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CASE REPORT

Lengthening of Tibia after Trans-Tibial Amputation: Use of a Weight Bearing External Fixator-Prosthesis Composite

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Introduction

When a patient encounters a traumatic injury to his or her lower limb, limb salvage is not always possible and amputation may be required. Other indications for amputation include tumor and peripheral vascular disease. There are major advantages to maintaining a trans-tibial amputation (TTA) and not converting to a trans-femoral amputation (TFA). Lower levels of amputation lead to better clinical outcomes due to preservation of the knee joint and the mechanics of standing and walking. While all amputations require increased energy for walking, there is better energy efficiency with a TTA (15–45% above normal) than a TFA (25–65% above normal). Other advantages of TTA over TFA include better ability to negotiate environmental barriers, better balance, better proprioception, better control of the prosthesis, and improved gait [14]. When possible, TTA is preferable to TFA.

Ideally, the tibia length for TTA is 12.5 to 17.5 cm depending on the body height [12]. Residual limbs shorter than 12.5 cm are less efficient. Patients with longer traumatic TTA stump lengths have lower metabolic cost of ambulation and lower steady heart rate [3, 4]. However, the length of the residuum cannot always be controlled due to the specific nature of the trauma or other level of pathology. Cases in which the residual limbs are excessively short present a problem. Proper fitting of the prosthesis becomes difficult and its use is limited. Patients often struggle transitioning back to performing everyday activities with ease and independence using their prosthesis.

Conventional treatment would be re-amputation at the next highest level. Not only would this be an added psychological burden for patients, this would undo the goal of joint preservation, which is the very purpose of a TTA. In our practice, we have become aware that lengthening a residuum is possible. Literature regarding TTA stump lengthening is limited [2, 5, 6, 8, 9]. The purpose of this case report is to present a case where lengthening of a residual tibia greater than 100% was achieved with no complications. Moreover, a special custom-made external fixator-prosthesis composite is described to allow for early weight bearing and exercising. This can help modify and improve the current treatment practices for problems related to very short TTA residual limb.

Case Report

The patient is a 25-year-old male who developed compartment syndrome after a traumatic fall in December 2009. This led to a TTA done on the right side at an outside medical center in February 2010. Although he was able to

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wear a prosthesis, he had poor control and difficulty walking. One year later, the patient presented to our clinic hoping to improve the fitting of his prosthesis. Radiographs showed the length of the tibial remnant was 7 cm (Fig. 1a, b). Knee motion was from full extension to 110° flexion. It was determined that difficulties with his TTA prosthesis were related to the short stump.

To improve the patient's prosthetic wear and save the knee, the treatment plan was to lengthen the residual tibia with the goal to achieve the optimal length of 15 cm. This called for an 8-cm lengthening, which is more than double the starting tibial length. To lengthen the residuum, an osteotomy just below the tibial tubercle was performed. Using the Ilizarov frame, the distraction was done at a slow rate of 0.5–0.75 mm per day for 4 months. This was done as slow bone healing was anticipated in the setting of trauma and compromised soft-tissue envelope. To prevent the distal tibia from eroding through the distal skin, soft-tissue recruitment was used. The distal skin was pulled distally and the distal multiplanar wires served to push that skin distal during the lengthening. The multiplanar wires were inserted in the very distal part of the tibia including the surrounding soft tissue. This served to distract and push the distal tibia along with its surrounding soft-tissue envelope as a unit. This was successful, and the bone did not erode through the skin.

The use of multiplanar fixation with crossing angles between wires and pins approaching 90° helped prevent the natural tendency for procurvatum deformity during lengthening. Half-pins 6 mm in diameter were placed in an anterior to posterior direction to counteract the sagittal plane bending force (Fig. 3a). The knee was protected from developing a flexion contracture with a diligent physiotherapy program focused on active and passive terminal knee extension and flexion.

