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Surgical technique

Tibial Tubercle Screw Fixation on Custom Metaphyseal Cone: Surgical Tip in Severe Metaphyseal Tibia Bone Loss

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ABSTRACT

Tibial tubercle osteotomy (TTO) facilitates exposure in knee arthroplasty revision. However, it comes with complications, especially if it invades the intramedullary canal. Most revisions are characterized by compromised femur and/or tibia bone stock, and the use of metaphyseal cones or sleeves for implant fixation has become increasingly frequent. Several methods of fixation of the tibial tubercle have been proposed, such as screw fixation, cerclage wiring, and suture repair. Despite screws providing the strongest fixation for TTO, their placement around a tibial intramedullary stem or a metaphyseal tibial cone may be difficult. We described the use of a custom-made metaphyseal tibial cone with holes in its anterior surface that allow the surgeon to achieve accurate TTO fixation by screws.

Introduction

Adequate exposure in revision total knee arthroplasty (TKA) is mandatory for the procedure to be a success [1]. However, the exposure in revision and especially in the case of re-revision might be technically demanding due to the contraction of the extensor mechanism and surrounding fibrotic tissue envelope from previous surgeries [2].

In the late 90s, the quadriceps snip was popularized as a noninvasive extensile approach which facilitates exposure when patellar eversion was difficult to accomplish. However, due to the risks of postoperative extensor lag, patella avascular necrosis, and rehabilitation restrictions, quadriceps snip is rarely considered by the authors [3].

Tibial tubercle osteotomy (TTO) is a well-known technique to improve exposure in difficult TKA [4]. It has the advantage of preserving the vascular supply of the patella, keeping the quadriceps tendon intact, and adjusting the patella height in cases of patella baja [5]. Classically, the TTO is a chevron-shaped bone cut performed on the anterior aspect of the tibia. Occasionally, osteotomy may be helpful in achieving exposure of the tibial canal for cement and stem removal. Different methods of fixation of the tibial tubercle, such as screw fixation, cerclage wiring, and suture repair, have been proposed [6]. It has been reported that the use of screws should always be sought in TTO fixation because they provide the strongest fixation [7]. However, most revisions are characterized by compromised femur and/or tibia bone stock, and the use of metaphyseal cones or sleeves for implant fixation has become increasingly frequent [8-10]. In such clinical settings, with the addition of intramedullary extension of TTO, the use of screws for TTO fixation can be difficult due to severe bone loss and thin peripheral cortical bone of tibia metaphysis.

In this surgical technique report, we developed a new custom-made porous metaphyseal cone that allows the surgeon to address the metaphyseal tibial bone loss and, at the same time, to get screw fixation of TTO. In the present study, we describe the surgical technique and our preliminary results and discuss prospects.

Surgical technique

Custom-made cone design and production process

The patient's knee anatomy is reconstructed from computed tomography scans taken following a predefined protocol.

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Metaphyseal cones are then designed accordingly with the aim of fitting the patient's bone defects and providing adequate support to the knee implant while restoring the correct joint line height. Sometimes, in order to restore the joint line level, it is necessary to take the contralateral leg articulation as a reference. Metaphyseal cones are then produced in titanium alloy employing the electron beam melting additive manufacturing technology. The external surface of the cones features a monolithic extra-rough surface with three-dimensional porosity to maximize the implant's primary stability and osseointegration. The cone's inner surface is also rough to maximize its hold with the bone cement used to fix the knee implant. The tibial cone's anterior part is designed to allow for tibial tuberosity screw fixation, as described in this paper (Figs. 1 and 2).

