Partial fibulectomy for treatment of tibial nonunion

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Background

Despite the improved rate of union reported in tibial shaft fractures, there continues to be a small number of patients with delayed union and nonunion who present a dilemma to the surgeons. Because the spectrum of injuries to the tibia is so great, many methods of treatment are available to treat tibial nonunions.

Aim

The aim of the study was to evaluate partial fibulectomy as an easy, simple, and effective treatment option in the treatment of certain types of tibial nonunions.

Patients and methods

This prospective study included 20 patients with established tibial nonunion. All patients were evaluated clinically in laboratory and radiologically before surgery and followed up until after complete union of the tibial fractures.

Results

All fractures were united at an average duration of 15 weeks (range 10–19 weeks) after partial fibulectomy, with acceptable alignment in the coronal and sagittal planes. There were no neurovascular complications, no limitation of joint motion, and no problems at the fibulectomy site.

Conclusion

The results were very satisfactory and were significantly in favor of using this easy, simple procedure in the treatment of certain patients of tibial nonunions.

Keywords:

compression at the fracture site, partial fibular resection, tibial nonunion

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Introduction

The cornerstones for successful bone healing are biomechanical stability and biological vitality of the bone, as they both provide an environment in which new bone can be formed [1].

A fracture is said to have 'gone on to nonunion' when the normal biological healing processes of bone cease to the extent that solid healing cannot occur without further treatment intervention. For the purposes of clinical investigations, the US Food and Drug Administration defines a nonunion as a fracture that is at least 9 months old and that has not shown any signs of progression to healing for 3 consecutive months [2,3].

Tibial nonunions have been treated with a variety of surgical methods, including plate osteosynthesis with bone graft, intramedullary nailing, and external fixation. These methods may fail because of limitations including the quantity of graft available, poor vascularity, persistence of infection, and extensive bone defects and deformity [4].

A fracture nonunion represents a chronic medical condition associated with pain and functional and psychosocial disability [5].

Biomechanical principles of partial fibulectomy

The fibula carries 6–15% of the load of the lower extremity; hence, a healed fibula distracts a high percentage of the load as well as resists compression at the tibial nonunion site [6].

Thomas *et al.* [7] used cadaver lower limbs to study the stress on the tibia and fibula. They demonstrated that during loading on an intact tibia the anterior surface was continuously in relative tension. This tension diminished after partial fibulectomy. When a transverse fracture was made on the tibia with an intact fibula, a decreased compressive force was noted, leading to formation of an anterior gap. Partial fibulectomy increased the compressive strain of the tibia anteromedially and helped in closing the gap [7].

The rationale of partial fibulectomy is simple. A fracture of the fibular shaft associated with a tibial fracture usually heals in 6 weeks; thus, the fibula usually is intact when delayed union or nonunion of a tibial fracture is diagnosed. If a tibial fracture is to be compressed in the presence of an intact fibula, a considerable fraction of the applied force is spent to deform the intact fibula, thereby decreasing the compression force on the tibial fracture fragments. Hence, the healed fibula may prevent effective compression at the tibial fracture site and healing is adversely affected [8].

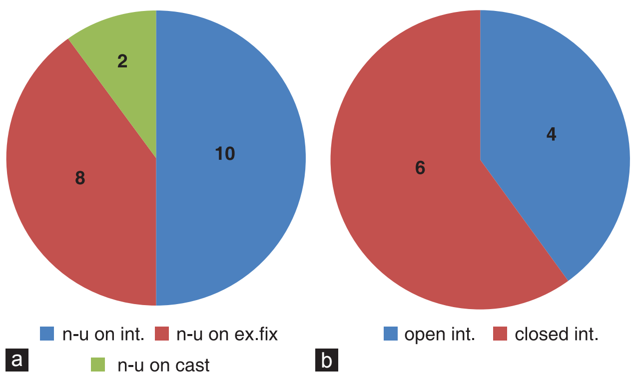
Patients and methods

This prospective study was conducted from September 2008 to March 2011 in the Orthopaedic Department of Benha University Hospital; 20 patients with established tibial nonunion were included. The duration of nonunion ranged from 8 to 18 months (mean 11 months). There were three (15%) female patients and 17 (85%) male patients. Their ages ranged from 8 to 42 years (mean 26 years).

