



## Original Article

## Endoscopically assisted allogeneic bone grafting for atrophic nonunion of femur and tibia

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## ABSTRACT

**Background:** The nonunion rate for all fractures is about 5–10%. The treatment of nonunion is based on the biologic and mechanical factors contributing to the cause of the nonunion. Debridement and bone grafting are the standard procedures used to treat nonunion of fractures.

**Purpose:** We evaluated the results of endoscopically assisted allogeneic bone grafting performed to treat the nonunion of tibial and femoral fractures.

**Methods:** Between May 2006 and January 2011, eight patients (two men and six women) with tibial or femoral fracture nonunion were enrolled into our study. The average age of the patients was 35.4 years (range, 24–56 years). All patients underwent endoscopically assisted allogeneic bone graft implantation. We recorded the union status, clinical symptoms, and complications in all patients.

**Results:** The average time from the fracture to surgery was 14.4 months (range, 9–22 months). The average follow-up period was 19.1 months (range, 9–28 months). Seven patients achieved bone union and only one patient required additional surgery. The average time between surgery and bone union was 6.4 months (range, 4–8 months). No major complications were reported.

**Conclusion:** Endoscopically assisted allogeneic bone grafting is a less invasive and effective treatment for atrophic nonunion of fractures.

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## 1. Introduction

The process of fracture healing can be divided into four phases: inflammation, soft callus, hard callus, and remodeling.<sup>1</sup> Stability of the fracture site, a minimal gap between the fracture ends, and good blood supply to the fractured bones are important for successful fracture healing. However, 5%–10% of all fractures fail to heal, even after proper management.<sup>2</sup>

Various methods have been described to treat nonunion or delayed union of tibial or femoral fractures,<sup>3</sup> including exchange intramedullary nailing,<sup>4–6</sup> open plating combined with bone grafting,<sup>7,8</sup> ultrasound/electrical stimulation,<sup>9,10</sup> and bone marrow injection.<sup>11,12</sup> The choice of treatment is based on the biologic and mechanical factors contributing to nonunion. For example, different treatment methods might be selected for septic nonunion than for aseptic nonunion or for hypertrophic and atrophic nonunion.<sup>3,13</sup> Kim and others<sup>14</sup> described a minimally invasive surgical procedure that was used to treat atrophic nonunion by

endoscopic autogenous bone grafting. However, donor-site morbidity still presents a major problem for autogenous bone grafts.<sup>15–23</sup> Allografts can also exert osteoconductive and minor osteoinductive effects that promote bone healing.<sup>24–27</sup> Therefore, we used endoscopically assisted allografts to treat atrophic nonunion of fractures to avoid the donor-site morbidity associated with autogenous bone grafts.

## 2. Materials and methods

Between May 2006 and January 2011, patients with post-operative atrophic nonunion of femoral or tibial fracture who received endoscopically assisted allogeneic bone grafting were reviewed in our retrospective study. The indication of endoscopically assisted allografting was atrophic nonunion with stable fixation. There were eight patients (two men and six women) enrolled into this study (Table 1). Among the patients, seven had tibial fracture nonunion and one had femoral fracture nonunion. The average age of the patients was 35.4 years (range, 24–56 years). All patients received previous surgical treatment for their fractures, including intramedullary nailing, wiring, plating, or external fixation. The diagnosis of nonunion was made on the basis of radiographic findings. Nonunion was defined as no radiographic

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**Table 1**

Patient demographics and history.

Patient No	Sex	Age (yr)	Original injury grade	Injury site	Side	Previous surgery <sup>a</sup>	Nonunion gap (mm)	Operation time (min)	Tourniquet time (min)	Time from initial injury to our surgery (mo)	Time to union (mo)	Follow-up period (mo)	Complications	Comorbidities
1	F	24	Closed	Tibia	L	Intramedullary nailing	13	65	75	13	8	20	—	—
2	F	56	Closed	Tibia	L	ORIF with Plate	14	81	96	22	Fail <sup>b</sup>	28	—	DM
3	M	28	Closed	Tibia	R	Intramedullary nailing, wiring	10	60	85	11	6	11	—	Gout
4	F	37	Open IIIB	Tibia	L	ESF, debridement Flap coverage Remove ESF, ORIF with Plate	30	78	91	9	7	31	Wound infection	—
5	F	25	Closed	Tibia	R	Intramedullary nailing Remove nail debridement ESF <sup>c</sup>	18	71	87	10	6	28	—	—
6	M	24	Closed	Femur	L	Intramedullary nailing	7	38	51	15	4	10	—	—
7	F	30	Closed	Tibia	L	ORIF with plate	9	42	54	17	6	6	—	—
8	F	59	Closed	Tibia	R	Intramedullary nailing	6	44	50	18	8	9	—	HTN

ESF = external fixation; DM = diabetes mellitus; HTN = hypertension; ORIF = open reduction and internal fixation.

