Composite Bone and Soft Tissue Loss Treated With Distraction Histiogenesis

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The purpose of this article is to describe the use of shortening and angulation to manage composite bone and soft tissue loss associated with combat-related type IIIB open tibia fractures. Four patients underwent placement of a software-driven circular fixator with acute shortening and angulation to manage composite bone and soft tissue loss. Frames were applied using the Rings First Method, and an induced deformity was created with the soft tissue defect within the concavity. Distraction histiogenesis was utilized to restore limb length and regenerate soft tissues. Three patients had healed fractures and mature regenerate allowing frame removal, while one remained in his frame for further consolidation. Mechanical alignment and limb length were restored in all patients. No major frame adjustments were required and all distracted soft tissues healed without complication. The article concludes that composite bone and soft tissue loss is effectively managed with distraction histiogenesis and the use of a software-driven circular fixator. (Journal of Surgical Orthopaedic Advances 19(1):23–28, 2010)

Key words: distraction histiogenesis, Ilizarov, shortening and angulation, Taylor spatial frame

Devastating extremity trauma remains a hallmark of the current military conflicts in Afghanistan and Iraq. Extremity injuries represent a large proportion of combat-related injuries and recently have been shown to utilize more resources and lead to greater rates of disability (1, 2). Tibia fractures represent a common injury seen in combat, often the result of blast injuries leading to multiple projectile penetrating trauma, and less commonly they are secondary to high-velocity gunshot wounds or blunt mechanisms; the high-energy nature of these injuries means that many of these fractures are open and may be associated with loss of either bone or soft tissue (1).

The presence of segmental bone loss represents a major hurdle in the management of acute tibia fractures, with high complication rates and the frequent need for multiple surgical interventions (3–8). The goals of limb salvage surgery in this setting are to restore length and alignment, regenerate bone loss, obtain fracture union, and provide a stable, functional extremity. There are multiple modalities available from which to achieve these goals, including primary shortening, cancellous autografting, vascularized free fibula transfer, and distraction osteogenesis. Distraction osteogenesis may be performed using the monofocal bone transport technique originally described and taught by G.A. Ilizarov, or with more advanced techniques, including shortening with or without angulation, bifocal or trifocal transport, transport over an intramedullary nail, or hemifibular transport (9–12).

Associated soft tissue defects may be managed with either a rotational flap or free tissue transfer. In specific circumstances soft tissue transport in conjunction with bone transport may be pursued, or shortening with or without angulation with secondary tissue lengthening (distraction histiogenesis) may be necessary to close a defect (11, 13). The use of free flaps may be limited in the setting of a single vessel limb because of the risk of microvascular steal syndrome and resultant limb compromise (14, 15). The decision to use a particular technique is complex and dependent on multiple factors, including fracture location and size of the bone defect, presence and location of associated soft tissue defects, and other extremity injuries. Furthermore, surgeon availability

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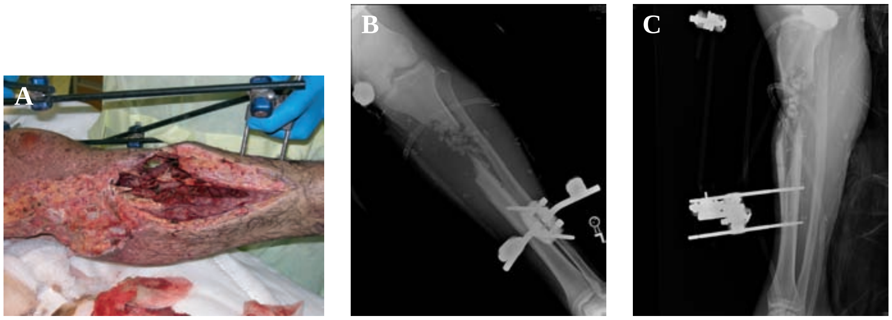

FIGURE 1 A 22-year-old soldier with severe bone and soft tissue loss from multiple projectile penetrating trauma from an improvised explosive device. The bone loss measured 7 cm. Severe injury to the medial head of the gastrocnemius was present, precluding safe use of a rotational flap to obtain soft tissue coverage.

plays a major role in determining the optimal treatment modality, with free tissue transfer dependent on the presence of a qualified flap surgeon.