Tibial tuberosity osteotomy

The patients were supine under general or regional anesthesia. A medial parapatellar approach was used. Previous skin incisions were followed when possible. If there was a difficult patella eversion with a risk of patellar tendon avulsion, patella baja for patellar tendon retraction, or inadequate exposure to perform revision arthroplasty, medial TTO was carried out. We used the technique that was described by Dolin [11] in 1983, which was later modified by Whiteside and Ohl [4]. Specifically, a long thick TTO fragment hinges on the lateral periosteum and anterior compartment musculature in order to preserve blood supply to the osteotomized site. To minimize the risk of nonunion, the length of tibial tubercle fragment needs to be approximately 8 cm [12]. The width and thickness of the osteotomy ranged from 2 to 3 cm and 1 to 2 cm, respectively.

Metaphyseal tibial bone preparation and custom-made cone implantation

First, it is necessary to remove the previous spacer or tibial component, and the medullary canal should be free from any residual bone cement. Metaphyseal tibial bone loss is assessed according to the Anderson Orthopedic Research Institute (AORI) classification [13,14].

The surgical technique for cone insertion involves host bone preparation with a broach or burr to optimize cone contact and enhance bone ingrowth. In cases of severe metaphyseal tibia bone loss (grade III according to the AORI classification), a metaphyseal cone is generally used to achieve adequate fixation in revision TKA.

It is important to consider that after removing implant and/or spacer, the existing bone defect could change compared with the preoperative computed tomography. For these reasons, host bone preparation of tibial metaphyseal and TTO fragment might be required to optimize contact and mechanical stability. The custom-made cone (Adler, Cormano [MI], Italy) is implanted with holes facing the anterior cortex of tibia (Figs. 3 and 4).

Once the final components have been cemented in place and the final polyethylene has been inserted, the knee is brought into full extension to reduce the tension on the soft tissue. The tibial tubercle fragment is reduced and fixed to the osteotomy site. A K-wire is used to find the corresponding holes of the cones on the tibial tubercle fragment. Fluoroscopic guidance could be used to find the correct position. A threaded drill guide 3.2 was used to keep the drill in the center of the hole to ensure coaxial drilling and screw placement. A torque-limited screwdriver (1.5 Nm) was used to seat the 4.5-mm locking screw. There are 10-mm, 14-mm, 18-mm, and

Figure 1. Porous custom-made cone for metaphyseal tibia bone loss with screws for tibial tubercle osteotomy fixation.

Figure 2. Porous custom-made cone and tibial component implant with a long stem.

Figure 3. A male patient aged 71 years underwent 2-stage revision surgery for periprosthetic joint infection. A custom-made implant was required to manage alignment, joint line, and bone loss. Tibial tubercle fixation was achieved by a custom-made metaphyseal cone with screws. Preoperative, postoperative, and 3-month follow-up radiographs.

22-mm screws provided by the manufacturer. It is recommended to choose the shortest possible screw that reaches the cone thread to guarantee bone compression. The procedure is repeated for the distal one (Fig. 5). Cerclage wires should be used to reinforce fixation of osteotomy fragments.

Patients' characteristics and preliminary results

We used this technique in 5 patients with a mean age of 75.3 years (range 72-79). The group included 3 males and 2 females, with 3 being a revision cases due to aseptic loosening of TKA and 2 being cases of a second-stage revision due to a periprosthetic infection. Baseline and follow-up values are reported in Table 1. All cases were re-revision with minimum 1 surgery of knee revision failed. Moreover, all patients underwent to TTO osteotomy during previous surgeries. The local institutional review board approved the retrospective analysis of cases. All patients required TTO for better exposure, and they were characterized by severe metaphyseal tibia bone loss (grade III AORI classification). Custom-made implants were required to address the severe bone loss and get adequate fixation. Patients were informed about the use of custom-made implants. They signed informed consent. As a part of postoperative rehabilitation, we allow immediate weight-bearing as tolerated. Patients should use a walker postoperatively and be safely mobilized with the guidance of a physical therapist. A walker or 2 crutches are used for 6 weeks, and then a cane is used as needed for ambulatory activities. We do not advise the use of knee brace. Flexion is restricted to 90° for 3 weeks and increased as tolerated to 120°.

