

Effect of Low-Intensity Pulsed Ultrasound Treatment for Delayed and Non-union Stress Fractures of the Anterior Mid-Tibia in Five Athletes

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Effects of optional use of low-intensity pulsed ultrasound (LIPUS) treatments for delayed and non-union stress fractures at the anterior mid-tibia in athletes were examined. The subjects were 5 competitive athletes (4 males and 1 female) with the anterior mid-tibia stress fracture, which was confirmed by radiography and bone scintigraphy (Technetium-99m). All patients consistently received daily 20-minute LIPUS treatment, until radiographic recovery was achieved. Recovery was evaluated using clinical symptoms, radiographic examination, bone scintigraphy and functional outcome. Patients returned to full sports activity at an average of 3 months after the onset of treatment (range, 2 to 4 months). Absence of pain was achieved at an average of 3.8 months (range, 2 to 5 months), and disappearance of bone umbauzone was achieved at an average of 11 months (range, 8 to 14 months). These results were clearly faster than that of other previously reported conservative treatments. Thus, the LIPUS treatment is useful for early alleviation of focal pain in anterior mid-tibia stress fracture (delayed and nonunion stress fracture), resulting in early return to sports activity. However, achievement of pain-free status did not coincide with radiological indications of bone healing, thus careful follow-up should be necessary.

Key words: LIPUS; chronic stress fracture; early recovery; conservative treatment

INTRODUCTION

Stress fractures of the tibia are relatively common injuries in young athletes. Focal pain of the tibia naturally reduces their ability and disturbs the participation in their sports events. Delayed and non-union stress fractures at the anterior mid-tibia (chronic or tension side stress fractures) are particularly problematic and often required long-term (over 6 months) conservative treatments with a highly risk of complete fracture [1-3], and frequently shows poor prognosis. In fact, complete fractures occurred in 5 of 6 patients with delayed union of the anterior tibial cortex in case of continuous participation in sports events [4]. To avoid the development to complete fracture, patients with delayed or non-union tibial stress fractures are often prescribed prolonged rest with non-weight-bearing ambulation or wheelchair use, and/or immobilization with or without electrical stimulation [1, 3]. Surgical attempts to accelerate bone healing have also done such as drilling [5, 6], excision and grafting [7]. Recent findings suggest that intramedullary nailing can produce better and faster recovery of this kind of stress fracture [8-10]. However, surgery itself potentially entails various physical and mental stresses for athletes.

The low-intensity pulsed ultrasound (LIPUS) treatment have been extensively used to treat fresh fractures and delayed union and/or non-union fractures, and demonstrated acceleration of fracture-healing

process as a safe and noninvasive method [11-14]. In addition, it has been reported that LIPUS treatment is an effective treatment for posterior-medial stress fractures (stress fractures of the proximal and distal tibia) as a viable alternative treatment to invasive surgery [15]. However, there is little information about the details and effects of LIPUS treatment especially on the delayed and non-union stress fractures of the anterior mid-tibia, which is a more refractory stress fracture than those of the proximal and distal tibia. In the present study, we examined the effects of LIPUS as a treatment for athletes with delayed and non-union stress fractures of the anterior mid-tibia. Results showed that the LIPUS treatment for the athletes enabled to return full sports activity within 2 to 4 months after treatment.

PATIENTS AND METHODS

Patients

The subjects were 5 athletes (4 males and 1 female) with delayed and non-union stress fractures of the anterior mid-tibia, who visited our hospital from 1998 to 2003 including 1 professional soccer player, 2 collegiate athletes (judo and tennis, respectively) and 2 high school basketball players. Details of the patients (subjects) are summarized in Table 1. The LIPUS treatment was started an average of 5.2 months (range, 3-7 months) after the onset of typical symptoms of stress fracture (focal pain at the anterior mid-tibia).