We present a series of four US military service members with combat-related type IIIB open tibia fractures treated at two military medical centers by the senior author (JRH) with composite bone and soft tissue loss reconstructed utilizing distraction histiogenesis with principles of acute shortening and angulation. All patients consented to the use of their medical records in conducting this research.

Objective

The objective of this study was to demonstrate that composite bone and soft tissue loss associated with combat-related type IIIB open tibia fractures can be effectively managed with Ilizarov techniques of shortening and angulation, and that the use of software-driven circular external fixation (Taylor Spatial Frame, TSF, Smith and Nephew, Memphis, TN) can simplify the process, avoiding the need for major frame adjustments and making correction of residual deformity easier.

Methods

Between May 2005 and March 2009, the senior author (JRH) treated four patients with distraction histiogenesis and principles of acute shortening and angulation to manage large composite bone and soft tissue defects. All four patients were active duty service members (three US Army and one US Marine). Each patient was a poor candidate for flap coverage because of various reasons. One poly-traumatized patient with burns was adamantly opposed to the use of a free flap from an uninjured part of his body. Another had a single patent posterior tibial artery, precluding free tissue transfer. The other two patients were smokers with severe local muscle injury, which eliminated safe use of either a soleus or gastrocnemius flap for rotational coverage (Fig. 1). All patients were male with an average age of 24 years (range, 22–26). Three involved segmental loss of the tibial diaphysis and one loss of the proximal tibia. All fractures were Gustilo and Anderson type IIIB injuries. Two of the four patients were tobacco users as mentioned previously.

Prior to definitive shortening and angulation, aggressive and thorough debridement was performed until only healthy, viable tissue remained within the wound bed. A Taylor Spatial Frame was then mounted using the Rings First Method. In this technique the rings are mounted orthogonal to the proximal and distal bone fragments first prior to shortening or angulation being performed. Using this method, no individualized preoperative planning or intraoperative frame construction is necessary. Once the rings and struts were mounted using wires and half-pins, an “induced deformity” was created by shortening and angulating the limb, with the soft tissue defect focused within the concavity of the deformity (Fig. 2). The limbs were shortened and angulated as much as necessary to obtain bone and soft tissue coverage; in one patient this distance was 8 cm.

Intraoperative Doppler testing was utilized to assess for changes in vascular status before and after shortening and angulating the limbs. In two patients the skin edges came into approximation and primary closure was possible. The third patient, once shortened and angulated, had redundant local muscle available for coverage and only split-thickness skin grafting was necessary. The final patient, whose anteromedial soft tissue defect would have required a large latissimus dorsi free tissue transfer for coverage (>17 cm in length), refused a free flap procedure and chose instead to undergo local rotational coverage. By shortening and angulating the limb, the resultant smaller wound was easily managed with a soleus flap and skin grafting. After a variable latency period of 2 to 4 weeks to allow soft tissue healing, routine anteroposterior and lateral radiographs were templated in order to perform a gradual correction of the induced deformity. We utilized the Taylor Spatial Frame software, version 3.0.1 (Smith and Nephew, Memphis, TN) and performed

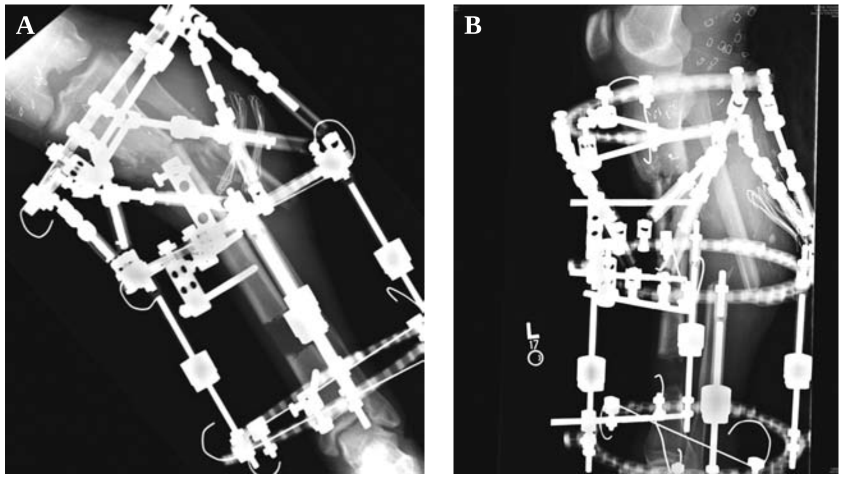

FIGURE 2 Anteroposterior and lateral radiographs after placement of Taylor Spatial Frame with acute shortening and angulation to obtain soft tissue coverage. A distal corticotomy with proximal bone transport was performed to restore limb length.