The mean follow-up of the patients was 28.2 weeks (range: 24-32 weeks), we did not observe any case of tibial tubercle migration. Moreover, TTO consolidation was achieved in each patient. None of the patients showed intolerance to the material, and no other complications were recorded.

Discussion

Stable and successful tibia tubercle fixation represents a challenge in revision TKA. Although TTO has been used in revision surgery with excellent clinical results, the significant complication rates of these surgeries have also been attributed to TTO [5]. Complications such as nonunion, tubercle fragment fracture, displacement of tibial tuberosity, and tibial metaphyseal fracture have been described [15,16]. The rate of complications is around 9%, and proximal migration of the tibial tuberosity is the most common one [17]. This percentage tends to increase in cases of more complex or multiple revision arthroplasties due to intramedullary extension of TTO. Indeed, Chalidis and Ries [18] found that the intramedullary extension of TTO is associated with an increase in union time, even though in all patients, bone unions occurred without any postoperative restrictions in mobility. It is worth mentioning that in most patients, screws were used for fixation. In the case of severe metaphyseal bone loss and/or intramedullary extension of TTO, screw fixation may be hampered due to the thin peripherical cortical bone of tibia metaphysis. Consequently, cerclage wires represent the only way to achieve fixation [6].

Using the custom-made metaphyseal tibial cone (Adler, Cormano [MI], Italy) with adaptable screw holes, the surgeon can achieve screw fixation of TTO directly on the cone to avoid the risk of tibial tuberosity displacement. Moreover, the custom-made device can be designed with the position of anterior holes that best fit for patellofemoral tracking.

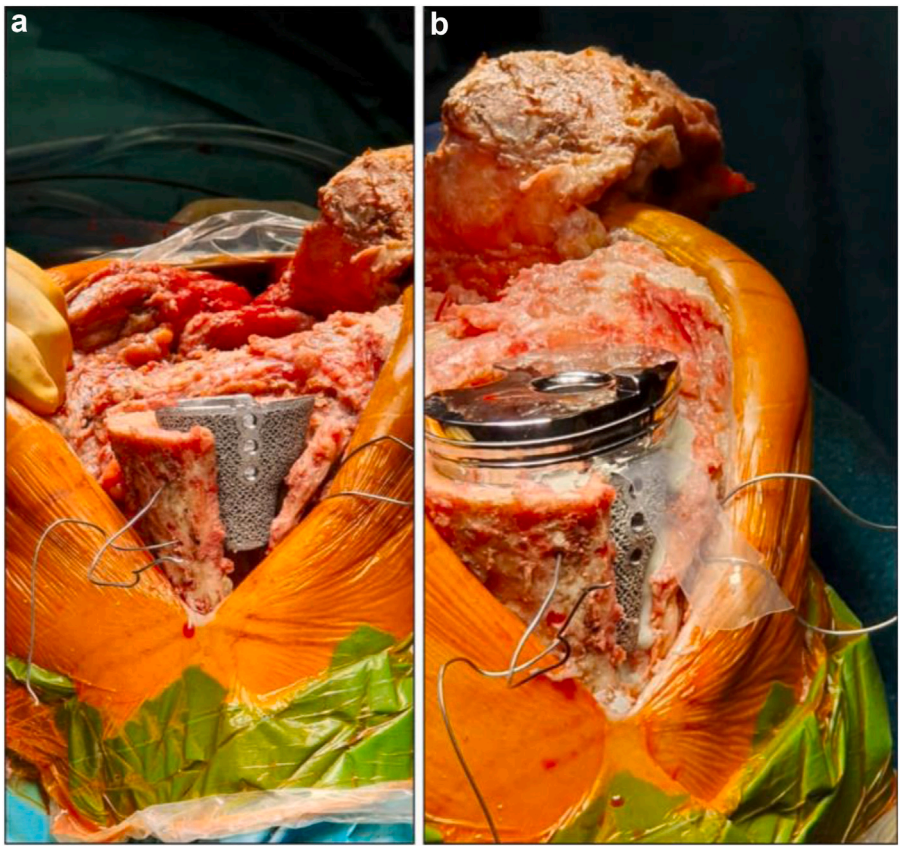

Figure 4. Intraoperative image. (a) Preparation of tibia with cerclage wire and custom-made metaphyseal cone. Attention is given to cone rotation in order to center the tubercle fragment. (b) Cementation of tibial component.