<sup>a</sup> Each numbered entry represents a separate trip to the operation room.<sup>b</sup> Open debridement and autogenous bone grafting were performed; Bone union was achieved 6 months later.<sup>c</sup> Interlocking nail was removed 4 weeks later after surgery because of infection. Infection was subsided after debridement and external fixator application.

evidence of fracture healing for more than 9 months.<sup>3,28</sup> The nonunion gap was recorded as the largest cortical gap between the nonunion site in the preoperative radiographs (Table 1). Patients with skeletal immaturity, signs of acute infection at the nonunion site, hypertrophic nonunion, pseudoarthrosis without stable fixation, or who were older than 65 years of age were excluded. Heavy smoker was also excluded for the sake of host factor.

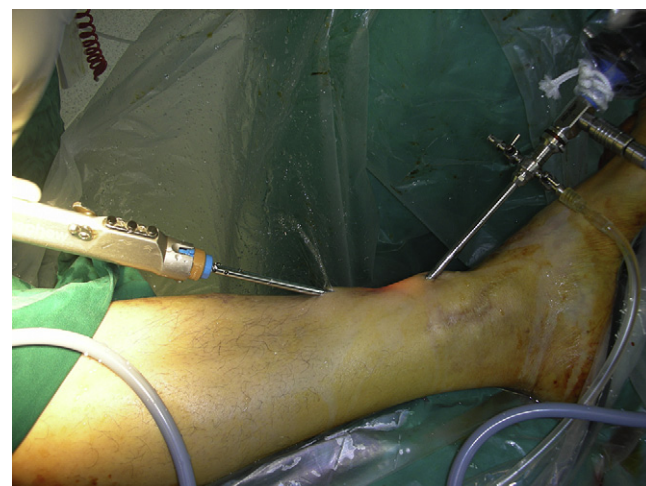
### 2.1. Allograft

The allogeneic morselized cancellous bone grafts were donated by patients who underwent total knee arthroplasty. The diameter of the bone grafts was about 3–5 mm. All patients who consented to the donation of their resected bone fragments from total knee arthroplasty were screened on the basis of medical history and blood tests for a variety of infectious diseases, including syphilis, hepatitis B, hepatitis C, and human immunodeficiency virus (HIV). We performed bacterial culturing during graft harvesting and implantation. All harvested bone grafts were packaged in three layers in an aseptic manner and immediately frozen at  $-75^{\circ}\text{C}$  in the bone bank, which was located in the operating room. The bank should be inspected monthly to make sure that all the blood test results and bacterial culture at the time of harvesting of the grafts were all negative. Before implantation, allografts were washed with copious sterile saline and bathed in cefamezin solution (1 g in 200 ml saline). The transplant procedures and the bone bank facility were verified and approved by the Food and Drug Administration, Department of Health of Taiwan.

### 2.2. Operative technique

The patient was placed in the supine position under adequate anesthesia. A pneumatic tourniquet was routinely applied on the thigh and inflated to 300–350 mm Hg. The nonunion site was located using a fluoroscope and marked. The skin was draped and the whole leg was disinfected. Two portals were created along the bone shaft, each 5 cm away from the nonunion site. An elevator was inserted through the portal to lift the soft tissue and create a space around the nonunion site for the introduction of the endoscope.

A 4-mm-diameter, 30-degree endoscope (Stryker, Mahwah, New Jersey, USA) was then introduced and used to identify the nonunion site. To avoid the risk of compartment syndrome, no infusion pump was used at any time during the operation. After confirming the nonunion site using endoscopy, a 5.0-mm motorized shaver (Dyonics, Smith&Nephew, Andover, Massachusetts, USA) was inserted through the other portal and used to remove any scar tissue in the nonunion site (Fig. 1). Sclerotic fracture ends were debrided and removed by an endoscopic burr and curette. To debride the nonunion site as completely as possible, the viewing portal and the working portal could be exchanged if necessary. Using an endoscopic grasper, allogeneic morselized cancellous bone grafts were then placed into the nonunion site and impacted to fill the fracture gap. No new implant was applied to fracture site and the previous implant used for fixation was kept for the adequate stability. After the procedure was completed, the portals were sutured and the wounds were loosely covered with gauze. Finally, the lower leg was wrapped with an elastic bandage from toes to operation site.