a total residual program. The skin edges of the wound were defined as the "structure at risk," and distraction was done at the rate of 1 mm per day until length and alignment were restored. Total residual programs were run at regular office visits until length and alignment were restored compared to the contralateral uninjured limb on standing bilateral hip-to-ankle radiographs.

In three patients corticotomy with distraction osteogenesis was required to restore limb length. In two limbs the corticotomy was distal and in one limb it was proximal. Bone grafting of the docking site or fracture was performed on a case-by-case basis at the discretion of the senior author. All three patients who underwent bone transport utilized low-intensity pulsed ultrasound to encourage regenerate maturation (Exogen, Smith and Nephew, Memphis, TN). None of the patients used nonsteroidal anti-inflammatory drugs as part of their postoperative pain pathway.

Results

At an average follow-up of 16.9 months (range, 4–33), 4/4 (100%) patients had a healed soft tissue envelope (Figs. 3 and 4). No cases of ulceration, breakdown, or wound separation occurred in this series of patients with correction of the induced deformity and resultant lengthening of the soft tissue. The three patients who had their frames removed had healed docking sites, and the fourth whose frame remained in place had a healing fracture without evidence of delayed union. In 2/4 (50%) of the patients, staged bone grafting of the docking site was performed directly through the distracted soft tissue bed without resultant complications. The average bone loss in this series measured 7 cm (range, 5–8 cm). In the four patients, there were no major frame adjustments necessary during their treatment course. Only routine strut changes were necessary, and these were performed during scheduled office visits.

The average frame time for the patients who completed therapy was 12.1 months (range, 8.8–17.0). The three patients who required bone transport had an average distraction gap of 7.67 cm (range, 7–8 cm). The estimated frame index for these three patients was 1.74 (range, 1.01–2.13). The average radiographic consolidation index, as defined by Paley and Maar (8), was 1.72 (range, 1.09–2.13). The patient whose frame time extended to 17 months was a tobacco user with persistent delay in regenerate consolidation.

Complications were defined as minor or major. Major complications required a return to the operating room. One patient had no complications, while the other three patients had a total of seven complications (five minor and two major). Four of the five minor complications were

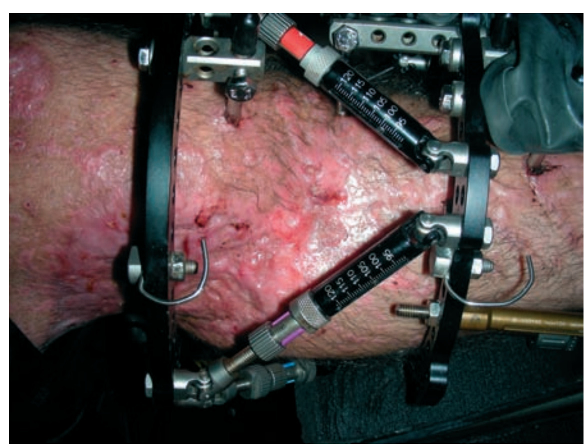

FIGURE 3 Healed soft tissue envelope at 3 months postoperatively.

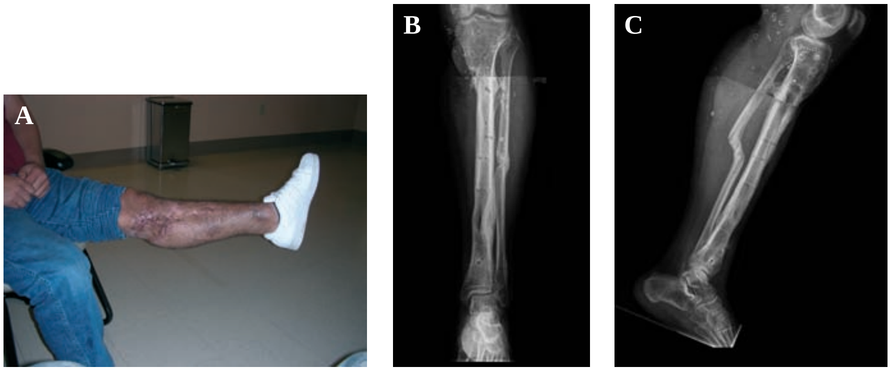

FIGURE 4 Mature soft tissue envelope at 1-year follow-up, with restoration of limb length and mechanical axis.