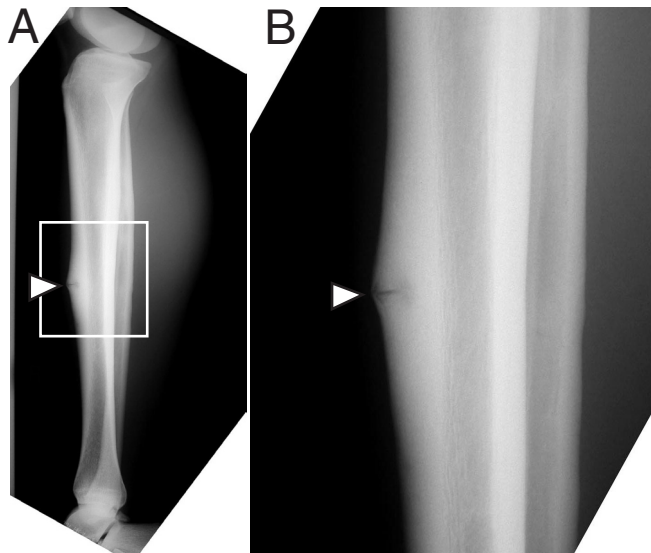


Fig. 1. Lateral radiograph of anterior mid-tibia stress fracture (A). High magnification photograph clearly shows site of typical stress fracture with V- or wedge-shaped defect in the cortex of the anterior mid-tibia (bone umbauzone) (B, arrowhead).

Table 1 Details of the patients and treatments

Cases	Age (y/o)	Sex	Sports	Side	Onset of symptoms (months)	Durations				
						LIPUS treatment (months)	Pain disappearance (months)	Radiologic union (months)	Return to full sports activity (months)	Inspection follow-up (months)
1	19	M	Tennis	R	6	9	4	9	3	9
2	21	M	Judo	L	3	11	5	11	4	6
3	20	M	Basketball	R	7	8	2	8	2	7
4	17	F	Basketball	R	4	14	4	14	3	12
5	33	M	Soccer	R	6	13	4	13	3	3
Average	22				5.2	11	3.8	11	3	7.4

LIPUS, low-intensity pulsed ultrasound; M, male; F, female; R, right side; L, left side

Durations of LIPUS treatment, pain disappearance, radiographic union and return to full sports activity are from the onset of LIPUS treatment

Duration of inspection follow-up is from the end of LIPUS treatment

Diagnosis and evaluation of recovery

Diagnosis of stress fracture was performed based on radiographic evidence of a V- or wedge-shaped defect at the anterior cortex of the mid-tibia on a lateral view (so-called bone umbauzone, Fig. 1A, B), and localized focal pain. Bone scintigraphy (Technetium-99m) was also performed for all patients at a lateral view of the lower legs. Follow-up inspection after the finish of LIPUS treatment was done by evaluations using clinical symptoms (disappearance of focal pain and point tenderness), radiographic examination (disappearance of bone umbauzone), bone scintigraphy (disappearance of hot spot) and functional outcome (acquisition of ability to return to full sports activity). In addition, we performed axial T2-weighted MR imaging to confirm the details for case 1 patient.

Treatment Protocol

All patients had accepted that the risk of complete fracture was not negligible completely in this kind of stress fracture, although the LIPUS treatment will be done. We consistently assigned to each patients to perform daily 20-minute self-treatments by one's own device (Exogen 2000™ or SAFHS, Smith and Nephew, Inc, Tennessee, USA) at home. The probe (3.88 cm²) was positioned on the skin over the lesion. The operating frequency was 1.5 MHz; 200 msec pulse width and

temporal average power was 117 mW. Each patient controlled the pain limits by oneself, and maintained normal daily physical activities as much as possible throughout the treatment period. The LIPUS treatment was stopped when disappearance of radiographic evidence (complete bone union) of stress fracture was observed.

RESULTS

The average LIPUS treatment and follow-up period was 11 and 7.4 months, with a range of 8-14 and 6-12 months, respectively. During the follow-up period, we did not observe recurrence of clinical symptoms or radiographic evidence of recurrent fracture. Patient details, symptoms and duration of LIPUS treatment are summarized in Table 1. There were no complete fractures in any patients, and patients returned to full activity at an average of 3 months (range, 2 to 4 months) after the onset of LIPUS treatment. Pain-free status was achieved at an average of 3.8 months (range, 2 to 5 months) after the onset of LIPUS treatment, and disappearance of radiographic evidence (bone umbauzone) was achieved at an average of 11 months (range, 8 to 14 months) after the onset of treatment.

