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"Bamboo Hut Technique" to Cover Large Defects During Tibiotalocalcaneal Fusion

Rajiv Shah, MS, Nikku M. Geevarughese, MS,† and Shivam Shah, MS‡*

Abstract: Tibiotalocalcaneal arthrodesis is a salvage procedure for severe ankle and hindfoot deformities, cases with bone loss, arthritis, and failed previous surgeries. Complex situations leave the surgeon apprehensive over large bone defects. Several options to bridge the bone gap have been described; however, the easy availability of allografts and cages poses a significant challenge for the less privileged surgeon. Here we describe a simple indigenous technique of utilizing autologous fibula to bridge large bone defects between the tibia and calcaneus during tibiotalocalcaneal fusion. The technique has advantages like the generation of compression at the site of fusion through the indigenously designed nail plus keeping grafts bonded like as in a bamboo hut.

Level of Evidence: Diagnostic Level V. See Instructions for Authors for a complete description of levels of evidence.

Key Words: tibiotalocalcaneal arthrodesis, avascular necrosis of talus, hindfoot nail, fibular autograft

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HISTORICAL PERSPECTIVE

Large bone defects around the ankle after trauma, avascular necrosis of talus, infection, Charcot arthropathy, distal tibia or talar tumors, and failure of total ankle arthroplasty pose a significant challenge for the foot and ankle surgeon. Similarly, concerns regarding inherent stability, nonunion, length restoration, and ankle and hindfoot deformity correction need to be addressed at the same time. Tibiotalocalcaneal (TTC) arthrodesis can stabilize the ankle and hindfoot and relieve pain at the cost of forgoing ankle movements. Various options have been described to bridge the defect, namely Blair fusion,[1] femoral head allografts,[2] talar allograft,[3] medial femoral condyle flaps,[4] titanium trusses or cages,[5] vascularized structural fibula,[6] or soft tissue-preserved fibular graft,[7] augmented with allogenic bone morphogenic protein, mesenchymal stem cells, and other orthobiologics. Intramedullary nail assisted TTC arthrodesis has been well reported and shown to be promising.[8,9] However, the easy availability of allografts, reproducibility of sophisticated techniques, and the options being cost-effective alternatives for less sophisticated centers will take considerable time.

Paul et al[10,11] had described a technique where a construct of 4 circular fibular autografts is used in conjunction with a hindfoot fusion nail and an anterior plate. However, we earlier have had instances when the struts were not tied together and the fibular strut got displaced in due course of time (Fig. 1). To overcome these complications, we describe 2 modifications in the technique.

The hollow stem of bamboo is used for making furniture and as scaffolding. It is cheap, easily available, and thence regularly used for creating an inexpensive shelter. An individual bamboo stem is weak, but when tied with each other, it becomes firm and is able to withstand more loads. Bamboos may be of different diameter and length, but when joined they give a stiffer construct. Joined by vertical and horizontal patterns and tied with strings to make a hut, they withstand different seasons and work as good shelter (Fig. 2).

We use 3 fibula strut grafts and position them at 12, 3, and 6 o'clock positions with the lateral half of sliced fibula serving the purpose of live fibular graft at 9 o'clock. Fibular struts are treated as bamboo stems and tied together around the intramedullary hindfoot nail strengthening the construct. Grafts are compressed with a compression force generated through the nut loaded in the nail. Such a modification drastically improves the structural stability of the construct and obliterates the bone gap. Also, the need for an additional anterior plate is not required because of the inherent biomechanical stability brought about by compression. The majority of the hindfoot fusion nails are more or less static in the configuration. The senior author (R.S.) coordinated with industry engineers to develop straight

FIGURE 1. Follow-up in one of our initial patients showing displacement of fibular strut graft on when the struts were not tied to each other.