pin-tract infections and one was a painful pin requiring removal. The first major complication included premature fibular consolidation leading to syndesmosis subluxation during tibia distraction. This required repeat fibular osteotomy and syndesmosis fixation. The second major complication was a scarred tibialis anterior tendon within the lengthened soft tissue requiring local release. Each of the major complications was successfully managed with a single additional operative procedure.

Final limb length and alignment were determined using serial bilateral standing hip-to-ankle radiographs. All four patients had the mechanical axis and limb length restored as determined on these radiographs. The three service members whose frames have been removed have returned to athletic activities, including some running. The fourth soldier, despite being in his frame, walks without the use of assistive devices, and can easily stand on his one injured leg. One patient has returned to active duty.

Discussion

Reconstruction of bone and soft tissue defects associated with high-energy open tibia fractures remains a challenging task under the best of circumstances. Flap complications and/or failure rates have exceeded 20% in some studies (16–18). Although rotational and free tissue transfer techniques account for the majority of the soft tissue reconstructions performed for high-energy traumatic wounds (19–23), there is growing attention being paid to the use of the Ilizarov method of external fixation, with use of temporary shortening with or without angulation to reconstruct soft tissue. This soft tissue can subsequently be lengthened under the tension-stress effect with expected lengthening of skin, muscles, nerves, and even blood vessels (24–29). Additionally, secondary bone grafting procedures at the fracture or docking site can safely be performed through this relengthened soft tissue (30). Multiple authors have demonstrated good results with shortening and angulation, with the principle goal of avoiding the need for rotational or free tissue transfer (13, 31).

Although three or four centimeters have arbitrarily been assigned as the maximal amount of acute shortening that may be safely employed (12), we have found that greater amounts of acute shortening can be safe. We routinely use intraoperative Doppler signaling to assess distal arterial flow before, during, and after acute shortening or angulation. Any change in the normal triphasic signal indicates possible vascular kinking, and shortening is relaxed until flow is restored and a normal Doppler signal is obtained. We successfully shortened all patients in our series acutely, even with defects of 8 cm, and had no change in Doppler signal concerning for vascular compromise. The importance of being able to shorten large defects acutely to obtain primary soft tissue closure is critical when one considers that most wound infections are nosocomial in nature and delays in closure are associated with increased rates of wound infection (32–37).

In contrast to previously described techniques of concomitant bone and soft tissue defect management with the Ilizarov apparatus, the Taylor Spatial Frame is unique in that it requires minimal preoperative frame planning or major postoperative frame adjustments. Despite the creation of complex and often dramatic appearing induced deformities, gradual correction is possible and further simplified with the use of the Total Residual Program software. Through the "virtual hinge" created by the Spatial Frame software, continuous fine tuning of the reduction can occur without frame revisions. The software allows this fine tuning at any step in the process. Furthermore, the Web-based Spatial Frame software simplifies the surgeon's ability to consistently provide 1 mm of soft tissue lengthening daily at the critical skin edge by defining it as the "structure at risk."

Complications when using ringed fixators are common, and our series of patients is no different. Two of the four patients (50%) in our series had major complications requiring an additional operation, which is similar to other reports using Ilizarov techniques (3, 8, 10). Many of the complications that we report in our series (5/7) are considered problems or obstacles by some authors rather than true complications (38). The frame times experienced in our series of patients and the time to consolidation are consistent with previous reports of larger series of patients from multiple authors (3, 7, 8, 10).

Conclusion

Acute shortening and angulation with use of software-driven circular external fixation is an effective treatment modality when managing composite bone and soft tissue loss. It allows for simple frame application, correction of residual deformity, and avoidance of major frame adjustments. Regeneration of lost bone and soft tissue can obviate the need for massive bone grafting and free tissue transfer.

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