Treatment of Delayed Unions and Nonunions of the Proximal Fifth Metatarsal with Pulsed Electromagnetic Fields

George B. Holmes, Jr.

Foot Ankle Int 1994 15: 552
DOI: 10.1177/107110079401501006

0198-0211/94/1510-0552$03.00/0
FOOT & ANKLE INTERNATIONAL

Treatment of Delayed Unions and Nonunions of the Proximal Fifth Metatarsal with Pulsed Electromagnetic Fields

George B. Holmes, Jr., M.D.
Chicago, Illinois

ABSTRACT

Nine delayed unions and nonunion of the proximal fifth metatarsal were treated with pulsed electromagnetic fields (PEMF). All fractures healed in a mean time of 4 months (range 2–8 months). Those fractures treated with both pulsed electromagnetic fields and a nonweightbearing cast healed in a mean time of 3 months (range 2–4 months). The average duration of follow-up was 39 months (range 24–60 months). There were no refractures.

When compared with reported healing times and morbidity for conventional casting, medullary curettage with inlay bone, and closed axial intramedullary screw fixation, pulsed electromagnetic fields provided an effective alternative for the treatment of delayed unions and nonunion of the proximal fifth metatarsal.

INTRODUCTION

The Jones fracture is defined by its occurrence at the base of the fifth metatarsal, distal to and within 1.5 cm of the tuberosity. It is distinguished from fractures through the tuberosity by its propensity for recurrence, delayed union, and nonunion. A third fracture of the proximal portion of the fifth metatarsal has been described as diaphyseal stress fracture.[7,11,13,16]

Torg has established the following roentgenographic classification of Jones fractures: type I, acute; type II, delayed union; and type III, nonunion.[18] Based in part upon this classification, there are three modalities of treatment available for Jones fractures and the diaphyseal stress fracture. Type I fractures are initially treated with immobilization in a nonweightbearing cast.[19] In the presence of an established delayed union or nonunion, treatment options include medullary curettage with inlay bone grafting or closed axial intramedullary screw fixation.[6,7,19] The drawbacks of surgical intervention include increased cost, the necessity of hospitalization, the risk of anesthesia, and the potential complications of wound infection and neuroma formation. Additionally, intramedullary screw fixation has the added considerations of fracture propagation at the time of screw insertion, screw breakage, reoperation for screw removal, postoperative screw head prominence, and metatarsalgia.[7,10]

It has been my observation that the length of time necessary to heal Jones fractures and diaphyseal stress fractures of the proximal fifth metatarsal is unsatisfactory. Invasive measures that may reduce the length of time also carry with them a measure of increased cost and morbidity. Low frequency pulsing electromagnetic fields (PEMF) have been advocated for the treatment of various delayed unions and nonunions.[4,12,14,15,17] Because of the unsatisfactory length of time for healing and the inherent drawbacks to surgical intervention, this preliminary study was undertaken to evaluate PEMF as a possible alternative to surgery or prolonged immobilization for the treatment of delayed union or nonunion of the proximal fifth metatarsal.

MATERIALS AND METHODS

From 1987 to 1990, nine Jones fractures with clinical and radiographic signs of delayed union and nonunion were selected from a multicenter pool of patients with foot fractures treated with PEMF (Table 1). There were five men and four women in the group. The mean age of the patients was 36 years (range 21–59 years). The mean height was 68 inches (range 60–82 inches) and the mean weight was 190 pounds (range 125–250 pounds). Seven of the nine fractures involved the left foot.

The mean duration of treatment prior to the use of PEMF was 2.8 months (range 1–5 months). The mean duration of follow-up was 39 months (range 24–60 months). Follow-up information was obtained by direct interview with the patient or questionnaire to the treating physician or podiatrist. Pre- and posttreatment ra-

Director of Foot and Ankle Surgery, University Orthopaedics, and Assistant Professor of Orthopaedics, Rush Medical School, Chicago, Illinois. Address reprint requests to Dr. Holmes at University Orthopaedics, 800 South Wells Street, Suite M30, Chicago, Illinois 60607.