From the *Sunshine Global Hospitals; ‡Department of Orthopaedics, SSG Hospital and Baroda Medical College, Vadodara, Gujarat; and †Department of Orthopaedics, All India Institute of Medical Sciences, Bhopal, Madhya Pradesh, India.

The authors declare no conflict of interest.

Address correspondence and reprint requests to Nikku M. Geevarughese, MS, c/o Geevarughese Mathew, Vattaparampil House, Thalavady PO, Allapuzha, Kerala 689572, India. E-mails: nikku.mathew@gmail.com; annnikitha@gmail.com.

FIGURE 2. Bamboo stems being tied closely in both horizontal and vertical manner for better strength and stability of the bamboo hut.

hindfoot nail. This nail yields compression of the grafts, as a compression nut is passed through the distal end of the nail, after passing 2 screws above the ankle and 1 into the calcaneus (Figs. 3, 4). To the best of our knowledge, no straight nail with a simple compression through the nail has yet been described in the literature.

INDICATIONS AND CONTRAINDICATIONS

Significant bone gaps resulting from avascular necrosis of talus, infection, failure of total ankle arthroplasty, Charcot arthropathy, tumors after neoadjuvant therapy involving distal tibia or talar, and trauma especially Hawkin type III and IV talar fractures are potential indications for TTC arthrodesis necessitating gap bridging techniques.[5] Institutions without tissue bank and 3D printing facilities are likely to benefit from indigenous methods of using fibular autografts, especially in settings without specialized hands for the harvest of vascularized free bone graft. This technique is contraindicated in the setting of persisting infection and limbs with compromised vascularity.

PREOPERATIVE PLANNING

Exhaustive history and medical comorbidities are of utmost importance, along with physical examination, laboratory values, and assessment of the associated joints and hindfoot alignment and with standard weight-bearing radiographs.

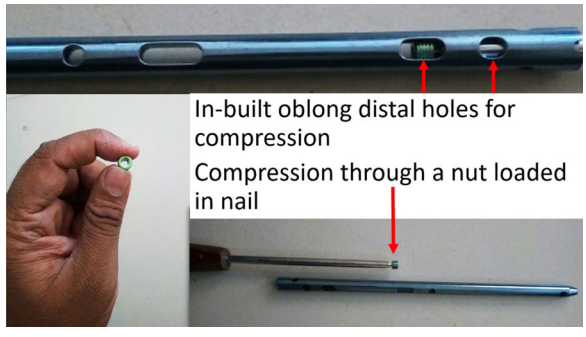

FIGURE 3. The MP Ankle Arthrodesis nail (Matrix Meditec, Gujarat) depicting the oblong distal hole with the compression nut loaded inside the nail.

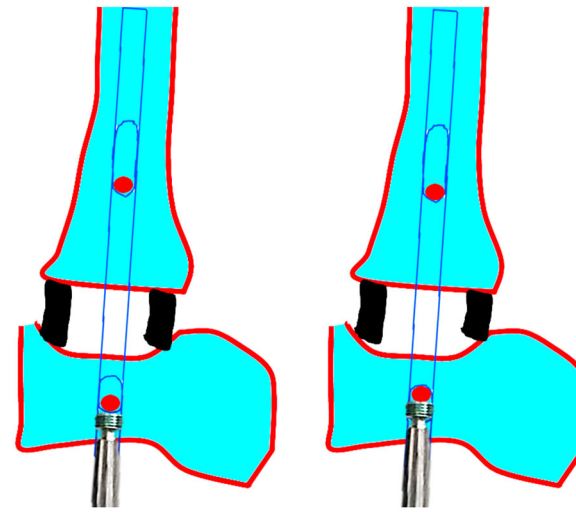

FIGURE 4. Schematic diagram of the lateral view of the hindfoot nail demonstrating tibiocalcaneal compression as the nut within the nail is tightened. The red circles depict the transversely placed screws, one into the tibia and another into the calcaneus.