Patients in this study were divided into different groups (Figs. 1a, b and 2): the first group included 10 (50%) patients with tibial nonunions on interlocking nail previously dynamized; the second group included eight (40%) patients with tibial nonunion after application of external fixators for open tibial fractures; and the third group included two (10%) patients with tibial nonunion after conservative treatment in the form of above-knee casts followed by walking casts (Fig. 1a).

In the group of tibial nonunion on interlocking nails previously dynamized, all patients had closed leg fractures. However, in four patients (40% of patients of tibial nonunion on interlocking nails previously dynamized) the interlocking was carried out after open reduction and exposing the fracture site, whereas in the remaining six patients (60% of patients of tibial nonunion on interlocking nails previously dynamized) the interlocking was carried out by a closed technique without exposing the fracture site (Fig. 1b).

Figure 1



(a) Different groups of tibial nonunion included in this study. (b) The two subgroups of patients of tibial nonunion on a dynamized interlocking tibial nail. ex.fix, external fixator; int., interlocking; n-u, nonunion.

Regarding the nonunion type, 16 (80%) patients had hypertrophic nonunions and four (20%) patients had oligotrophic and atrophic nonunions with one patient with segmental tibial fracture. At the time of presentation, only four (20%) patients were infected with nondraining and quiescent type of infected nonunion.

Inclusion and exclusion criteria

Any type of noninfected or infected active nondraining (no drainage but the area is warm, erythematous, and painful) and quiescent (no drainage or local signs or symptoms of infection for 3 months or more or patients without a history of infection but with a positive indium or gallium scan) tibial nonunion without bone loss was included in this study, irrespective of the biological potential for healing of the fracture (hypertrophic, oligotrophic, or atrophic) and of the method of previous fixation and treatment (interlocking nails, external fixators, or casting).

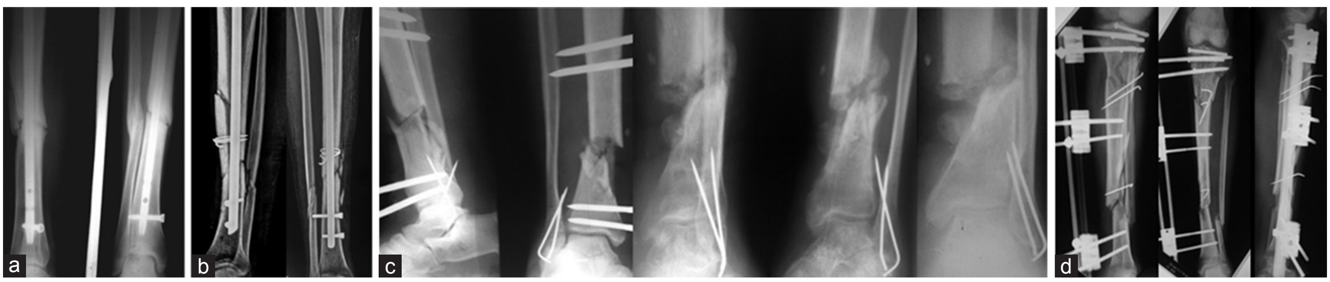
Any case of infected purulent draining tibial nonunion either internally or externally fixed or nonunion with bone defect was excluded from this study.

The ideal candidate for this line of treatment is a patient with a noninfected, hypertrophic nonunion, aligned in both the coronal and sagittal planes and fixed by interlocking tibial nail carried out by a closed technique for a closed fracture and that was dynamized later with either an intact fibula or a fibular fracture that had already united.

The preoperative evaluation of the patients

No two patients presenting with a fracture nonunion are identical, and the goal of the evaluation is to

Figure 2



(a, b) Tibial nonunion on dynamized interlocking. (c, d) Tibial nonunion on external fixators.

discover the cause of the nonunion. All patients were evaluated preoperatively. The evaluation process begins with a thorough history taking, including the date of injury and the mechanism of injury resulting in the initial fracture. Any pre-existing medical problems (e.g. diabetes, malnutrition, and metabolic bone disease), disabilities, or associated injuries that may have an impact on the treatment plan or expected outcome should be ascertained. An exhaustive review of all prior surgeries to treat the fracture and fracture nonunion, including the specific details of each surgical procedure, must be obtained [9].