In Case 1 patient, MR images of transverse portion of lower leg that was obtained before and after 1 and 4 months were shown in Figure 2A-C. Higher-intensity

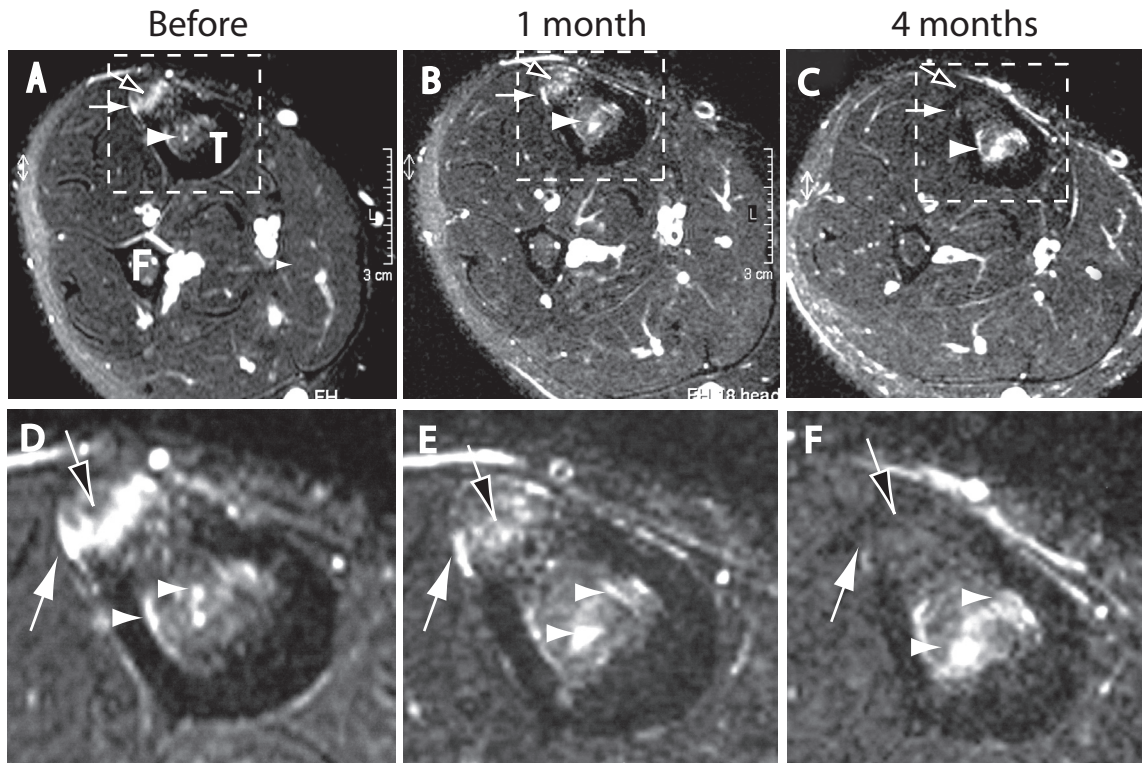


Fig. 2. Axial T2-weighted MR images (transverse-section) of lower leg before and after 1 and 4 months of LIPUS treatment. The squares (dotted line) in panels A-C corresponds panels D-F. High signal of periosteal edema (surface of cortical bone, arrow) and abnormalities of cortical zone (open arrows) did not change before (A and D) and 1 month (B and E) after treatment, however these high signals disappeared 4 months (C and F) after treatment, whereas signal of bone marrow edema (arrowhead) did not change after LIPUS treatment. T, tibia; F, fibra.

signals were clearly visible on the surface (arrow), anterior cortical zone (open arrow), and bone marrow (arrowhead) of tibia (T) before LIPUS treatment (Fig. 2A and D), representing periosteal edema, cortical abnormalities and bone marrow edema respectively. This trends still observed at 1 month after LIPUS treatment (Fig. 2B and E), however, periosteal edema (arrow) and cortical abnormalities (open arrow) had completely disappeared at 4 month after LIPUS treatment (Fig. 2C and F). However, high intensity area of bone marrow edema did not change before and after 4 month of treatment (Fig. 2A-F, arrowheads), whereas pain-free status was already achieved at this period.

TYPICAL CLINICAL CASE

One of the present patients (case 4) was a 17-year-old (height, 172 cm; weight, 58 kg) female high school basketball player. She developed focal pain in the right mid-tibia approximately 4 months before LIPUS treatment. She typically felt the most severe pain during jumping and running (8cm by Visual Analogue Scale [VAS]), and indicated that the cortical break (so called "the bone umbauzone") is clearly visible in the anterior tibia cortex on lateral radiograph (Fig. 3-A, arrowhead). Moreover, a clear hot spot was detected in the anterior cortex of the mid-tibia by bone scintigraphy (Fig. 3-D, arrowhead). She has self-controlled the limits of the pain, and maintained normal daily physical activities as much as possible throughout the treatment period, and she had accepted the risk of complete fracture. After 1 month of LIPUS treatment, the focal pain has reduced (VAS; 4cm), and she was able to