TABLE 1
Data on the Nine Patients

Case	Sex, age (yr)	Fracture type	Healing time PEMF (mo)	Weightbearing	Immobilization technique	Follow-up (mo)	Refracture
1	M, 30	Nonunion	4	Yes	Cast	24	None
2	M, 21	Delayed	3	No	Cast	48	None
3	F, 59	Nonunion	3	Yes	Cast	36	None
4	M, 26	Delayed	3	No	Cast	48	None
5	F, 55	Nonunion	8	Yes	Cast	60	None
6	F, 20	Nonunion	3	No	Cast	42	None
7	F, 41	Delayed	6	Yes	Boot/shoe	40	None
8	M, 50	Delayed	4	Yes	Cast	34	None
9	M, 27	Delayed	2	No	Cast	26	None

Fig. 1. Oblique radiograph of an acute Jones fracture.

diographs were also available for review for all patients. Anteroposterior and lateral radiographs were evaluated for confirmation and classification of the fracture. Completion of healing was determined by radiographic evidence of trabecular bridging across the fracture line, pain-free gait, and the achievement of ambulation without a cast, walking boot, or postoperative wooden shoe.

All fractures represented as closed injuries. Only those fractures that were classified as Jones fractures or diaphyseal stress fractures and further subclassified as delayed union or nonunion according to the criteria of Torg[18,19] were included in this study. The acute fractures treated with PEMF were not included in this study. Acute fractures were characterized by: (1) no history of previous fractures with or without a history of prodromal pain or discomfort, (2) an absence of intramedullary sclerosis, (3) well-defined margins of the fracture line without widening or radiolucency, and (4) minimal or absent cortical hypertrophy or periosteal reaction (Fig. 1). The features of the delayed unions were: (1) a history of a previous injury or fracture, (2) the fracture line involving both cortices with associated periosteal bone, (3) ill-defined fracture margins with

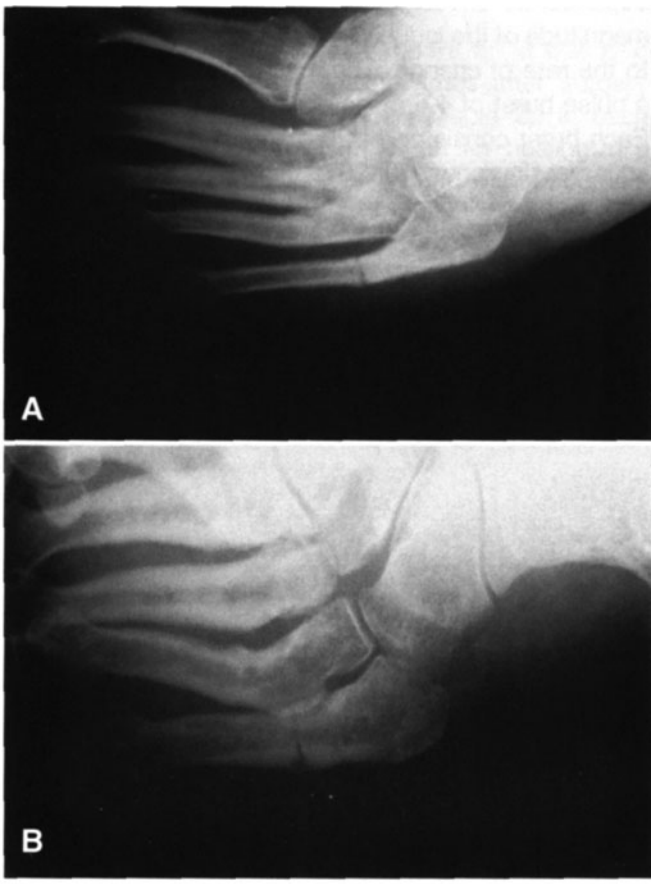

Fig. 2. *A*, Anteroposterior radiograph of a Jones fracture with a delayed union. *B*, Oblique radiographs of a Jones fracture with a delayed union.

widening and adjacent radiolucency, and (4) intramedullary sclerosis (Fig. 2, A and B). The criteria for the establishment of nonunions were: (1) a history of repetitive injury and recurrent symptoms, (2) a widened fracture line, (3) the presence of radiolucency and periosteal reaction, and (4) obliteration of the medullary canal along with the presence of sclerotic bone. At the time of treatment, three patients had a previous history

of recurrent symptoms or refracture (Fig. 3, A and B). All but one patient had a fracture pattern involving both cortices and had early or complete sclerosis of the fracture site. Six patients had widening of the fracture site and one had extensive periosteal reaction.