After obtaining a thorough history, a physical examination is performed. The fracture zone should be inspected for the status of the overlying skin and soft tissues. The presence of active drainage and sinus formation should be noted. The presence and description of deformity at the fracture site should be documented. Manual stress testing of the nonunion site is carried out to evaluate motion and pain. In general, nonunions that display little or no clinically apparent motion have callus formation to some degree and have good vascularity at the fracture surfaces. Nonunions that display more motion generally have poor callus formation, but they may have vascular or avascular fracture surfaces. Accurate assessment of motion at a nonunion site is difficult in the case of a limb with paired bones when one of the bones is intact. Neurovascular examination should be performed to rule out or to document vascular insufficiency and motor or sensory dysfunction. Active and passive motion of the joints proximal and distal to the nonunion should be assessed [9].

The radiologic examination begins with a review of the original fracture films. This initial step offers tremendous insight into the character and severity of the initial bone injury.

Evaluation of the nonunion with good-quality radiographs is very important. They should include an anteroposterior and lateral radiograph of the involved bone (including the adjacent proximal and distal joints); evaluation of the nonunion site includes anatomic location, healing effort, bone quality, surface characteristics, status of previously implanted hardware, and deformities. Complete blood count, C-reactive protein, and erythrocyte sedimentation rate were performed in all patients. C-reactive protein, erythrocyte sedimentation rate, and TLC were elevated in four patients who were infected with the nondraining and quiescent types of infected nonunion.

The procedure

Partial fibulectomy was performed under anesthesia in the operating room under complete aseptic conditions, with tourniquet applied to provide a bloodless field to facilitate dissection. A skin incision was made just behind the fibular shaft about 15 cm above the lateral malleolus, where there is internervous plane lying between the peroneal muscles, supplied by the superficial peroneal nerve, and the flexor muscles, supplied by the tibial nerve. Deep surgical dissection begins by developing the plane between the peroneals and the soleus. Incision of the periosteum of the fibula down to bone was performed longitudinally in line of the plane of cleavage. All muscles that originate from the fibula have fibers that run distally from proximal to distal toward the foot and ankle. Therefore, they were stripped from distal to proximal. The interosseous membrane has fibers that run obliquely upward. To complete the fibular dissection, the interosseous membrane was stripped from proximal to distal.

After complete exposure of the fibula, a segment about 2.5 cm was cut from the fibula. Excision of less than 2.5 cm of the fibula may allow healing of the fibula to occur before consolidation of the tibia, and resection of an excessive length of fibula may result in gross instability at the site of the tibial fracture, necessitating prolonged use of a long cast. Care must be taken during cutting and removing the osteotomized fibular segment because the peroneal artery and veins lie just behind it and are vulnerable to injury. Before closure, it is very critical to release tourniquet and assure hemostasis; if in doubt regarding hemostasis, a suction drain could be used. After wound closure, patients in whom a previously dynamized interlocking was carried out, a postoperative casting was not needed, as the tibia was already aligned and fixed by the interlocking (Fig. 3a and b). An above-knee cast was used in perfect alignment assured by c-arm in all patients after application of external fixators (Fig. 3c and d).

The postoperative regimen

Full-weight-bearing walking initiated from the second postoperative day and gradually increased as tolerated by the patient. Radiological follow-up was carried out at 3 weeks intervals to detect compression at the fracture site and early formation of callus.

Results

Results in this study were assessed according to the criteria given by the Association for the Study and Application of the Methods of Ilizarov [10] that include both radiological and functional scoring systems. Patients were followed up for an average of 6 months (range 4–9 months). All fractures united at an average duration of 15 weeks (range

10–19 weeks) after partial fibulectomy, with acceptable alignment in the coronal and sagittal planes. The union time in patients in whom fibulectomy was performed and fixed by interlocking was significantly less when compared with the union time in patients in whom it was fixed only by casts after external fixators removal or in patients who were treated by casts from the beginning (13 and 18 weeks, respectively).

