiographs. Secondary evaluation criteria were time to union, osteotomy fragment migration, patellar height, and the IKS score at last follow-up. We included 65 patients with a mean age of 72 ± 11.3 years including 39 (60%) undergoing septic revision and 26 (40%) aseptic revision. Mean follow-up was 27.8 ± 10.7 months; there was 1 early death, which was unrelated to the surgery, and another patient was lost to follow-up.

Results: TTO union was achieved in 59/63 (93.7%) patients. Fragment migration occurred in 4 (6.3%) patients. Mean time to union was 16.9 ± 5.1 weeks overall, 12.4 ± 2.0 in the aseptic revision group, and 18.9 ± 4.8 in the septic revision group (P = 0.0005). Patellar height at last follow-up was not significantly changed compared to the preoperative value (P = 0.09). At last follow-up, the mean IKS knee and function scores were significantly improved (P < 0.05).

Conclusion: TTO hinged on the lateral soft tissues and fixed by circumferential cable cerclage ensured union in the vast majority of patients, with a low rate of tubercle migration.

Level of evidence: IV, retrospective study.

© 2014 Elsevier Masson SAS. All rights reserved.

1. Introduction

Obtaining adequate exposure during total knee arthroplasty (TKA) may be challenging. The risk of damage to the extensor mechanism has been estimated at 0.17% to 1.4%\textsuperscript{[1,2]} in primary TKA and is probably higher in revision TKA (RTKA).

Tibial tubercle osteotomy (TTO) is widely used to improve exposure during primary or RTKA of difficult knees. Dreaded complications of this procedure consist of extensor mechanism disruption and poor TKA outcomes in the event of difficult repositioning of the osteotomy fragment. The antero-medial approach is standard for both primary and RTKA, whereas the lateral approach is advocated in patients with severe knee deformities or patello-femoral osteoarthritis\textsuperscript{[3–6]}. Piedade et al.\textsuperscript{[7]} found no significant differences in outcomes between TTO via the lateral approach and standard antero-medial exposure without TTO.

Potential complications consist of secondary osteotomy fragment displacement due to inadequate internal fixation and non-union, both of which may result in loss of active knee extension; fracture of the osteotomy fragment; discomfort caused by the fixation material; and skin necrosis\textsuperscript{[7]}.

Adequate TTO fixation is imperative to allow knee rehabilitation without osteotomy fragment migration. The main methods are screw fixation and trans-osseous suturing, both of which may prove inadequate if the tibial bone stock is limited. In addition, screw fixation of the osteotomy fragment carries a risk of vascular injury.

The objective of this study was to evaluate fixation efficacy when the TTO was left hinged on the tibialis anterior muscle and fixed

\textsuperscript{*} Corresponding author. Tel.: +33 62 83 50 478.
E-mail addresses: klouche.shahnaz@yahoo.fr, sklouche@gmail.com (S. Klouche).

http://dx.doi.org/10.1016/j.otsr.2014.02.012
1877-0568/© 2014 Elsevier Masson SAS. All rights reserved.
using one or two circumferential cables in patients undergoing revision TKA followed by early active rehabilitation. Our working hypothesis was that this technique was associated with a low non-union rate and good functional outcomes.

2. Patients and methods

We conducted a single-centre retrospective study in consecutive patients who underwent RTKA with TTO between January 2008 and December 2010 for septic or aseptic prosthesis failure. The need for TTO was established intra-operatively when dislocation of the patella proved difficult. TTO was performed more readily in septic revisions to allow complete synovectomy.

2.1. Description of the patient population

During the study period, 100 patients underwent RTKA at our centre, including 55 for infection. TTO was performed in 65 patients, including 39 (60%) with and 26 (40%) without infection. There were 29 males and 36 females with a mean age of 72 ± 11.3 years. TTO had been performed previously in 11 patients, (9 for infection).