Patients were treated with an external coil device which provided PEMF. The daily coil usage goals were 8 to 10 hr a day. The devices used consisted of looped copper wire coils in formed plastic. These were positioned over the lateral border of the foot centered over the base of the fifth metatarsal in the Helmholtz configuration. The pulse form is demonstrated as the time dependence of rate of change of magnetic flux. The magnitude of the induced electric field was proportional to the rate of change. The magnetic field consisted of a pulse burst of 4.5 msec duration repeated at 15 Hz. Each burst consisted of 20 magnetic field pulses with an increasing phase (0–20 gauss) of 200 μsec duration and a decreasing phase of 20 μsec followed by a 5-μsec pause.

Treatment with PEMF was augmented by either a short leg nonweightbearing cast, short leg weightbearing cast, or weightbearing postoperative shoe. One patient had failed an attempt at bone grafting prior to use of PEMF.

Fig. 3. *A*, Anteroposterior radiograph of a Jones fracture with a nonunion. *B*, Oblique radiograph of a Jones fracture with a nonunion.

RESULTS

All fractures healed with a mean time to healing of 4 months (range 2–8 months). In each case, after complete healing had been obtained, there were no further requirements of additional interventions. There were no recurrences of symptoms or refractures. All patients returned to their preinjury activities.

Three patients received PEMF fields in addition to being placed in a nonweightbearing cast. Healing was accomplished in these patients at 3 months (2, 3, and 4 months, respectively). The remaining six patients were treated in a short leg weightbearing cast or postoperative shoe. Healing was obtained in a mean time of 4½ months (range 2–8 months).

DISCUSSION

Treatment of Jones fractures and diaphyseal stress fractures has been marked by a relatively high incidence of delayed union or nonunion.[5,6,10,20] A classification of these fractures as either acute, delayed union, or nonunion has been advocated by Torg[18] for its usefulness in selection of the appropriate treatment intervention. It has been recommended that acute fractures be treated with a nonweightbearing plaster cast for a period of at least 6 to 7 weeks.[19] Torg[19] reported in 1984 that of 10 patients with delayed unions treated with a short leg weightbearing cast, seven went on to unite in a mean time of 14.8 months. The remaining three were initially treated surgically, with all healing in 12 weeks. In this same series, a total of 20 fractures were treated with bone grafting for symptomatic delayed union or nonunion. A 95% union rate was achieved between 12 and 16 weeks after surgery. The other option advocated for the treatment of delayed union or nonunion is the use of closed axial intramedullary screw fixation.[10] However, with this technique, Kavanaugh et al.[10] reported perioperative complications of screw fracture, prominence of the screw head, and failure to place the screw within the medullary canal. Using a similar technique, DeLee et al.[7] reported no perioperative complications. However, in their series of 10 patients, 30% had persistent tenderness over the proximal head of the screw and 50% had pain under the head of the fifth metatarsal. Seven patients required shoe modifications or orthotic devices after surgery. Roentgenographic evidence of healing was achieved on average at 7.5 weeks (range 6–8 weeks).