No significant difference was found in the union time according to the fracture site within the same group of patients. No significant difference was observed in the union time between patients of nonunion after interlocking was performed by either closed or open technique.

Radiographically, During the follow-up period with walking and compression at the fracture site, there was a gradual progression in the callus formation until complete union occurred with crossing trabecullae in at least three cortices; the axial alignment in all the planes was excellent (Fig. 4).

Even in patients with oligotrophic or atrophic nonunions, gradual axial compression at the fracture site after fibulectomy by full weight bearing can result in gradual formation of callus at the nonunion sites (Fig. 5a and b). The explanation is that mechanical stimulation by axial loading at the fracture site may alter the biological behavior of the nonunion site.

Bone healing was evaluated radiologically on the basis of union, infection, deformity, and limb-length discrepancy and was classified as excellent, good, fair, and poor (Table 1). The results were evaluated functionally according to five criteria that include return to activity, pain, limping, range of motion of adjacent joints, and sympathetic dystrophy and were classified as excellent, good, fair, and poor (Table 2).

Figure 3

(a, b) Fibulectomy without casting on dynamized interlocking. (c, d) Fibulectomy and casting after external fixators removal.

During the last follow-up, there was no pain or movement at the fracture site, full range of knee and ankle joints, no limb-length discrepancy, no operative wound infections, and no symptoms at the site of fibular resection or in the ankle; however, there was limping in two patients (associated knee ligamentous injury) (Fig. 6).

Discussion

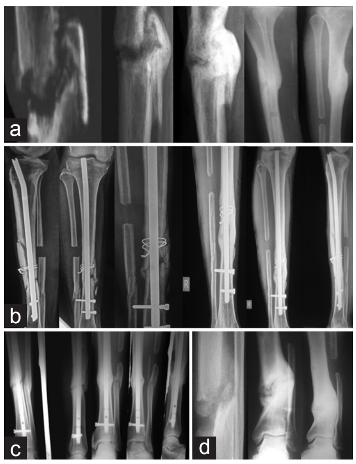
Two main factors increase the nonunion rate: the damage of vascularity at the fracture site and the instability at the fracture site. Causes that can lead to poor vascularization at the fracture site are high-energy injuries with damage

Table 1 Radiological results of patients in this study according to the Association for the Study and Application of the Methods of Ilizarov scoring system

Bone results	Criteria	Number of patients
Excellent	Union	18
	No infection	
	Deformity <7	
	LLD <2.5 cm	
Good	Union + any two of the following:	2
	Absence of infection	
	Deformity <7	
	LLD <2.5 cm	
Fair	Union + any one of the following:	0
	Absence of infection	
	Deformity <7	
	LLD <2.5 cm	
Poor	Nonunion/refracture/union + infection + deformity >7 + LLD >2.5 cm	0

LLD, limb-length discrepancy.

Figure 4



Gradual progression of bone union and consolidation at the fracture site after fibulectomy in different situations of tibial nonunion. (a) Tibial nonunion after conservative treatment in a cast. (b) Tibial nonunion on a dynamized interlocking nail that was performed by an open technique. (c) Tibial nonunion on a dynamized interlocking nail that was performed by a closed technique. (d) Tibial nonunion after external fixator for an open comminuted lower third tibial fracture.

Figure 5

The progression of bone union in the nonunion site in an oligotrophic nonunion. (a) Oblique view. (b) Anteroposterior view.

to the soft tissues, open fractures, comminuted fractures, bone loss, too much stripping of the periosteum during an open procedure, open insertion of a nail, or multiple failed procedures. Fracture instability can be caused by poor fixation [11].

Despite the improved rate of union reported in tibial shaft fractures, there continues to be a small number of patients with delayed union and nonunion who present a dilemma to the surgeons.

Because the spectrum of injuries to the tibia is so great, many methods of treatment are available to treat tibial nonunions.

Although treatment is directed at healing the fracture, this is not the only objective because a nonfunctional, infected, deformed limb with pain and stiffness in the adjacent joints is an unsatisfactory outcome for most patients, even if there is solid healing of nonunion. Emphasis must be placed on returning the extremity and the patient to the fullest function possible during and after the treatment process [12].

Partial fibulectomy has been described and used for more than five decades to promote healing in tibial nonunion because it allows better axial loading of the tibia [6].