Negative nicotine screening 6 weeks preoperative is advisable for chronic smokers.[5] Computed tomography imaging gives a complete picture of the bony architecture, bone loss, collapse, and alignment, whereas MRI validates bony necrosis. These modalities give a comprehensive assessment of the bone loss and the probable length, which needs to be attained using the fibular strut.

TECHNIQUE

The patient is positioned in a supine position with a bump under the ipsilateral gluteal region. A thigh tourniquet is inflated. An extended lateral transfibular approach is taken with a vertical limb extended about 15 cm above the tip of the fibula (Fig. 5). The distal end of the incision is extended up to the base of the fourth metatarsal. Full-thickness anterior and posterior flaps are developed. A short oblique osteotomy of the fibula is carried out at 2.5 cm above the lateral malleolus in a proximal-lateral to the distal-medial direction. The fibula is reflected down by excising all anterior soft tissue attachment. The use of a sharp towel clip to hold the osteotomized fibula helps in this maneuver. This distal segment of the fibula is sectioned coronally into medial and lateral halves. Lateral half remains as a live plate after nailing (at the 9 o'clock position at the tibiotalar level). Depending upon the case, clearance between

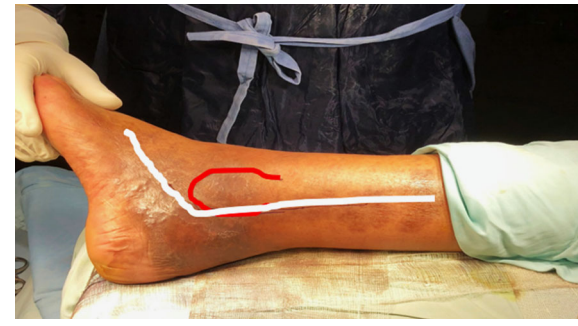

FIGURE 5. Schematic representation of the skin incision for the extended lateral transfibular approach to the ankle joint.

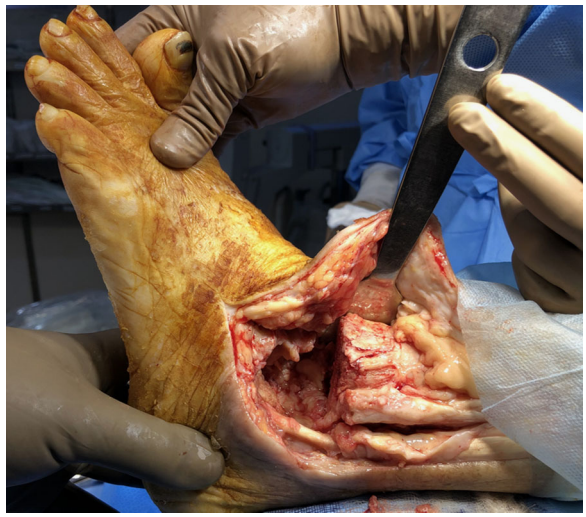

FIGURE 6. The resultant gap after adequate debridement of the talus, lower end of the tibia, and the upper surface of the calcaneus.

tibia and calcaneus is carried out by the removal of necrotic bone, scar tissues, and retained implants. The articular cartilage over the lower end of the tibia and the upper end of the calcaneus are debrided thoroughly, such that the surfaces are adequately prepared for fusion (Fig. 6). Drilling using Kirschner wires (K-wire) is recommended, as drill bits further remove the cancellous bone. Also, frequent wet mopping of K-wire tips is required to prevent thermal necrosis. Rose petalling prepares the cortical bone at the fusion site to be more receptive. The resultant bone gap is reassessed and held in length with the help of laminar spreader or Hintermann retractors (Fig. 7).