The total time the patient wore the frame was 13 months. AP and lateral radiographs showed union of 8 cm regenerated (Fig. 2a, b). The external fixation index (EFI) was 1.5 months/cm.

External Fixator-Prosthesis Composite

During the treatment process, early weight bearing was desirable as it helped prevent disuse osteopenia and helped advance bony union. This was accomplished by attaching a prosthetic pylon and foot to the distal ring of the external fixator by the attending prosthetist right after surgery (Fig. 3). Two parallel stainless steel bars were bolted to the distal ring and oriented in an AP direction. A prosthetic modular inverted pyramid (adjustable coupling mechanism) was positioned and attached to the stainless steel bars using conventional prosthetic alignment techniques. The pylon and foot were attached to this coupling mechanism.

The patient could not remove the prosthesis from the external fixator. Initially, the patient was instructed to use partial weight bearing through the fixator/prosthesis. The patient soon felt confident enough to bear full weight through the fixator and was able to ambulate without any assistive device. Follow-up with the prosthetist occurred on a regular basis. As the patient's weight bearing and balance

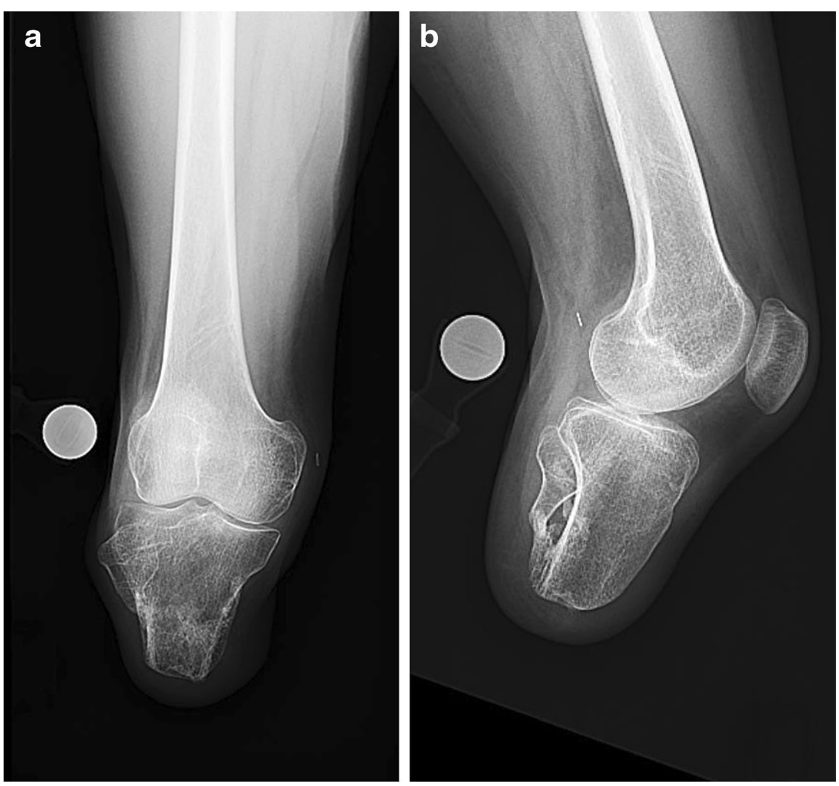

Fig. 1. Anteroposterior (AP) and lateral radiographs of the right limb showing a 7-cm residual tibia and fibula.