2.2. Operative technique

An antero-medial arthrootomy was performed. Chevron TTO with gentle tapering was achieved using an oscillating saw (Fig. 1). The bone fragment was left hinged on its lateral attachments, in continuity with the tibia aneurterior muscle. The TTO facilitated cement removal in patients with cemented prostheses. Mean osteotomy fragment length was 7.7 ± 1.6 cm. The fragment was fixed in its original position using Dall-Miles™ cable cerclage (Stryker, Kalamazoo, MI, USA). Cable diameter was 1.6 mm. The cable was passed circumferentially, around the posterior aspect of the tibia (Fig. 1), with the knee flexed at 90° to maintain the popliteal pedicle at a safe distance. A cable passer was used to pass the cable in a three-step procedure (Fig. 2). Two cables were used in the first 8 patients then a single cable due to changes in practice in the next 57 patients. The cable lock was positioned laterally to ensure sufficient soft-tissue coverage, thereby minimising the risk of injury. The knee was immobilised in an extension splint for 1 month. Rehabilitation was started immediately after the revision, with active flexion to 90° and passive extension. Standard thromboprophylaxis with low-molecular-weight heparin was given.

2.3. Outcome assessment methods

In each patient, the surgeon performed a clinical evaluation after 1, 2, 3, 6, and 12 months then every 2 years. All imaging studies were analysed specifically for the study.

The primary evaluation criterion was ATT union (yes/no) defined as disappearance of the osteotomy line on standard radiographs, which included weight bearing antero-posterior, lateral, and 30°-flexion skyline views obtained at each postoperative visit.

Secondary evaluation criteria were time to union, osteotomy fragment migration greater than 5 mm (yes/no) [8–10], patellar height as assessed using the Blackburne-Peel Index (BPI, Fig. 3) [11] (BPI < 0.5, patella baja; 0.5 < BPI < 1, normal height; and BPI > 1, patella alta), and knee motion ranges including active extension lag and the International Knee Society (IKS) score [12] at last follow-up.

2.4. Statistical methods

Distribution normality was assessed using the Shapiro-Wilk test. When distribution was normal, quantitative variables were compared using the paired Student’s t test (preoperative versus postoperative) or unpaired Student’s t test (independent groups); whereas qualitative variables were compared using the McNemar test (preoperative versus postoperative) or chi-squared test (independent groups). Non-normal quantitative variables were compared using the Wilcoxon test (preoperative versus postoperative) or Mann-Whitney test (independent groups) and non-normal qualitative variables using the exact McNemar exact (preoperative versus postoperative) or exact Fisher test (independent groups). Values of P less than 0.05 were considered significant.

3. Results

Of the 65 patients, 1 (septic revision) died of a cause unrelated to the surgery and another (aseptic revision) was lost to follow-up, leaving 63 patients for the analysis, including 8 (2 septic and 6 aseptic revisions) managed with two cables and 55 (36 septic and 19 aseptic revisions) with a single cable. Mean follow-up was 27.8 ± 10.7 months (range, 12–52 months). Osteotomy union occurred in 59 (93.7%) of the 63 patients (all 8 patients with two cables and 51 of 55 patients with a single cable) (Fig. 4). Non-union occurred in the remaining 4 (6.3%) patients (2 septic and 2 aseptic revisions, P=0.66). Of these 4 patients, 2 had a previous history of TTO. Symptomatic fragment migration occurred in 1 patient with non-union and was managed with bone grafting and repeated cerclage, which ensured union of the ATT.

ATT migration was noted in 4 (6.3%) patients, including 1 of the 8 patients with two cables and 3 of the 55 patients with a single cable. The first patient experienced early migration with upwards displacement of the osteotomy fragment on day 15 during a rehabilitation session. Revision surgery was performed for cerclage with a single cable, and union was achieved. The second patient had two previous TTO for prosthesis infection and was managed with arthrodesis. In the remaining 2 patients, the osteotomy fragment showed 1 cm of migration 2 months after surgery and healed in this position. These patients had active extension lags of 20° and 30°, respectively, but did not undergo further surgery.

No cases of tibial or patellar fracture or of extensor mechanism disruption were recorded.

Mean time to healing was 16.9 ± 5.1 weeks overall, 18.9 ± 4.8 weeks in the 38 septic revisions, and 12.4 ± 2.0 weeks in the 25 aseptic revisions (P=0.0005).
Fig. 2. Three-step procedure for cable passage. A. The anterior tibial tuberosity is hinged laterally on the tibialis anterior muscle. B. First step, passage from the posterior aspect of the tibia to the medial tibial cortex. C. Second step, passage from the lateral cortex to the posterior aspect of the cortex. D. Third step, passage through the tibialis anterior muscle to the anterior aspect of the anterior tibial tuberosity.