**Fig. 1.** After confirming the nonunion site by endoscopy, a 5.0-mm motorized shaver was inserted through the other portal to debride the fibrous tissue.

### 2.3. Postoperative care

No postsurgical prophylactic antibiotics were prescribed. Nonsteroidal anti-inflammatory drugs (NSAIDs) were given, and ice packing was applied for the first 24 hours after surgery. No limb immobilization was required postoperatively. Partial weight bearing with crutch assistance was recommended for 4 weeks after which full weight bearing was encouraged. Patients were discharged from the hospital 2 days after the operation and visited our outpatient clinic for follow-up examinations once each month.

### 2.4. Patient evaluation

We evaluated surgical results on the basis of pain, wound condition, complications, and bone union status. Standard radiographic examinations (anteroposterior and lateral) of the fracture site were performed at each follow-up. Postoperative radiographs were reviewed by an experienced orthopedic doctor who was not involved in the care of the patients. Bone union was defined as cortical bridging in 3 out of 4 cortices on the standard radiographs and no clinical symptoms of pain at weight bearing. If there was no radiographic progression of the nonunion site 8 months after surgery, we considered the procedure to have failed. Additional surgery to facilitate bone union was suggested for these patients.

## 3. Results

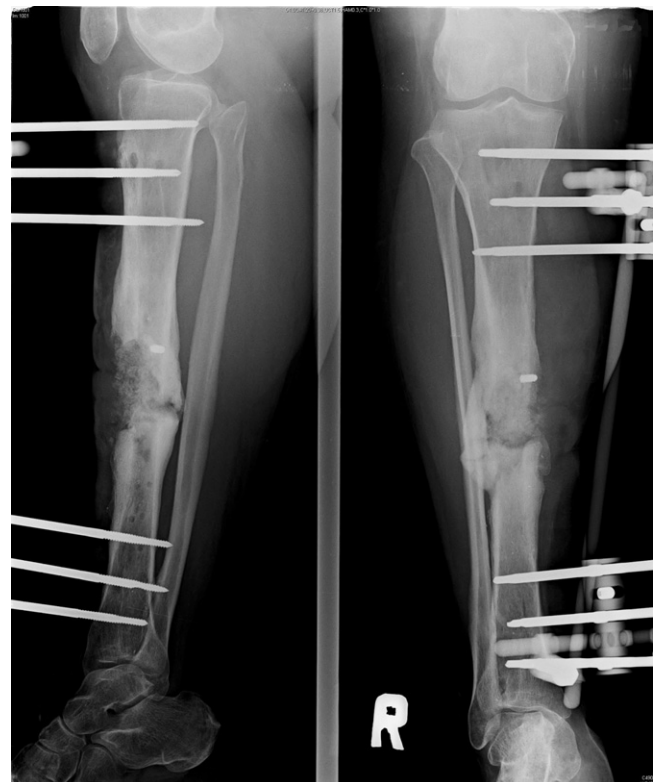
The average time between fracture and surgery was 14.4 months (range, 9–22 months). The average nonunion gap was 13.4 mm (range, 6–30 mm). The average operation time was 59.9 minutes (range, 38–81 minutes). The average tourniquet time was 73.6 minutes (range, 50–96 minutes). The average follow-up period was 19.1 months (range, 9–28 months). Only one patient with nonunion of a tibial fracture was not able to achieve bone union 8 months after surgery. This patient underwent additional operations, open debridement, and an autogenous bone graft, and the fracture healed 6 months later. One patient had a superficial wound infection and was treated with oral antibiotics. No major complications, such as compartment syndrome or neurovascular injury, were found in any of the patients in this study. Seven patients achieved bone union after endoscopic surgery without the clinical symptoms of pain (Figs. 2–4). The average time required for these patients to achieve bone union was 6.4 months (range, 4–8 months).

## 4. Discussion

Nonunion of tibial or femoral fractures can reduce patient activity and ability to perform self-care. Treatments for fracture nonunion are based on the causes of nonunion. Infection control, adequate stability, and good blood supply are the principle requirements for bone union.<sup>3</sup> Hypertrophic nonunion is treated by increasing mechanical stabilization without a bone graft. Infected nonunion is treated with debridement, soft tissue coverage, and bone grafting with or without further stabilization.<sup>29,30</sup> There are many treatment options available for atrophic nonunion. Changing reamed intramedullary nails can provide an internal bone graft and create further mechanical stability. Alternately, ultrasound/electrical stimulation can increase the vascularity of the nonunion site. In some cases, the nonunion site is filled with fibrous tissue that should be debrided completely in order to allow bone grafting. Generally, open debridement, removal of sclerotic fracture ends, and bone grafting comprise the standard treatment for atrophic nonunion. However, open surgical procedures may further damage



**Fig. 2.** A 25-year-old woman with tibial fracture. An interlocking nail was applied first and shifted to an external fixator because of infection. Radiography showed tibial nonunion without cortex bridging.