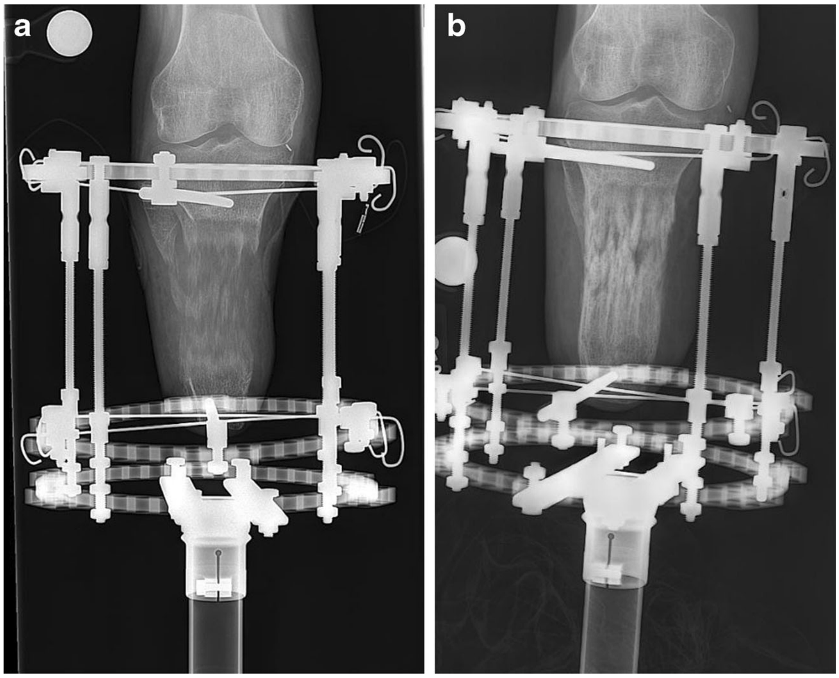

Fig. 2. **a** AP radiograph at 6 months after surgery showing distraction gap. **b** AP radiograph at 12 months after surgery showing union of the 8-cm regenerate. Frame removal was done shortly after this.

improved, modifications were made to the alignment of the prosthesis. Additionally, as the residuum and external fixator lengthened, compensatory length adjustments were made in the prosthetic pylon.

The design of this system allowed the patient to remain active and ambulatory with minimal assistive devices during the lengthening process. The knee range of motion and strength remained at near normal levels throughout the lengthening process (Fig. 4). The psychological advantages were not measured but the patient expressed surprise and satisfaction with his functional abilities and did not complain of pain associated with the prosthesis or weight bearing.

Outcomes

At the latest follow-up, a well-healed bone 15 cm in length without deformity was observed (Fig. 5a, b). The right knee motion was from full extension to 130° flexion (Fig. 6). Prosthetic wear improved.

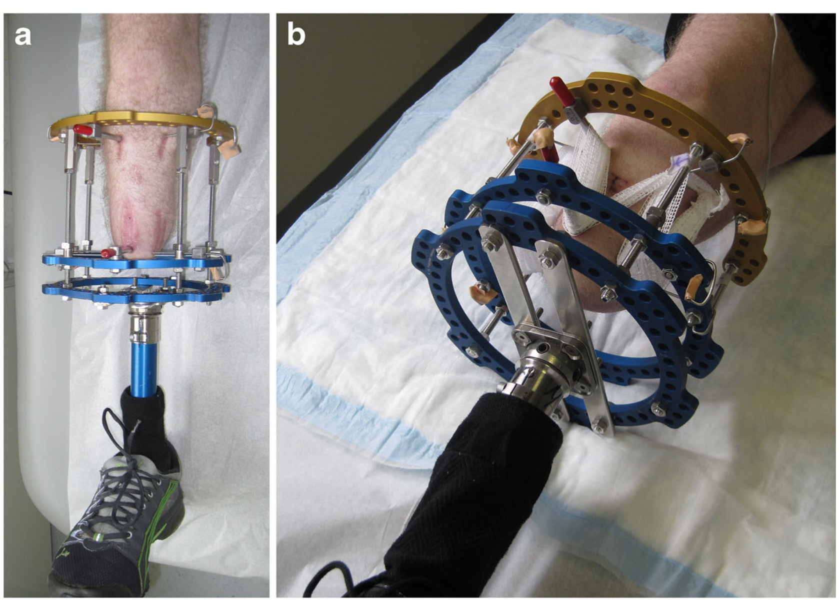

Fig. 3. Multiple views showing the external fixator-prosthesis construct assembled right after surgery.

