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Functional bracing in the treatment of delayed union and nonunion of the tibia

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Abstract We treated 16 delayed unions and 57 nonunions of the tibial diaphysis with a below-the-knee functional brace. In 48 cases, bracing was preceded by fibular osteotomy, and ten patients had an additional bone graft. We were able to follow 67 patients, of whom six (8.7%) failed to respond to treatment. In patients with nonunion, bony healing occurred with a median of 4 months. There was no difference in the speed of healing according to the level of the defect. Shortening of the limb following osteotomy of the fibula had a mean of 3 mm in the delayed-union group and 5 mm in the nonunion group.

Résumé Nous avons traité 16 retards de consolidation et 57 pseudarthroses de la diaphyse tibiale avec une botte de type Sarmiento. Dans 48 cas l'appareillage a été précédé par une résection partielle du péroné et dix avait une greffe osseuse complémentaire. Nous avons suivi 67 malades dont six (8,7%) n'ont pas répondu au traitement. Chez les malades avec pseudarthroses la guérison osseuse s'est produite avec un temps médian de quatre mois. Il n'y avait aucune différence dans la vitesse de consolidation d'après le niveau du défaut osseux. Le raccourcissement du membre par la résection du péroné avait une moyenne de trois millimètres dans le groupe avec retard de consolidation et cinq millimètres dans le groupe avec pseudarthrose.

Introduction

Nonunion of fractures remains a challenge to the orthopedic community, and the literature is rich in reports dealing with a variety of surgical and nonsurgical approaches. In the more developed nations, some method of internal osteosynthesis currently is the most widely accepted approach. The use of internal osteosynthesis often is precluded because of financial considerations or deficiencies in the medical infrastructure. The functional treatment reported by us is based on the authors' clinical and laboratory experiences. These experiences indicate that rigid immobilization is not necessary for spontaneous repair of acute diaphyseal fractures, and that activity and physiologically controlled motion at the fracture site are conducive to osteogenesis. We extrapolated that similar premises could be made applicable to delayed unions and nonunions of the tibia.

Material and methods

We arbitrarily chose to define a delayed union as a fracture that failed to unite within the fifth and ninth months, and a nonunion a fracture that failed to unite after 9 months.

Seventy-three adult patients with aseptic delayed union or nonunion of the tibial diaphysis constituted the clinical material. Six patients were lost to follow-up. Of the remaining 67, 51 were male. Patient age ranged from 16 to 67 (median 27) years. Fifty patients had open fractures.

Treatment received at initial injury was casting in 21 patients, plating in 29, intramedullary nailing in six, and external fixation in 11. At initiation of functional treatment, no patient had internal devices in place. Fracture level was the proximal third of the tibia in 12, of which five were delayed unions and seven nonunions; 22 in the middle third of the tibia, of which three were delayed unions and 19 nonunions; and 21 in the distal third, of which six were delayed unions and 25 nonunions. Two were segmental fractures, of which one was a delayed union and the other a nonunion. Two different radiographic views demonstrated pathology. Fifteen conditions were delayed unions and 52 nonunions. Of the nonunions, 44 were hypertrophic and eight atrophic.

Prior to the initiation of functional bracing, patients with delayed union had been disabled from 5 to 9 (median 7) months and patients with nonunion between 9 months and 8 years (median 11

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Fig. 1 **a** Roentgenogram of tibial nonunion after multiple surgical attempts to achieve union. Notice the large defect. **b** Segment of the fibula and bone graft from the pelvic bone was placed against the nonunion site. A brace was then applied. **c** Fracture healed uneventfully

months). Functional treatment instituted for the pathological conditions consisted exclusively of bracing in nine patients, fibular osteotomy followed by bracing in 48, and osteotomy followed by bone graft and bracing in ten. In all instances, the functional method of treatment was applied to patients whose affected tibial diaphysis had, in the opinion of the authors, deformities that were aesthetically acceptable. We chose to add a graft to ten nonunions because of history of multiple previous unsuccessful surgical attempts to overcome the pathological condition. When motion at the fracture site was minimal, bracing was used without osteotomy or bone graft. All others had a fibular osteotomy.

The osteotomy was performed opposite the fracture approximately 2 cm above or below the lesion. The amount of bone removed was 1 cm. In the group who had no osteotomy, the functional brace was applied on the day the pathological diagnosis was made. In the group who had an osteotomy, with or without a bone graft, the below-the-knee brace was applied an average of 7 (maximum 35) days postoperatively. All patients were encouraged to bear weight on the extremity to a degree dictated by intensity of symptoms.