In the 60s, fibulectomy was a well-established procedure in the treatment of tibial fractures and nonunions. Sorensen [13] reported healing in 26 of 30 tibia fractures treated with partial fibulectomy and weight bearing in a cast in an average of 7 months.

Fernandez-Palazzi [14] mentioned 100% success in the treatment of 14 delayed unions following partial fibulectomy and cast within 7–18 weeks. In 1981, Delee *et al.* [8] reported 37 healed tibial nonunions out of 48 after fibulectomy and weight bearing, with an average healing time of 25 weeks. Partial fibulectomy as a method for the treatment of tibial fractures and nonunions has thus been advocated for five decades, but its value now seems to be overlooked [6].

Figure 6

Clinical results of some patients. (a) Full knee and ankle range of motion, perfect alignment, no operative wound infections. (b) A case of an open fracture after external fixator removal, treated by fibulectomy, full knee and ankle range of motion, perfect alignment, no operative wound infections. (c) The patient with segmental nonunion, union occurred after fibulectomy with valgus attitude because of associated knee ligamentous injury.

Table 2 Functional results of patients in this study according to the Association for the Study and Application of the Methods of Ilizarov scoring system

Functional results	Criteria	Number of patients
Excellent	Active	19
	No limp	
	Minimum stiffness (loss of <15 knee extension/ <15 ankle dorsiflexion)	
	No RSD	
	Insignificant pain	
Good	Active with one or two of the following:	1
	Limp	
	Stiffness	
	RSD	
	Significant pain	
Fair	Active with three or all of the following:	0
	Limp	
	Stiffness	
	RSD	
	Significant pain	
Poor	Inactive (unemployment or inability to return to daily activities because of injury)	0

RSD, reflex sympathetic dystrophy.

Rankin and Metz [15] reported four patients who had a fibular osteotomy and had union of the tibial fracture site at an average of 4.1 months after fibulectomy. Moed and Watson [16] and Seldge *et al.* [17] used partial fibulectomy together with exchange-reamed intramedullary nailing in the management of nonunion of tibia.

Teitz *et al.* [18] studied the load on a fresh frozen adult human lower limb after creating an oblique tibial fracture while keeping both the fibula and interosseous membrane intact. With increasing load the interosseous membrane buckled and the distal tibia fragment developed varus angulation. This causes strain in the tibia and fibula that in the clinical condition may lead to nonunion or malunion. In a series of 26 patients with tibial fractures but intact fibula, they reported six delayed unions and six varus malunions [18].

Catagni and colleagues [19] consider partial fibulectomy as an essential part of the treatment for tibial nonunion to allow sufficient compression when used in combination with the Ilizarov frame. The rationale is that a healed fibula distracts a greater percentage of the load as well as resists compression at the tibial nonunion site. The fibula carries 6–15% of the load of the lower extremity [6]. As the Ilizarov frame resists translational shear, but with a low axial stiffness allowing optimal axial compression, the combination with partial fibulectomy offers an ideal tool for treating tibial nonunions [20].

Most nonunions still have enough biological potential once an optimal mechanical environment is created [21]. Although nonunions may be longstanding and appear atrophic and poorly vascularized, immunohistochemical localization of bone morphogenic proteins signalling components can be documented, even in the areas of dense fibrous tissue, as shown by Kloen *et al.* [22]. If cell signalling is preserved, the bone repair process restarts under well-aligned mechanical loading. Hence, good mechanical condition can restore a disabled biological system that could promote healing.

Conclusion

Partial fibulectomy has the following advantages:

(1) This operation is technically easy and can be performed by less-experienced surgeons.
(2) Operation upon the fracture site itself is avoided with the consequent risk for infection or added vascular damage to the fractured bony ends.
(3) The patient is mobilized the second day after the operation.
(4) This operation is applicable despite bad skin or skin defects over the fracture site.
(5) It retains the option of bone grafting with or without plating if union fails to occur.
(6) It affords the opportunity to correct any malposition.

Partial fibulectomy should be added to the algorithm for the treatment of tibial nonunion as a simple, easy, rapid, and inexpensive method to treat certain types of tibial nonunion.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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