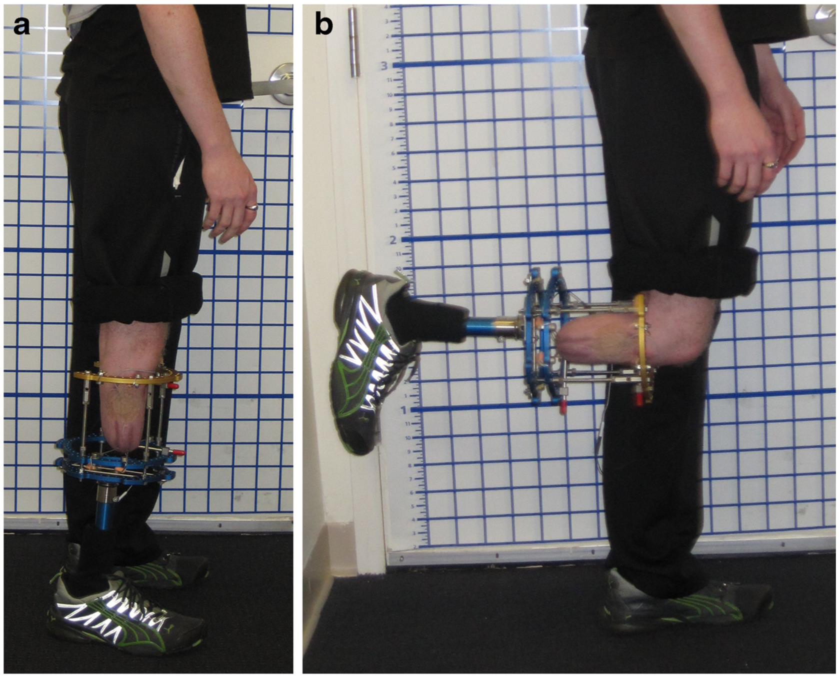

Fig. 4. Multiple standing views showing patient function while wearing the external fixator-prosthesis construct. Note the weight bearing and the active knee motion.

Discussion

Adequate stump length is critical for efficient prosthetic use and rehabilitation for TTA patients. A longer residuum provides a longer lever arm, thereby requiring less energy to lift a prosthesis and providing sufficient power to perform the gait cycle. In addition, skin breakdown is minimized as a longer stump has more surface area to transmit load. Subsequently, patients with short residual limb after TTA presents a problem and have