All fractures selected for this study fulfilled the Torg criteria for delayed union or nonunion. The overall time to healing with PEMF was 4 months. This time was

TABLE 2
Comparison of Healing Times

Ref.	Fracture type	Treatment	No. treated	No. healed	Healing time	Complications*						
						A	B	C	D	E	F	G
Torg et al.[19]	Delayed union	Cast/weightbearing	10	7	15 mo	0	0	0	3	0	0	0
Torg et al.[19]	Nonunion	Bone graft	9	0	3 mo	0	0	0	1	0	0	0
DeLee et al.[7]	Delay/nonunion	Screw fixation	10	10	7.5 wk	3	2	0	0	0	0	0
Zelko et al.[20]	Unclassified	Cast/weightbearing	15	2	12 mo	0	0	0	5	0	0	0
Zelko et al.[20]	Unclassified	Bone graft	9	0	3.5 mo	0	0	1	0	0	0	0
Kavanaugh et al.[10]	Delay/nonunion	Screw fixation	13	13	6 wk	0	0	0	1	3	2	1
Holmes, present study	Delay/nonunion	PEMF/weightbearing	6	6	4.5 mo	0	0	0	0	0	0	0
Holmes, present study	Delay/nonunion	PEMF/nonweightbearing	3	3	3 mo	0	0	0	0	0	0	0

* Complications: A, pain at screw head; B, pain beneath fifth metatarsal head; C, refracture; D, secondary procedure; E, screw fracture; F, screw misses medullary canal; G, screw removal.

reduced further to 3 months when patients were kept nonweightbearing while using the PEMF. The mean time to healing with PEMF for both the nonweightbearing and weightbearing patient groups (16 weeks) was comparable to the healing times reported for either the conservative protocols of a nonweightbearing cast (14.8 weeks) or the operative treatments (12–16 weeks). PEMF plus a nonweightbearing cast reduced the healing time to 12 weeks. Further, for all patients treated with PEMF, there were no failures, refractures, complications, or requirements for posttreatment shoe modifications.

If one were to consider the time involved in the treatment of the those patients who failed to heal with an initial trial of conservative treatment for a nonunion or delayed union, then the treatment time with PEMF is considerably less. After 14.8 weeks of cast immobilization for delayed unions or nonunions, Torg encountered a 30% rate of failure. An additional 12 weeks was required for surgical intervention. Therefore, for the failed patient group, the total treatment time was on the order of 26 weeks.

Since the early 1980s, there have been numerous reports of the use of PEMF for the treatment of fracture nonunions.[1–3,8,9,17] A central criticism of some of these earlier studies was the lack of adequate double-blind trials comparing the use of immobilization versus immobilization along with PEMF for similar types of fractures. Some of these criticisms were addressed recently in a series by Sharrard.[16]

Despite the lack of a prospective double-blind trial protocol, the results reported here are important for several reasons. The previous reports of Torg have outlined clinical and radiographic criteria for the classification of Jones fractures. Several studies have established the healing times for nonoperative and surgical treatment of delayed unions and nonunions.[7,10,19,20] This provided the opportunity to compare the results of immobilization alone versus immobilization (weightbearing and nonweightbearing) and PEMF. It was also possible to compare the healing times after surgery versus immobilization with PEMF (Table 2). In each instance, the use of PEMF provided for healing in a comparable or shorter time course and with no complications when compared with immobilization alone or surgery.

The results of this retrospective analysis indicate that with respect to delayed unions and nonunions of the proximal fifth metatarsal, PEMF used for 3 months supplemented with a nonweightbearing cast may be an effective alternative treatment to prolonged immobilization, inlay bone graft, and axial screw fixation. Of course, the ultimate effectiveness of electrical stimulation for the treatment of these fractures will be determined by directly comparing the results of electrical stimulation, prolonged immobilization, inlay bone graft, and axial screw fixation.