Results

Six patients failed to respond to the treatment protocol. For patients with delayed unions, the mean period of brace stabilization was 3 (2–5) months. For patients with nonunions, the mean period was 4 (2.5–13) months (Figs. 1, 2, and 3). Six patients failed to heal; five were nonunions, of which three were the hypertrophic type. In the group treated exclusively with the brace, one of nine failed to heal. In the group treated with osteotomy, three of 48 failed to heal, and in the group in which bone grafting was added, two of ten failed. Median healing time for patients who united was 3–4 months. Five of the six patients who failed to heal had open fractures.

Of the 39 patients who sustained the injury in a motor-vehicle accident, four failed to unite, as did two of the 20 patients who had gunshot injuries. There were no

Fig. 2 **a** Roentgenogram of 1-year-old tibial nonunion prior to osteotomy of the fibula. **b** Roentgenogram obtained 1 year after osteotomy of the fibula. Notice nonunion of fibular osteotomy

failures among those with injuries produced from direct blows or falls. Location of the original fracture had no relation to the rate of union. Of lesions in the proximal third of the tibia, one of 12 failed to unite; in the middle

Fig. 3 **a** Roentgenogram of 13-month-old nonunion of the distal tibia obtained shortly before the performance of a fibular osteotomy and application of a below-the-knee functional brace. **b** Roentgenogram illustrating union of the fractured tibia 6 months after surgery. Notice nonunion of fibular osteotomy

third, two of 22 failed; and in the distal third, three of 31 failed. Both cases with primarily segmental fractures healed. Shortening of the osteotomized fibula did not exceed 10 mm. In 10 cases, nonunion of the fibula was found; however, the tibias healed uneventfully.

Discussion

We conducted clinical and laboratory studies dealing with acute fractures, and these studies indicate that motion at the fracture site from weight bearing encourages osteogenesis [6, 12, 11]. Furthermore, the callus that forms possesses stronger mechanical properties than the one that forms in the presence of rigid immobilization [6, 9, 10]. Others have also documented the salutary effect of motion at the fracture site. We have documented that, in axially unstable tibial fractures treated with functional braces, "pistoning" motion between the fragments, at the end of the first postinjury week, approaches 0.5 cm [12]. The current preference for intramedullary nailing over plate osteosynthesis in the treatment of diaphyseal fractures seems to support the value of motion at the fracture site in fracture care. Nailing, however, contrary to our reported method of treatment, was not designed for the primary purpose of increasing motion at the fractures, particularly when the nail is of the interlocking type. A fibular osteotomy followed by application of a brace encourages additional motion at the nonunion site. The Ilizarov method of treatment of nonunions has further documented the value of motion at the fracture site, since this method calls for weight bearing during a rhythmic distraction/compression protocol [4].

In our retrospective analysis of tibial delayed unions and nonunions, we observed a failure rate of 8.9%. This

failure rate is comparable to that reported by others in recent years using other treatment modalities. Wiss et al. reported a failure rate of 8% in a group of 49 patients treated by compression plating, with an infection rate of 8% and fatigue fracture of the plate in 8% [13]. Seventy-eight percent of patients had an associated bone grafting procedure at the time of plating. Wiss reported that in 92% of patients nonunions healed "in an average of 7 months without further intervention." Time before union in our series ranged from 2.5 and 13 months.

Alho et al. obtained 100% union in a group of 25 patients treated with locked intramedullary nailing without bone grafting. All patients had a fibular osteotomy. They identified infection as a complication in 3% patients [1]. Rosson and Simonis encountered a failure rate of 8% in a group of 24 patients treated with locked intramedullary nailing [8]. Court-Brown et al. obtained 100% success in a group of 33 patients treated with exchanged intramedullary nailing [2]. Wiss and Stetson reported a failure to achieve union of 10.7% from a group of 47 patients treated with reamed intramedullary nailing [14]. De Bastiani et al. had a failure rate of 7% in a group of 21 patients with hypertrophic aseptic nonunions treated with a unilateral fixator [3]. Rijnberg and van Linge experienced a failure rate of 6% in a group of 48 nonunions treated with central intramedullary grafting [7]. Meskens et al. reported a failure rate of 25% in a group of 57 nonunions treated with pulsed electromagnetic fields [5].

The above brief summary of the literature suggests that different treatment modalities are associated with acceptable degrees of success. It appears to us that no clear advantages have been firmly documented to indicate that a given treatment is always superior to all others. We believe the use of functional braces following osteotomy of the fibula, with or without additional bone

grafting, is a viable method of treatment in aseptic delayed and nonunion of the tibia when minor, aesthetically acceptable angular deformity is present.

We suspect that the osteotomy of the fibula and the introduction of weight bearing constitute an episode similar to that of a new injury. This new "injury" probably provokes the biological responses that follow an acute fracture when graduated weight bearing and the resulting increased motion at the fracture site are introduced.

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