return to full sports activity 3 months after the onset of LIPUS treatment. Significant improvement such as disappearance of focal pain and point tenderness was observed 4 months after the onset of LIPUS treatment (VAS; 0cm). The cortical break gradually fused over at 4-month period after treatment (Fig. 3-B, arrowhead), and then completely fused at 14 months after treatment (Fig. 3-C, arrowhead). Similarly, severe hot spots on bone scintigraphy were visible before treatment (Fig. 3-D, arrowhead), and the hot spots gradually disappeared over a 14-month period after treatment (Fig. 3-E and F, arrowheads). The patient maintained competition level of basketball player with symptom-free condition, and recurrence of the stress fracture was not observed at final inspection (>2 years).

DISCUSSION

In the present study, we demonstrated successful recovery of five cases of anterior mid-tibia stress fracture after LIPUS treatment. These findings indicate that LIPUS treatment enabled athletes to return normal sports activity in relatively shorter term than other conservative treatments [1,3,6]. However, there are some differences in method between our treatment and other conservative treatment. Other conservative treatment forbade sport activities until complete reduce of pain and bone union was achieved. Therefore, we admitted athletes to attend sports activities during LIPUS treatments because of their faster reduce of pain.

Therefore, Table 2 shows a comparison between the effects of present LIPUS treatment and those of other conservative treatments in cases of anterior mid-tibia

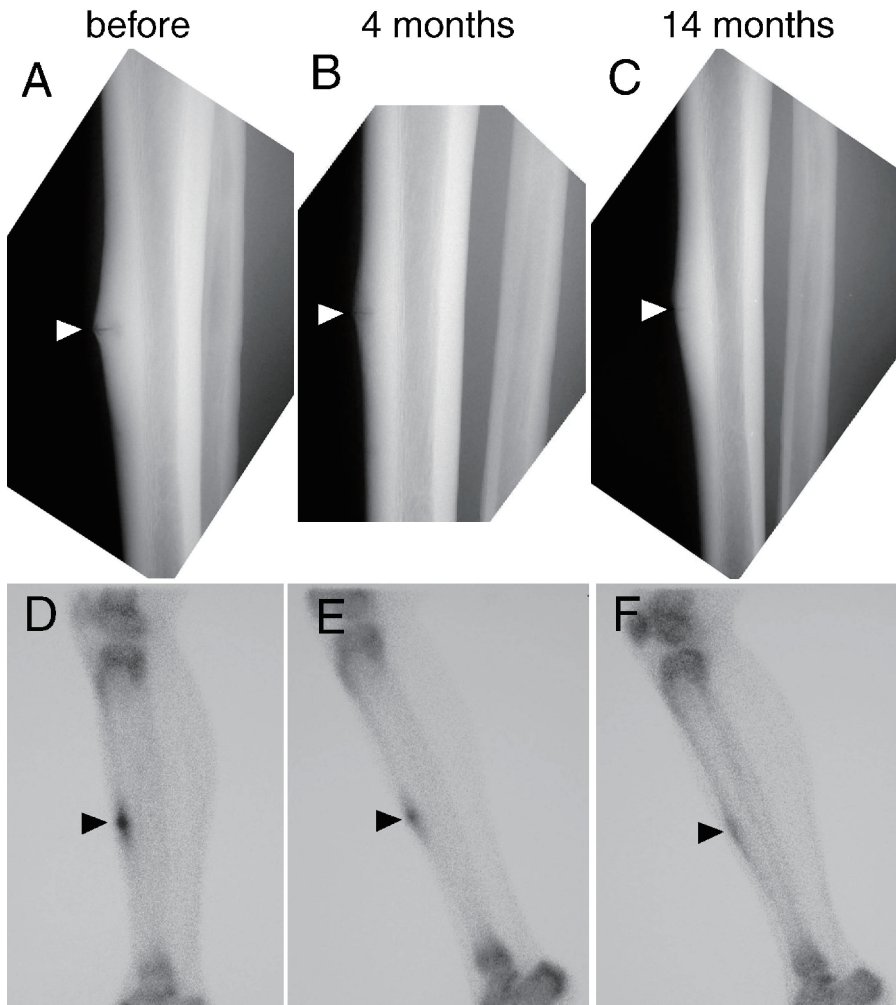


Fig. 3. Typical recovery (case 4) of before and after 4 and 14 months of LIPUS treatment after anterior mid-tibia stress fracture. The umbauzone is clearly visible in the anterior tibia cortex on lateral radiography (A, arrowhead). This umbauzone gradually fused 4-months after treatment (B, arrowhead), and completely fused at 14 months (C, arrowhead). Similarly, by one scintigraphy, densely hot spots were visible on the umbauzone before treatment (D, arrowhead). These spots on gradually disappeared 4 and 14-months after treatment (E and F, arrowheads).