REFERENCES

1. **Barker, A.T., Dixon, R.A., Sharrard, W.J.W., and Sutcliffe, M.L:** Pulsed magnetic field therapy for tibial non-union: interim results of a double-blind trial. Lancet, **1**:994–996, 1984.
2. **Bassett, C.A.L., Mitchell, S.N., and Gaston, S.R.:** Treatment of ununited tibial diaphyseal fractures with pulsing electromagnetic fields. J. Bone Joint Surg., **63(A)**:511–523, 1981.
3. **Bassett, C.A.L., Valdes, M.G., and Hernandez, E.:** Modification of fracture repair with selected pulsing electromagnetic fields. J. Bone Joint Surg., **64(A)**:888–895, 1982.
4. **Borsalino, G., Bagnacani, M., Bettati, E., Fornaciari, F., Rocchi, R., Uluhogian, S., Ceccherelli, G., Cadossi, R., and Traina, G.C.:** Electrical stimulation of human femoral intertrochanteric osteotomies. Double blind study. Clin. Orthop. Rel. Res., **237**:256–263, 1988.
5. **Carp, L.:** Fracture of the fifth metatarsal bone. With a special reference to delayed union. Ann. Surg., **86**:308–320, 1927.
6. **Dameron, T.B., Jr.:** Fractures and anatomical variations of the proximal portion of the fifth metatarsal. J. Bone Joint Surg., **57A**:788–792, 1975.
7. **DeLee, J.C., Evans, J.P., and Julian, J.:** Stress fractures of the fifth metatarsal. Am. J. Sports Med., **5**:349–353, 1983.

8. **Fontanesi, G., Giancecchi, F., Rotini, R., and Cadossi, R.:** Treatment of delayed union and pseudoarthrosis by low frequency pulsing electromagnetic stimulation: study of 35 cases. Ital. J. Orthop. Traumatol., **9:**305–318, 1983.
9. **Hinsenkamp, M., Ryaby, J., and Burney, F.:** Treatment of nonunion by pulsing electromagnetic fields: European multi-center study of 308 cases. Reconstr. Surg. Traumatol., **19:**147–151, 1985.
10. **Kavanaugh, J.H., Brower, T.D., and Mann, R.V.:** The Jones fracture revisited. J. Bone Joint Surg., **60A:**776–782, 1978.
11. **Lawrence, S.J., and Botte, M.J.:** Jones' fractures and related fractures of the proximal fifth metatarsal. Foot Ankle, **14(3):**358–365, 1993.
12. **Marcer, M., Musatti, G., and Bassett, C.A.I.:** Results of pulsed electromagnetic fields (PEMFs) in united fractures after external skeletal fixation. Clin. Orthop., **190:**260–000, 1984.
13. **Reinherz, R.P., Sink, C.A., and Westerfield, M.:** Management of trauma to the fifth metatarsal bone. Foot Surg., **28(4):**301–307, 1989.
14. **Rinaldi, E., Negri, V., Marenghi, P., and Braggion, M.:** Treatment of infected pseudarthroses with low-frequency pulsing electromagnetic fields: report of 16 cases. J. Bioelectr., **4:**251–264, 1985.
15. **Sedel, I., Christel, P., Duriez, J., Duriez, R., Evard, J., Ficat, C., Cauchoix, J., and Witvoet, J:** Resultats de la stimulation par champ electromagnetique de la consolidation des pseudarthroses. Rev. Chir. Orthop., **67:**11–23, 1981.
16. **Sharrard, W.J.W.:** A double-blind trial of pulsed electromagnetic fields for delayed union of tibial fractures. J. Bone Joint Surg., **72(B):**347–355, 1990.
17. **Sharrard, W.J.W., Sutcliffe, M.L., Robson, M.J., and MacEahern, A.G.:** The treatment of fibrous non-union of fractures by pulsing electromagnetic stimulation. J. Bone Joint Surg., **64(B):**189–193, 1982.
18. **Torg, J.S.:** Fractures of the base of the fifth metatarsal distal to the tuberosity. Orthopedics, **13(7):**731–737, 1990.
19. **Torg, J.S., Balduini, F.C., Zelko, R.R., Pavlov, H., Peff, T.C., and Das, M.:** Fractures of the base of the fifth metatarsal distal to the tuberosity. J. Bone Joint Surg., **66A:**209–214, 1984.
20. **Zelko, R.R., Torg, J.S., and Rachun, A.:** Proximal diaphyseal fractures of the fifth metatarsal—treatment of the fractures and their complications in athletes. Am. J. Sports Med., **7:**95–101, 1979.