Of the 11 patients with a previous history of TTO, including 9 during septic revision, 9 (81.8%) achieved ATT union, after a mean of $17.7 \pm 3.7$ weeks. In 4 of these 11 patients, screw fixation of the osteotomy fragment had been used previously.

Patellar height was comparable preoperatively and at last follow-up, although the $P$ value was near the significance threshold ($P=0.09$) (Table 1). The number of knees with patella alta was significantly greater at last follow-up than preoperatively (12/63 vs 4/63, $P=0.03$). Of the 12 knees with postoperative patella alta, 3 had non-union of the ATT fragment but did not undergo revision surgery, 2 had migration of the ATT with union, and 2 had preoperative patella alta.

Mean flexion-extension range was $87.8 \pm 16.5^\circ$ preoperatively and $103.7 \pm 12.9^\circ$ at last follow-up ($P<10^{-5}$). Active extension lag at last follow-up was no greater than $10^\circ$ in 11/63 (17.5%) patients, $20^\circ$ in 1 patient, and $30^\circ$ in 3/63 (1.6%) patients.

Fixed flexion deformity of the knee was present in 7/63 (11.1%) patients preoperatively and 10/63 (15.9%) at last follow-up. Fixed flexion was $<10^\circ$ in 7/63 (11.1%) patients and $10^\circ$ to $20^\circ$ in 3/63 (4.8%) patients ($P=0.60$).

Mean IKS scores were significantly improved at last follow-up compared to the preoperative values in both the septic and aseptic revision groups (Table 2). Preoperatively, mean IKS knee and function scores were significantly better in the aseptic than septic group ($P=0.01$ and $P=0.007$, respectively). At last follow-up, only the IKS function score was significantly better in the aseptic group ($P=0.02$).

4. Discussion

In our study, 93.7% of patients achieved ATT union 17 weeks on average after TTO hinged on the tibialis anterior muscle and fixed using circumferential cable cerclage with one or two cables during RTKA. In the septic revision group, the healing rate was 92% and mean time to healing was 19 weeks.

Union was achieved in all 8 patients managed using two cables and in a highly satisfactory proportion of those managed using a single cable. Given the potentially higher risk of vascular injury with two cables, we recommend cerclage with a single cable.

Several factors may contribute to TTO union. Fragment length must be sufficient to ensure the extent of bone–bone contact needed to achieve union and to allow internal fixation with no risk of fracture. Mean fragment length in our patients was 7.7 cm. Union was obtained in most patients and no fractures occurred. Wolff et al. [13] reported that a fragment length of less than 3 cm precluded adequate internal fixation. Whiteside et al. [14] advocated a fragment size of 8–10 cm in length, 2 cm in width, and 2 cm in depth. In a study by Chalidis et al. [8], compared to intracortical osteotomy, intramedullary extension of the cut may increase time to union by diminishing the surface area of cortical–bone contact. Chevron osteotomy with intramedullary extension is self-locking and minimises transverse shear stress.

The lateral edge of the osteotomy fragment is left continuous with the tibialis anterior muscle to preserve the vascular supply to the bone by sparing the branches of the anterior tibial recurrent artery [15], a factor that seems crucial in promoting ATT union. In addition, the musculo-periosteal flap limits the risk of skin necrosis, haematoma formation and, therefore, infection [16].

Fixation of the ATT must allow early rehabilitation, which is essential in TKA. Screw fixation is the most widely used method. In most cases, two screws are implanted, one on either side of the tibial stem, in a postero-medial and postero-lateral direction, respectively, to accommodate the triangular shape of the tibial shaft. However, screw fixation can cause anterior knee pain at the screw heads and can weaken the osteotomy fragment and tibial shaft, inducing a risk of fracture [17]. In patients undergoing RTKA, particularly those with sepsis, the bone stock may be diminished, resulting in insufficient purchase of screws and transosseous cerclage wires. Circumferential cerclage provides primary fixation strength and therefore keeps the ATT in the proper position even in the event of delayed union. In our study, of the 4 patients with non-union, 3 were asymptomatic and had no migration of the osteotomy fragment. Of the 4 patients who had previously undergone TTO with screw fixation, revision fixation using circumferential cerclage ensured union of the ATT. A precaution of the utmost importance is protection of the popliteal pedicle and, most notably, of the popliteal artery, which courses near the posterior aspect of the tibia. Therefore, the cerclage cable must be passed with the knee flexed at 90° to keep the artery at a safe distance [18]. Three-step cable passage using a cable passer ensures continuous contact with the bone.