Table 2 Comparison between LIPUS treatment and other conservative treatments

Author	Cases	Treatments	Recovery period		
			Pain (months)	Full sports activity (months)	Bone union (months)
Retting ³	6	Rest with ES	7.5 (5-11)	7.5 (5-11)	7.5 (5-11)
Orava ⁶	8	Rest	6 (3-10)	Unknown	6 (3-10)
Batt ¹	3	Pneumatic lower leg brace	9 (3-14)	12 (11-14)	9 (3-14)
Present result	5	LIPUS	3.8 (2-5)	3 (2-4)	11(8-14)

ES, electrical stimulation; LIPUS, low-intensity pulsed ultrasound

stress fracture. The average time to achieve symptom-free status and bone union were 3.8 months and 11 months, respectively, in the present LIPUS treatment, while others showed 6-9 months (6 months by rest only, 7.5 months by rest with electrical stimulation, 9 months by pneumatic lower leg brace). Furthermore, the time to return full and/or competitive sports activity in the present LIPUS treatment (average, 3 months) was clearly shorter than other conservative treatments (average, 7.5-12 months). These results suggest that the average time to achieve symptom-free status and the time to return full and/or competitive sports activity in LIPUS treatment are available and comparatively better conservative treatment for delayed or non-union stress fractures of the anterior cortex of the tibia. However, LIPUS treatment did not shorten the period of bone union. This may be due to the reason that

anterior tension of tibia bone can be reduced the cases of intramedullary nailing or non-weight bearing.

On the other hand, resent report suggested that after the intramedullary nailing for reduce anterior tension of tibia bone, there were no differences in period of return to full sports activity and achievement of pain free status between 5 stress fractures of anterior tibia in 3 patients with LIPUS treatment and 6 fractures in 4 patients with non-LIPUS treatment [10]. Unfortunately, this report did not describe how the LIPUS treatment has done, and the definition for the failed LIPUS treatment was unclear. Therefore, the reason of the discrepancy against the present study is unknown. Probably, the term and continuity of LIPUS treatment may affect the healing process of stress fracture.

Importantly, present study showed that the aver-

age time to achieve pain-free status was 3.8 months, but a bone umbauzone remained at an average of 11 months (range, 8 to 14 months) after LIPUS treatment. Thus, achievement of pain-free status did not coincide with radiological healing in anterior mid-tibia stress fracture. A possible reason for this discrepancy is that LIPUS treatment effectively reduces bone edema. In this regard, Gaeta M *et al.* reported that MR T2-imaging in stress fracture represent bone marrow edema, periosteal edema and cortical abnormalities (osteopenia, resorption cavity and/or striation) [16].

In our cases, achievement of pain free status was about 4 months after treatment. For this reasons, our MR imaging showed disappearance of the periosteal edema (Fig. 2 arrow) and cortical abnormalities (Fig. 2 open arrow) in tibia umbauzone 4 months after LIPUS treatment (Fig. 2C and F). Therefore, we suggest that stimulation of LIPUS treatment may accelerates fluid permeability of bone and soft tissues around the umbauzone, and ameliorate bone and tissue edema. Reduction of periosteal edema and cortical abnormalities may induced reduction of focal pain, and resulted shorter achievement of pain-free status. However, bone healing was not completed at this period, thus, careful follow-up should be need for athletes.

After all, we recommend that the LIPUS treatment is a better conservative treatment for the anterior mid-tibia stress fracture in young athletes. However, the main weakness in this treatment was that achievement of pain-free status did not always coincide with radiological indications of bone healing as described above. It is likely that LIPUS treatment did not accelerate the bone union in itself. Therefore, if there is no improvement of the pain over 4 months of the LIPUS treatment, we also recommend that intramedullary nailing should be need for early return to sports events.

In conclusion, the present findings indicate that LIPUS treatment is useful for early alleviation of focal pain in anterior mid-tibia stress fracture (delayed and nonunion stress fracture), resulting in early return to sports activity.

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