Hindfoot and ankle are held in the desired position of fusion (neutral flexion, 5-degree valgus, and minimal external rotation) and maintained by two 2.5-mm, bridging K-wires, passed in such a manner that they do not hinder the passage of the nail. A guidewire is inserted through the plantar insertion point under fluoroscopic control to be used later for medullary reaming of the nail. A straight retrograde intramedullary hindfoot nail (MP Ankle Arthrodesis nail, Matrix Meditec, Gujarat, India) (Fig. 3) of adequate size is passed under fluoroscopic guidance. Two lateral-to-medial directed transverse screws are passed through the nail

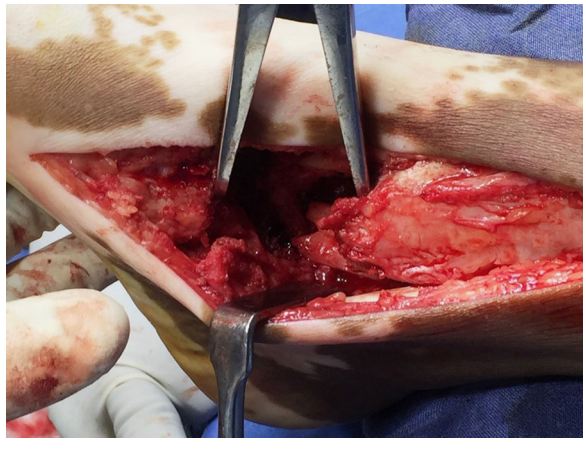

FIGURE 7. The bone gap held to the length of the limb with the help of lamina spreader.

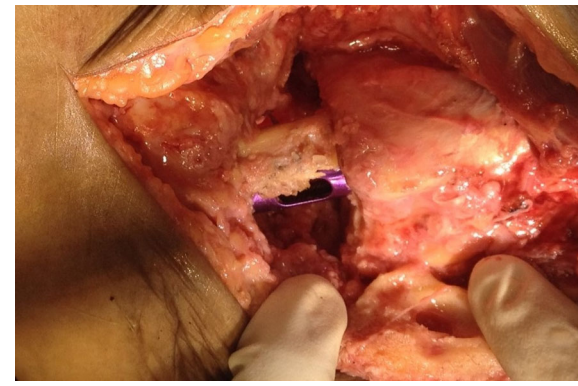

FIGURE 8. Fibular strut graft placed anterior to the nail at 12 o'clock position.

above the ankle joint. A transverse screw is passed in calcaneus from the lateral to the medial direction (Fig. 4). The help of jig makes the passage of interlocking screws easy. This construct, together with the help of lamina spreader, holds the position with the deficit gap at the talar level. The defect is measured using a flexible ruler. Next, the ipsilateral fibula is harvested by performing a high transverse fibular osteotomy, 10 cm proximal to the previously osteotomized level of the fibula. This fibular graft is divided into 3 equal segments depending on the final bone gap and placed vertically in the defect area around the hindfoot nail, preferably at 12, 3, and 6 o'clock positions where 12 o'clock position is anterior, 3 o'clock is medial, and 6 o'clock is posterior to nail (Figs. 8–10). Gaps measure 3 cm on an average, but are not even between the calcaneus and tibia, hence, usually the anterior strut is longer than the others by 2 to 3 mm. Every fibular strut is horizontally drilled in the midway with a 1.5-mm K-wire, and No. 2 FibreWire or Ethibond is threaded through this hole. The FibreWire is wrapped around the fibular piece tightly with 2 or 3 turns (Fig. 11). Bridging K-wires are removed. The construct of fibular strut grafts is now ready to undergo compression.