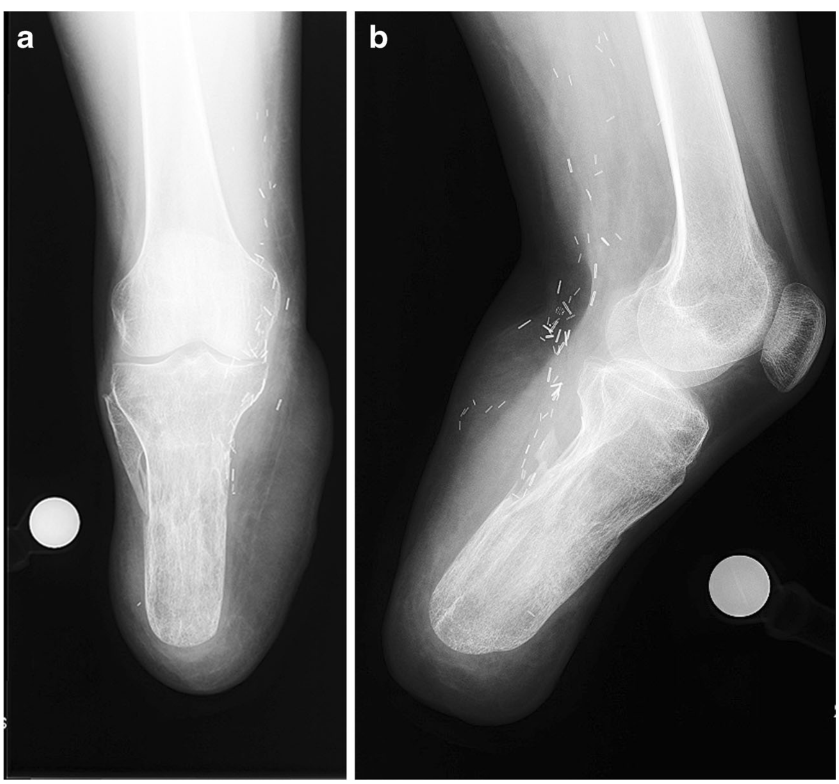

Fig. 5. AP and lateral radiographs 2 years after surgery. Note the well-healed bone 15 cm in length without deformity.

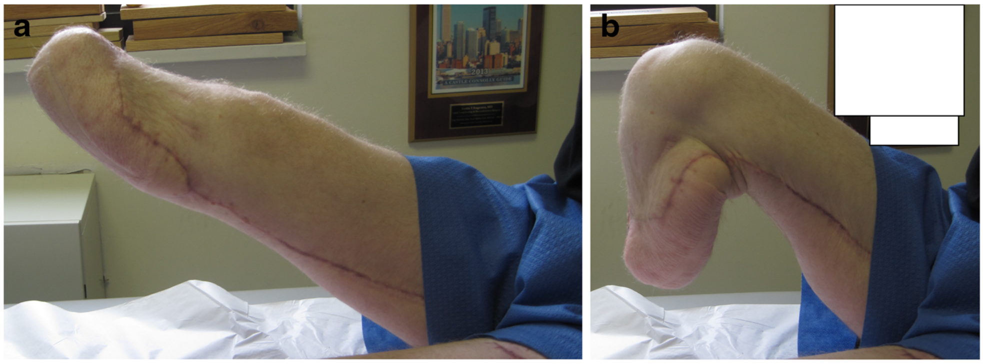

Fig. 6. Clinical photos showing the appearance and length of the residual limb after lengthening. Prosthetic wear was improved.

limited options. For many orthopedic surgeons, amputation at the next highest level is recommended. Lengthening of a short residual limb is not commonly done and is not commonly known in the orthopedic or prosthetic communities.

Several methods of lengthening a short stump have been sparsely documented. Schnur et al. described a case in which an allograft bone was attached using internal fixation to lengthen a residual arm [10]. However, a major issue was soft-tissue coverage. Additionally, there is a chance of failure due to tissue rejection. Younge et al. and Pant et al. reported using a bone flap as an alternative technique to lengthen a TTA residuum. A portion of the tibia is excised and the foot was disarticulated from the ankle. With the posterior soft tissues kept intact, the heel pad was turned up and attached to the proximal tibia by fixing it with a wire [7, 15]. While the authors reported success with this technique, this is not possible for patients with a previously performed TTA. It is something that has to be decided well in advance before surgery. Furthermore, this requires healthy posterior and distal tibia tissues and vessels and nerves to be intact. Bone healing is another potential complication.

Lengthening of an amputated residual limb using an external fixator and the Ilizarov technique is another viable option. Although uncommon, it has been performed with good results. Literature review within the last 15 years has yielded a few published studies on this technique (Table 1) [2, 5, 9, 11, 13]. Mertens et al. and Bowen et al. both reported lengthening of the tibia greater than 100% [2, 5]. Despite this, individual lengthening in Bowen et al.'s study were not reported. Therefore, it cannot be concluded if lengthening of over 100% occurred in all eight patients. In both cases, significant complications were identified. As Orhun et al. noted, two major complications to be careful of during lengthening are soft-tissue coverage and joint contractures [6]. Other complications include pin site infection and pain [9]. Both Mertens et al. and Bowen et al. reported knee stiffness and poor soft-tissue coverage during the lengthening process [2, 5]. Similarly, the development of flexion contracture led to early cessation of lengthening and only a 27% lengthening was achieved in the case reported by Savage et al. [9]. Villarruel reported an 87.5% lengthening of a left short trans-tibial limb with a final length of 15 cm. However, the distraction had to stop because of increased tension of the skin covering the distal portion of the tibia [13]. Tellisi et al. reported improved prosthetic wear and no complications after lengthening and deformity correction of congenital limb deficiencies [11]. In this present case, not

