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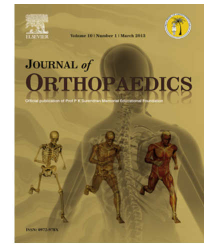

Original Article

Mechanobiology in the management of mobile atrophic and oligotrophic tibial nonunions

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ABSTRACT

Background: Recent research indicates that atrophic nonunions are biologically active and may heal in the optimal biomechanical environment.

Methods: Thirty-three patients with mobile atrophic and oligotrophic tibial nonunions were treated with circular external fixation and functional rehabilitation. Seven patients required autogenous bone graft procedures.

Results: Bony union was achieved after the initial surgery in 31/33 (93.9%) tibias. Two persistent nonunions were successfully treated with repeat circular external fixation without bone graft. This resulted in final bony union in 33/33 (100%) patients.

Conclusion: Mechanobiological stimulation of tibial nonunions can produce union even if the biological activity appears to be low.

1. Introduction

The clinical entity of tibial nonunion incorporates a variety of conditions that range from mobile to stiff, hypertrophic to atrophic, with deformity or without, and even large segmental bone defects, with or without limb length discrepancy.[1–3] The proposed management of these subdivisions is almost as numerous as the variation in nonunions themselves, and even within groups, the management can be affected by host factors, condition of the surrounding soft tissues, and the nonunion morphology itself.[2,4]

The treatment of tibia nonunions is mostly based on small series of cases that frequently include a variety of nonunion subtypes and even infected cases.[2,5,6] Fixation methods vary from internal fixation, including conventional compression plating, locked plating, and reamed intramedullary nailing, to external fixation, with either monolateral fixators, circular fixators, and hybrid fixators.[2,5,7,8] Some authors have proposed cast immobilization and isolated fibula osteotomy.[9] Adjuvants to surgical management include the use of autogenous bone graft, autologous bone-marrow aspirate, bone morphogenic proteins (BMPs), low-intensity ultrasound, and hyperbaric oxygen.[10–15] This lack of uniformity in the available literature

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has rendered the establishment of an evidence-based, reproducible protocol for the management of tibial nonunions difficult, if not impossible.

In this retrospective review, we focus on the management of mobile atrophic and oligotrophic tibial nonunions. We report our results of a uniform series of tibial nonunions treated by circular external fixation. In addition, we aim to show that the correct biomechanical environment can promote bone healing without the need for routine bone graft and expand on the concept of mechanobiology in the management of tibial nonunions.

2. Methods

From January 2010 to January 2014, 36 patients with mobile atrophic and oligotrophic tibial nonunions were treated at our tertiary level limb reconstruction unit. Three patients were excluded because they did not complete the proposed treatment. These included a 33-year-old male and a 44-year-old female, and both died of systemic complications of chronic disease. Both these patients were HIV positive and developed nonunion following open fractures. The third patient presented to our unit three years after sustaining an open fracture. He was a chronic smoker and his previous treatment included three different external fixators, cast immobilization, internal fixation, and surgery for metalware removal. This patient was unwilling to continue reconstruction after 12 weeks in a circular external fixator and requested amputation.

Nonunions were defined as at least six months time elapsed since the fracture and union deemed unlikely without further intervention. Nonunions were classified according to radiographic appearance on preoperative radiographs. Atrophic nonunions demonstrated no callus formation or periosteal reaction while minimal callus formation designated oligotrophic nonunions. Nonunions were further classified as mobile if more than 7° motion was possible at the nonunion site. Motion was assessed preoperatively and then confirmed intraoperatively following fibula osteotomy. There were 22 atrophic and 11 oligotrophic nonunions as determined by preoperative radiographs.

Open fractures were the initial injury in 20 patients. Nine injuries were Gustilo-Anderson IIIB, nine Gustilo-Anderson IIIA, and two Gustilo-Anderson II open fractures.[16,17] Four patients had tibia fractures following gunshots and three of these patients had emergency fasciotomies at the time of injury. Nine patients had closed fractures; five were initially treated by closed manipulation and cast immobilization and the other four were treated by intramedullary, interlocked nails (Fig. 1). Duration of nonunion ranged from six to 192 months since the initial injury, with a mean of 25 months.

A standard physical, laboratory, and radiographic evaluation was performed on all patients as per protocol. Any modifiable risk factors that were identified were optimized. These included cessation of smoking, optimal glycemic control in diabetics, and the commencement of highly active antiretroviral therapy for HIV positive patients with low CD_4 counts, prior to surgical intervention. All patients with infected nonunions were excluded. Screening consisted of a detailed history to exclude any previous wound drainage, sinus formation, or treatment for infection of the nonunion site. This was supplemented with clinical and laboratory evaluation that consisted of complete blood count, erythrocyte sedimentation rate, and C-reactive protein level.

Fig. 1 – Antero-posterior and medio-lateral radiograph of tibial nonunion 10 months after intramedullary nail.

Partial fibula resection prior to circular external fixator application was performed in all cases. Resection was performed under tourniquet control and at the level of the fibular deformity if present. Direct surgical approach between the peroneal and soleus muscles was made. The fibula was exposed by subperiosteal dissection and a small oscillating saw was used to resect approximately 10 mm of fibula to prevent early fibular consolidation. Fascia and skin were closed in layers over a drain. The tourniquet was deflated for the remainder of the operation.

External fixation started with a custom prebuilt frame for each patient. Standard frame construct consisted of a four-ring frame with two rings making up a ring block for each bone segment. Frame application proceeded in a stepwise approach starting with proximal and distal reference wires, followed by gradual nonunion reduction as fixation is added toward the two middle rings of the frame.[18] Frames were applied in a hybrid method, using a combination of tensioned fine wires and maximum two hydroxyapatite (HA) coated half pins. Once mechanical alignment and stable fixation were achieved, the nonunion site was compressed manually by adjusting the distance between the proximal and distal ring blocks (Fig. 2).

The nonunion site was not routinely exposed or debrided and bone graft was only used for specific indications. These