**Fig. 3.** Some callus formation and cortex bridging can be seen approximately 6 months after endoscopically assisted allograft implantation.





Fig. 4. The external fixator was removed after complete union.

the soft tissue and blood supplies of the nonunion site that were injured in the initial trauma or during previous operations.

Bhan and colleagues<sup>31</sup> described a percutaneous bone graft for treatment of nonunion of the tibial shaft. Although they reported a high union rate (19/21 cases), fibrous tissue and sclerotic fracture bone ends cannot be removed using this procedure. In a study of endoscopic bone grafting as a treatment for delayed union of the humerus, Johnson and colleagues<sup>32</sup> reported that the endoscopic technique has the advantages of minimal incisions, accurate debridement, precise bone graft, and minimal vascular injury to the surrounding tissues. Kim and others<sup>14</sup> described a minimally invasive endoscopic curettage and autogenous bone grafting procedure used to treat femoral and humeral shaft fractures with nonunion. Using this technique, Kim and others<sup>14</sup> were able to remove fibrous tissue, refresh the fracture end, and create space for bone grafting. They reported that six of the eight patients who underwent the procedure successfully healed within an average of 4.1 months of surgery and that none of the patients experienced any major complications. In 2008, Lui<sup>33</sup> also described the use of endoscopic debridement and autogenous bone grafting to treat the nonunion of the fifth metatarsal avulsion fractures.

Although previous authors have described autogenous bone grafts with endoscopic assistance, we used allografts for the treatment of fracture nonunion. Autogenous bone grafts have properties of osteoinduction, osteoconduction, and osteogenesis that promote the bone healing process. However, insufficient graft quantity and donor-site morbidity, including additional incisions, prolonged donor-site pain, and temporary sensory loss associated with autogenous bone grafts remain an important concern.<sup>21–23</sup> Therefore, we used allogeneic morselized cancellous bone grafts for the procedure described in this study.

Lin and coauthors<sup>34</sup> compared the results of treatment for the humeral nonunion with autograft or morselized fresh-frozen

allograft. The union rates, time to union and function outcomes were no different in both graft types. Although there are some concerns regarding disease transmission through allografts,<sup>35</sup> they still provide a good bone graft source for orthopedic doctors, provided allografts are harvested, processed, and screened carefully and under cautious supervision. The allografts we used were fresh-frozen grafts. These grafts have osteoconductive and mild osteoinductive effects.<sup>24–27</sup> Seven patients achieved bone union after undergoing the procedure we described. Only one patient needed an additional operation. None of the patients experienced any major complications. Therefore, we believe endoscopically assisted allogeneic bone graft implantation is an effective and safe procedure for the treatment of nonunion of fractures.

Some aspects of our technique require special caution. First, this procedure is technically demanding. Surgeons must be familiar with endoscopic techniques before attempting this surgery. Second, the position of the portals should be carefully selected. Because of variations between patients, such as the location of the nonunion site, the position of metal implants, and the anatomy of neurovascular bundles, judicious selection of the portals is the key to successful surgery. Third, some doctors find the risks associated with using allografts to be unacceptable. There are many synthetic bone substitutes available that are capable of osteoconduction. Synthetic bone substitutes may provide an alternative to allografts. Fourth, there is a risk of compartment syndrome due to fluid extravasation during endoscopic surgery. To avoid this complication, we used gravity instead of an infusion pump for delivery of irrigation fluid, and there were no instances of compartment syndrome among the patients in this study. Fifth, it is remained uncertain about how much of the nonunion gap can be treated with our technique. The largest nonunion gap of our cases was about 30 mm. However, the maximal nonunion gap can be treated with our technique should be evaluated in the further study. Finally, the number of cases included in our series is relative small. Even though this is a simple, harmless, and effective procedure, further investigation and case collection are needed to confirm the efficacy of this technique.

## 5. Conclusion

Endoscopically assisted allogeneic bone grafting for the treatment of atrophic nonunion is a less invasive procedure that can promote bone union in the nonunion site of tibial or femoral fractures.

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