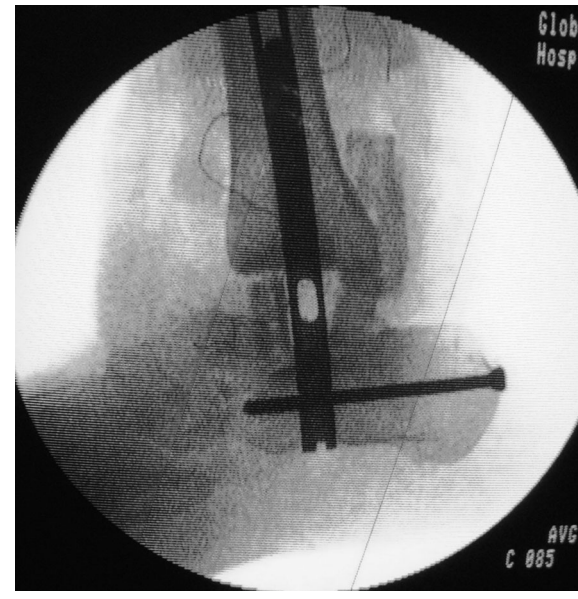

FIGURE 9. Intraoperative fluoroscopic image showing the vertically placed fibular strut grafts between the tibia and calcaneus.

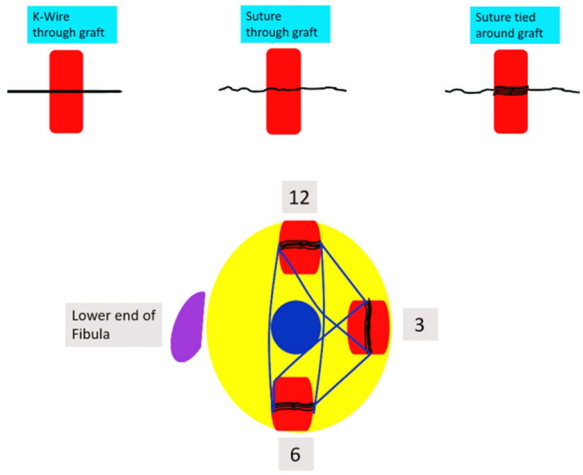

FIGURE 10. Schematic diagram representing the passage of threads through the fibular grafts and placement of the grafts around the hindfoot nail. Top left—K-wire being passed through the fibular graft to create a tunnel. Top middle—thread passed in this tunnel. Top right—multiple turns of the thread taken around the fibular graft. Bottom—fibular grafts placed at 12, 3, and 6 o'clock positions around the nail and lateral half of distal fibula acting a live lateral plate at 9 o'clock position.

Next, a compression nut is passed through the distal end of the nail, up to the previous transverse calcaneal screw, such that on tightening of the compression nut, the nail slides down and brings about compression at the bamboo grafts placed between the calcaneus and tibia (ie, at the level of the talus). Compression generated through the nail is just sufficient to hold struts snuggly into the defect and not to dislodge or splinter them. Compression is performed in a controlled manner and under direct vision. Following this, a static posteroanterior screw is passed through the nail into the calcaneus. The lateral half of the split fibula is fixed with tibia and talus by 4-mm cannulated cancellous screws, thus serving as a strut placed at 9 o'clock position. The medial half of the lower end of the fibula is used as corticocancellous grafts and is packed in any visible bone gap. This precludes the need for an extra incision and related morbidity elsewhere, solely for harvesting bone graft. Finally, the optional proximal-most screw is passed at the tip of the nail by free hand. The press-fit configuration and biomechanical stability of the construct, help forgo further use of implants for added stability. The wound is closed in layers over a drain, and a below-knee plaster slab is applied.

COMPLICATIONS

Overzealous debridement of the joint surfaces or inadequate planning can lead to even larger defects, which may necessitate harvesting a longer segment of the fibula. If due care is not exercised, injuries to sural, superficial peroneal, and deep peroneal nerves may result. Osteoporotic bones are known to collapse; hence, distraction and retraction should be careful. Because of the proximity of the posterior and anterior tibial arteries, their protection during flap dissection is of utmost importance. Overzealous tightening of the compression nut can create splinters in the fibular autograft and end up destroyed. A maximum of 7-mm compression is possible with the compression nut. Because of large cancellous regions being exposed, the likelihood of postoperative bleeding should be anticipated, and preoperative tranexamic acid administered if not contraindicated.