Table 1 Comparison between reports of lengthening of a TTA stump within the last 15 years

Authors	Year	Number of patients	Initial length (cm)	Length gained (cm)	% Lengthening	Complications
Mertens et al. [5]	2001	2	4.0 6.0	6.5 7.0	163% 117%	One case: • Knee stiffness • Repetitive skin breakdown • Ulcerations
Villarruel [13]	2003	1	8.0	7.0	87.5%	None
Bowen et al. [2]	2005	8	4.8 (avg)	6.9 (avg)	144% (avg)	• Insufficient distal soft tissue coverage (2) • Adjacent joint flexion contractures (4) • Deep infection (1)
Tellisi et al. [11]	2008	1	11.8	5.0	42.4%	None
Savage et al. [9]	2014	1	8.6	2.3	26.7%	• Pain and irritation from wires • Poor knee extension • Synovial fluid leakage

only was a lengthening of over 100% achieved, no major complications occurred as well.

Another unique and important aspect of this case was the approach taken to enable the patient to bear weight and walk throughout the 13-month treatment. In surgical procedures involving the lower limb, early weight bearing is desired as there are tremendous physiological and psychological benefits. It can prevent joint stiffness and muscle weakness as well as promoting bone healing. More importantly, it can give the patient more confidence and the feeling of independence. Several authors have reported successful methods to allow for early weight bearing. Ali et al. described cases in which patients following TTA had a removable prosthesis that can be attached directly to the plaster cast protecting the residuum. Furthermore, the authors compared the clinical outcomes of those TTA patients managed with immediate postoperative prosthesis (IPOP) placement and traditional soft compressive dressing placement. They found that the IPOP placement patients had less surgical revisions, falls, and stump trauma illustrating the benefits of having early weight bearing [1].

Additionally, attempts have been made to enable early weight bearing during different periods in the lengthening process of a TTA stump. Bowen et al. and Villarruel both fitted a temporary prosthesis around the external fixator after the lengthening period has completed, during the consolidation phase [2, 13]. On the other hand, Park et al. had early weight bearing during the lengthening period by extending the distal end of the external fixator all the way to the ground [8]. In this current case, early weight bearing was also enabled during the lengthening period. To achieve this, a prosthesis was connected directly to the distal ring of the external fixator by our prosthetist soon after surgery. A few studies have reported this similar technique. Mertens et al. fitted a temporary prosthesis on the external fixator during femoral stump lengthening [5]. Savage et al. designed a similar construct for their patient as well [9]. However, their external fixator comprised of four rings while the design described in this case consist of only three rings.

Very few orthopedic surgeons are aware of the possibility of lengthening a residual limb. Together with other similar cases, this case report can add to the limited literature and bring awareness to both the orthopedic, prosthetic, and amputation communities that, aside from additional amputations, lengthening of the residuum is a viable option. This is beneficial to the patient in the long term. In addition, this is one of a few cases in which a prosthesis is attached to an external fixator early on in the treatment. This provides significant advantages in the recovery process for the patient. The success documented in this case report can inform orthopedic surgeons to consider this treatment modification in the future and the overall use of TTA limb lengthening procedure.

Disclosures

Conflict of Interest: Aaron Lam, BA and Glenn Garrison, CPO have declared that they have no conflict of interest. S. Robert Rozbruch, MD is a paid consultant for Smith & Nephew, Ellipse, and Stryker, and receives royalties from Stryker, outside the work.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was waived from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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