In previously reported studies, time to union was 12 [14] to 16 weeks [19] after primary TTO and 21 weeks [8] after repeat TTO, in keeping with the data from our study. Although time to union was significantly longer in the septic revision group, union was achieved eventually in most patients. Of the 11 patients with a previous history of osteotomy, including 9 during septic revision, 9 (81.8%) achieved union. We believe that circumferential cerclage is particularly useful in septic revisions, as the infection slows the bone healing process and the bone stock is limited. Support for this

**Fig. 3.** Method for determining the Blackburne-Peel Index. The joint space is represented as a line tangent to the prosthetic condyle and parallel to the prosthetic tibial plateau. The superior (P) and inferior (A) margins of the patellar articular surface are identified. A line is drawn through point A and perpendicular to the line representing the joint space. Point T is the intersection of the two lines. The postoperative Blackburne-Peel Index is computed as the ratio of AT over AP.

**Fig. 4.** Examples of anterior tibial tuberosity (ATT) migration and union. A. Patient #1, immediate postoperative period. B. Patient #1 after 1 month, non-union and migration of the ATT. C. Patient #2, immediate postoperative period. D. Patient #2: union of the ATT.
Table 1
Patellar height preoperatively and at last follow-up.

<table>
<thead>
<tr>
<th>Patellar patellar height</th>
<th>Patella baja</th>
<th>Normal patellar height</th>
<th>Patella alta</th>
<th>Patella baja, n = 3 (BPI* = 0.47 ± 0.01)</th>
<th>Normal patellar height, n = 56 (BPI = 0.72 ± 0.11)</th>
<th>Patella alta, n = 4 (BPI = 1.08 ± 0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patella baja</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>Patella baja, n = 3 (BPI* = 0.47 ± 0.01)</td>
<td>Normal patellar height, n = 56 (BPI = 0.72 ± 0.11)</td>
<td>Patella alta, n = 4 (BPI = 1.08 ± 0.01)</td>
</tr>
<tr>
<td>Normal patellar height</td>
<td>1</td>
<td>45</td>
<td>10</td>
<td>Patella baja, n = 3 (BPI* = 0.47 ± 0.01)</td>
<td>Normal patellar height, n = 56 (BPI = 0.72 ± 0.11)</td>
<td>Patella alta, n = 4 (BPI = 1.08 ± 0.01)</td>
</tr>
<tr>
<td>Patella alta</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>Patella baja, n = 3 (BPI* = 0.47 ± 0.01)</td>
<td>Normal patellar height, n = 56 (BPI = 0.72 ± 0.11)</td>
<td>Patella alta, n = 4 (BPI = 1.08 ± 0.01)</td>
</tr>
<tr>
<td>Patella baja, n = 2 (BPI = 0.2)</td>
<td>Normal patellar height, n = 49 (BPI = 0.84 ± 0.13)</td>
<td>Patella alta, n = 12 (BPI = 1.59 ± 0.40)</td>
<td>Patella baja, n = 3 (BPI* = 0.47 ± 0.01)</td>
<td>Normal patellar height, n = 56 (BPI = 0.72 ± 0.11)</td>
<td>Patella alta, n = 4 (BPI = 1.08 ± 0.01)</td>
<td></td>
</tr>
</tbody>
</table>

* BPI: Blackburne-Peel index.

Table 2
Mean International Knee Society (IKS) scores preoperatively and at last follow-up.

<table>
<thead>
<tr>
<th>IKS knee score</th>
<th>IKS function score</th>
<th>Last follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>Last follow-up</td>
<td>Preoperative</td>
</tr>
<tr>
<td>Overall population (n = 63)</td>
<td>49.4 ± 7.4</td>
<td>76.9 ± 6.7</td>
</tr>
<tr>
<td>Septic revisions (n = 38)</td>
<td>47.9 ± 6</td>
<td>76.4 ± 6.4</td>
</tr>
<tr>
<td>Aseptic revisions (n = 25)</td>
<td>52.3 ± 8.6</td>
<td>77.7 ± 7.2</td>
</tr>
</tbody>
</table>

