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Bone transport versus acute shortening for the management of infected tibial non-unions with bone defects

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ABSTRACT

Introduction: This study compared bone transport to acute shortening/lengthening in a series of infected tibial segmental defects from 3 to 10 cm in length.
Methods: In a retrospective comparative study 42 patients treated for infected tibial non-union with segmental bone loss measuring between 3 and 10 cm were included. Group A was treated with bone transport and Group B with acute shortening/lengthening. All patients were treated by Ilizarov methods for gradual correction as bi-focal or tri-focal treatment; the treating surgeon selected either transport or acute shortening based on clinical considerations. The principle outcome measure was the external fixation index (EFI); secondary outcome measures included functional and bone results, and complication rates.
Results: The mean size of the bone defect was 7 cm in Group A, and 5.8 cm in Group B. The mean time in external fixation in Group A was 12.5 months, and in Group B was 10.1 months. The external fixation index (EFI) measured 1.8 months/cm in Group A and 1.7 months/cm in Group B ($P = 0.09$). Minor complications were 1.2 per patient in the transport group and 0.5 per patient in the acute shortening group ($P = 0.00002$). Major complications were 1.0 per patient in the transport group versus 0.4 per patient in the acute shortening group ($P = 0.0003$). Complications with permanent residual effects (sequelae) were 0.5 per patient in the transport group versus 0.3 per patient in the acute shortening group ($P = 0.28$).
Conclusions: While both techniques demonstrated excellent results, acute shortening/lengthening demonstrated a lower rate of complications and a slightly better radiographic outcome. Bone grafting of the docking site was often required with both procedures.
Level of evidence: Level III; Retrospective comparative study

Introduction

Infected tibial non-unions have always been extremely difficult to manage successfully, and this challenge is magnified when a segment of bone is absent [1–6]. Chronic osteomyelitis may require additional resection of necrotic bone to eradicate an active nidus of infection [7,8]. Major soft-tissue injuries, deformity, or a leg-length discrepancy can significantly influence the functional outcome and may further complicate the presentation. They are often the consequence of high-energy trauma and many have already failed to respond to multiple prior surgical procedures, resulting in further soft tissue compromise. This may impair local vascularity surrounding the non-union, exposing the limb to greater risk of

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treatment failure [7,8]. Underlying host factors such as smoking or diabetes may further compromise conditions.

There are several treatment options available to manage patients who have tibial non-unions with bone defects in the presence or absence of infection [1,9–13]. These include cancellous bone grafting [4,14–16], Papineau open cancellous bone grafting [17], vascularized free-tissue transfers [18–20], and combined approaches with both microvascular tissue transfers and bone grafts [3]. Masquelet developed the induced membrane technique almost 20 years ago, to enhance graft incorporation [21,22]. However, acute corrections are often limited by soft tissue constraints, and these methods may not allow the surgeon to completely correct alignment and restore limb length. Regardless of the option selected, treatment times associated with limb salvage are usually long with frequent complications [4,14–16,23–25]. Alternatively, amputation may be considered a reasonable surgical reconstructive option for those patients who seek a definitive procedure with a more predictable outcome [7,8,26,27].

Distraction histogenesis [25,28–30] techniques and methods using external fixation for gradual correction have dramatically expanded the options available for the treatment of tibial non-unions and associated bone defects [1,2,9–12,23,31–35]. These methods, pioneered by Ilizarov [29,32], have been used successfully outside Russia for over 30 years [1,2,15,16,34–36]. In contrast to other methods, these techniques can simultaneously address the multiple elements of pathology including shortening, deformity, bone loss, joint contractures, and some soft tissue defects. The Ilizarov method for the treatment of tibial non-unions associated with bone defects generally involves bifocal or trifocal osteosynthesis [1,34], compressing bone at one level to achieve union while simultaneously applying distraction to the same bone at another level to regenerate bone mass. These Ilizarov methods of limb salvage include both bone transport [1,4,5,7,9–12,34,36–43] and acute shortening/lengthening [5,7–9,36,44–48].