POSTOPERATIVE MANAGEMENT

A compressive dressing followed by a below-knee slab is advised to decrease venous congestion and to ensure immobilization. The first inspection of a wound is done at the end of 48 hours, followed by the removal of sutures on the 12th day. Non–weight-bearing foot range of motion and strengthening exercises are started by this time. The below-knee plaster splint is removed at the end of 6 weeks, and ankle series x-rays are taken for evaluation of fusion (Fig. 12). Gradual, progressive weight-bearing is advised after 10 to 12 weeks with serial radiologic monitoring of the arthrodesis.

POSSIBLE CONCERNS, FUTURE OF THE TECHNIQUE

Implant removal is usually not necessary unless symptomatic, but solid fusion should be confirmed before implant removal.

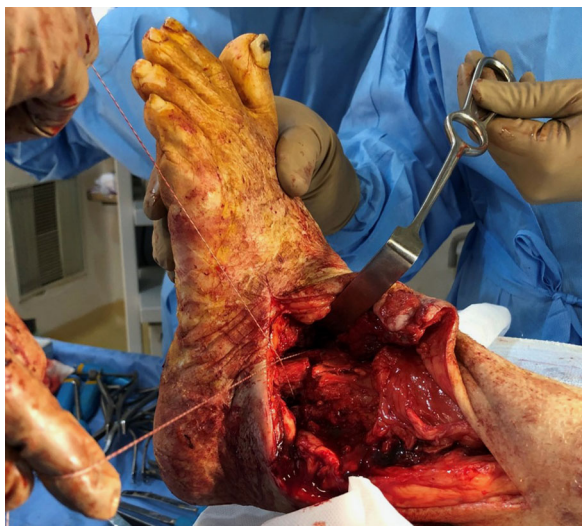

FIGURE 11. The 3 fibular "bamboo" grafts are tied together with nonabsorbable suture material (FibreWire).

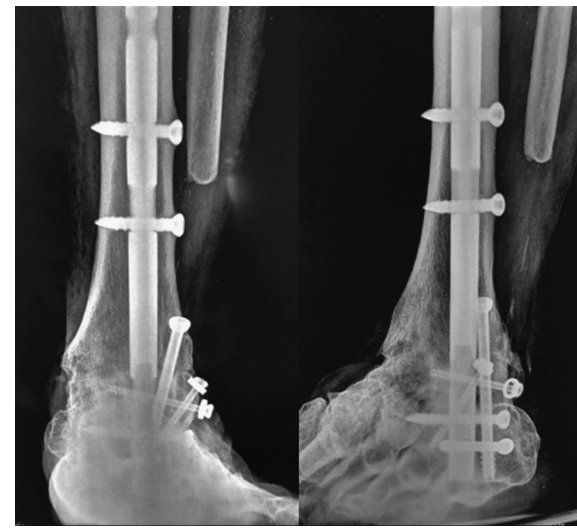

FIGURE 12. Tibiotalocalcaneal fusion with hindfoot nail and 3 cancellous screws.

We have operated 5 cases with this technique without any graft dislodgement as they were compressed and tied together. All patients had uneventful healing of the arthrodesis in 4 months. We learn that the modifications described in this technique are better over previous descriptions for the following reasons: 3 graft segments are used rather than 4 as split lateral half of distal fibula remains as a live plate on the lateral surface, the grafts being tied together like bamboo pillars make the construct stronger, compression imparted by the modified nail facilitates faster union and prevents the grafts from slipping, and lastly, only a smaller incision is required hence averting injury to branches of the superficial peroneal nerve.

Similarly, easy availability of allograft and orthobiologics remains a far-fetched option in several parts of the globe, wherein regular and less sophisticated procedures utilizing the patient's own fibula with few indigenous technical tricks play a vital role in bridging significant defects in the ankle, along with giving structural stability to the nail-graft construct.

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