Table 3
Previous studies reporting complications of anterior tubial tuberosity osteotomy.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Number of patients</th>
<th>Type of fixation</th>
<th>Non-union Patellar fracture</th>
<th>Tibial fracture</th>
<th>ATT fracture</th>
<th>Skin necrosis</th>
<th>ATT migration</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>van der Broek [20]</td>
<td>2006</td>
<td>39 RTKA</td>
<td>3 screws</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>3 (7.7%)</td>
</tr>
<tr>
<td>Piedade et al. [7]</td>
<td>2008</td>
<td>126 PTKA</td>
<td>2 screws</td>
<td>2 (1.6%)</td>
<td>–</td>
<td>–</td>
<td>3 (2.4%)</td>
<td>4 (3.2%)</td>
<td>–</td>
</tr>
<tr>
<td>Tabutin et al. [21]</td>
<td>2011</td>
<td>14 RTKA</td>
<td>Screw fixation</td>
<td>–</td>
<td>1 (4.7%)</td>
<td>2 (9.5%)</td>
<td>1 (4.7%)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Whiteside [14]</td>
<td>1995</td>
<td>110 RTKA</td>
<td>Trans-osseous cerclage</td>
<td>–</td>
<td>3 (2.2%)</td>
<td>2 (1.5%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Mendes et al. [23]</td>
<td>2004</td>
<td>67 RTKA</td>
<td>Trans-osseous cerclage</td>
<td>2 (3%)</td>
<td>1 (1.4%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>3 (4.5%)</td>
</tr>
<tr>
<td>Young et al. [24]</td>
<td>2008</td>
<td>40 RTKA</td>
<td>Trans-osseous cerclage</td>
<td>–</td>
<td>2 (4.8%)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>9 (22%)</td>
</tr>
</tbody>
</table>

ATT: anterior tubial osteotomy; RTKA: revision total knee arthroplasty; PTKA: primary total knee arthroplasty.

opinion can be found in a study by de Bruni et al. [10], in which union was achieved in all 39 patients undergoing RTKA for sepsis with TTO fixed using trans-osseous cerclage.

Weight bearing with the knee immobilised in an extension splint without rehabilitation therapy has been recommended to allow union of the osteotomy fragment [16]. Piedade et al. [7] advocate limited active extension for 2 months after primary TKA. Our patients received immediate postoperative rehabilitation therapy with weight bearing, active flexion to 90°, and passive extension. With this programme, early ATT fragment migration occurred in a single patient and the overall postoperative motion ranges were significantly improved.

The complications of TTO have been well documented (Table 3). Fracture of the osteotomy fragment occurs in 1% to 10% of patients [7,21,22] and fracture of the tibia during the osteotomy cut in 1% to 5% of patients [21–23]. None of our patients experienced tubial or patellar fractures and none had disruption of the extensor mechanism. The gently tapered cut prevented secondary fracture lines. Osteotomy fragment migration is the most common complication after screw fixation (6.7% [8]) or cerclage (22% [24]) and has a variable clinical impact [22]. In our case-series, migration occurred in 6% (4/63) of patients. Given the large proportion of septic revisions, this rate is relatively low. Thus, in a case-series study of septic RTKA with trans-osseous suturing of the osteotomy fragment, Choi et al. [9] reported migration in 30% (4/13) of cases. Others [4,5] advocate performing a step-cut create an abutment proximal to the patellar ligament attachment, thereby preventing secondary migration.

The IKS knee and function scores improved significantly. TTO does not jeopardise the functional outcomes of TKA. Piedade et al. found no significant difference in IKS scores between TKA with and without TTO [7].

Our study has several limitations. The design was retrospective but the number of patients was comparable to that in other studies and few patients were lost to follow-up. Furthermore, we elected to study patients with both septic and aseptic revision. This decision hinders comparisons with earlier studies but provides information on the TTO technique in consecutive patients, regardless of the reason for revision.

5. Conclusion

TTO fragment fixation using circumferential cable cerclage is simple and effective in revision TKA, even in septic revision with a limited bone stock. This fixation technique allows early rehabilitation therapy without increasing the rate of osteotomy fragment migration.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

PHD is a consultant for Zimmer and Arthrex. YP L, SK, and TB declare that they have no conflicts of interest concerning this article.

Please cite this article in press as: Le Moulec YP, et al. Tibial tubercle osteotomy hinged on the tibialis anterior muscle and fixed by circumferential cable cerclage in revision total knee arthroplasty. Orthop Traumatol Surg Res (2014), http://dx.doi.org/10.1016/j.otsr.2014.02.012
References