Bone transport is characterized by the gradual translocation of a segment of bone, often together with its surrounding soft tissue envelope, from an adjacent healthy area into the region of bone loss [1,4,5,7,9–12,36–43]. A low energy osteotomy or corticotomy [29,30,49] is performed at a location outside the zone of injury, and the external fixator used to gradually transport the bone segment under carefully controlled mechanical conditions. As the bone defect gradually becomes smaller the process of distraction osteogenesis generates new bone in the distraction gap, restoring bone mass and skeletal continuity [29,30]. The hallmark of bone transport is that the length of the limb does not change since the rate of lengthening in the distraction gap is equal to the rate of shortening at the bone defect site.

Acute shortening/lengthening is characterized by shortening of the limb through the region of the bone defect itself, and can be performed acutely, gradually, or as a combination [5,9–12,36,44–48]. The shortened limb is concurrently lengthened to equalize limb lengths through bifocal osteosynthesis, analogous to the technique used for bone transport. An external fixator is used to apply compression across the defect to achieve union, and length is gradually restored by simultaneous distraction through an osteotomy at another level. The hallmark of acute shortening/lengthening is the early contact across the original area of bone loss [5,9–12,36,44–48]. This early compression enhances the mechanical stability of the bone-fixator composite, and offers the potential of more rapid union resulting from immediate contact. Recent publications discussing this approach have unfortunately suffered from limitations in study design and sample size, or have been less robust statistically [45–48].

Soft tissue and vascular considerations dictate the extent of acute correction possible. Cases with large bone defects are generally treated by bone transport, and cases with small bone defects are more often treated by acute shortening/lengthening. The purpose of this study was to compare bone transport to acute shortening/lengthening in the treatment of a series of cases of tibial segmental defects. We hypothesized that acute shortening/lengthening would result in fewer docking site complications and procedures, and a shortened treatment time, compared to bone transport.

Materials and methods

Study design

This retrospective non-randomized comparative study was based on hospital records and analysis of routine radiographs obtained during the course of treatment. This project was part of a clinical audit and exempted from IRB approval. Inclusion criteria were adult patients with post-traumatic tibial non-unions with bone loss measuring between 3 and 10 cm. Patients were excluded if the medical record was incomplete or follow-up was less than one year. Surgery was conducted by three experienced Ilizarov surgeons at multiple sites all within a single medical system in Baltimore, MD, USA. All patients were managed using Ilizarov methods and the Ilizarov circular external fixator (Smith & Nephew, Memphis, TN), either by bone transport or acute shortening/lengthening. Treatment selection was based on clinical parameters according to surgeon judgment, individualized to the specifics of each particular case. Some of the patients in the bone transport group were already included in the study cohort of a prior publication dedicated to that technique [39].

The total bone loss was calculated as the sum of the length of the bone defect and the magnitude of any limb length discrepancy, if present. The radiographic consolidation time for the distraction gap was measured according to the criteria of Fischgrund, et al. [28]. The principle outcome measure was the external fixation index (EFI), determined by dividing the time in external fixation by the length of bone regenerated (in months/cm). Clinical outcomes were divided into bone results and functional results according to the evaluation system previously reported by Paley and Maar [39]. Complications were recorded, and these were considered either minor (treated non-operatively), major (treated operatively), or sequelae (unresolved after treatment) [24].

Surgical considerations

Detailed descriptions of the surgical techniques for bone transport [39,42,43] and acute shortening/lengthening [44,48] have been published previously. Cases with large bone defects (>10 cm) are generally treated by bone transport, while small bone defects (<3 cm) are most often treated by acute shortening/lengthening. Soft tissue and vascular considerations generally dictate the extent of acute correction possible, when indicated. Despite its more direct nature acute shortening/lengthening should be considered the more technically demanding procedure, particularly in cases with bone defects exceeding 4 cm. Acute shortening requires additional soft tissue dissection, while bone transport is a less extensive procedure with no need to expose the fibula. The immediate risk is often greater with acute shortening compared to bone transport, with an increased possibility of catastrophic vascular injury. Although no vascular injuries were encountered in this series, it remains a genuine risk and the vascular response to shortening must be monitored carefully. If any significant change in circulation was identified after acute shortening, the limb was lengthened a centimeter and circulation reassessed. The residual bone defect was then managed by gradual shortening at a relatively rapid rate (2–3 mm/day) over the next two weeks. Dense scarred soft tissues must be resected completely