In the present case series, we used cerclage wires in addition to screw fixation. It is mandatory to consider that the present technique is original and innovative; therefore, no previous comparison could be done. Furthermore, as recently reported, we used peripheral cerclage wires applied on the posterior side of intramedullary canal that surround the tibial cone once implanted. In this way, the cerclage wires could make compression on tibial tuberosity fragment obtaining a greater solidity of the synthesis [19].

The present technique has limitations. First, a surgeon could reproduce the present technique only with the use of custom-made cone because none of the cones manufactured present adaptable screw holes. For these reasons, the present technique should be limited in case of custom-made implants in a re-revision setting. Up to date, the elevated costs and the long production time related to custom-made implants make this technology unsuitable for application on a large scale.

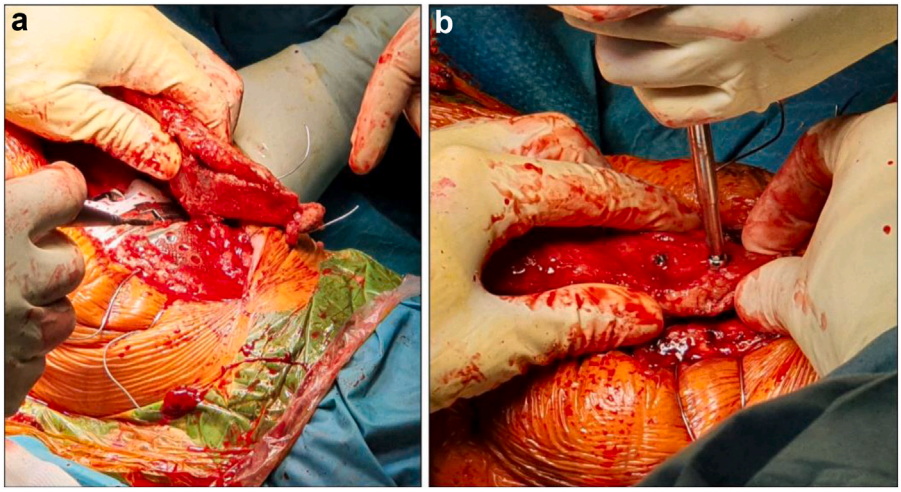

Figure 5. (a) Positioning of tibial tubercle fragment in correct position. (b) Fixation by locking screws on the cone.

Table 1
Patients' baseline and follow-up characteristics.

Variables	Preoperative baseline	Postoperative follow-up
Fixed flexion deformity, mean (range)	16° (range 10-20°).	0° (0°)
Passive maximum knee flexion, mean (range)	73° (60-90°)	95.3° (85-110°)
Oxford knee score, mean (range)	18.8 (15-23)	42 (40-44)

Summary

Multiple revision TKAs may require extended TTO into the intramedullary canal to allow a direct exposure for removing the implant and/or cement. Moreover, re-revision TKA are often characterized by severe metaphyseal bone loss that requires cones or custom-made implants for adequate fixation. Under this circumstance, the solid fixation of TTO may be challenging. In this setting, the production of custom-made cone with anterior holes allows the surgeon to achieve a solid TTO fixation with satisfied preliminary results.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Informed patient consent

Not required as this is not a clinical study.

Availability of data and materials

Not applicable.

Authors' contributions

G.P. and C.Z. conceived of the presented idea. L.F., D.S., and L.P. wrote the manuscript. A.P.G. supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

Ethics approval

The local institutional review board (IRB) approved the retrospective analysis of cases.

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