Sports Medicine and Arthroscopy Review
2:293-300 © 1994 Raven Press, Ltd., New York

Treatment of Anterior Midtibial Stress Fractures

Thomas O. Clanton, M.D., Barry W. Solcher, M.D., and Donald E. Baxter, M.D.

Summary: Anterior midtibial stress fractures are an uncommon but difficult entity for the sports medicine physician. When a transverse radiolucent line is visible in the anterior tibial cortex ("the dreaded black line"), the problem takes on the characteristics of a nonunion and rarely responds to conservative treatment. We recommend taking a more aggressive approach with the use of electrical stimulation for the recreational athlete and drilling plus bone grafting or intramedullary nailing for the professional athlete. Key Words: **Tibia—Stress fracture—Ballet—Football—Intramedullary nailing—Bone grafting—Cortical** drilling.

The rising emphasis on sports and physical conditioning over the past few decades has spawned an increasing number of sports-related bone and joint injuries. A vast array of chronic overuse injuries involving the lower extremities is now recognized (1,2). Stress fractures are among the most common of these afflictions (3-6). Stress fractures often occur in normal bone that is subjected to repetitive forces that exceed the body's reparative capabilities. The type of sports activity is often correlated with the type of stress lesion. In running and jumping sports, the tibia is the most commonly affected bone due to its load-carrying function (7). These fractures typically involve the proximal or distal third of the tibia (8). A less common location for tibial stress fractures is the anterior midtibial cortex. While this may present only as increased uptake on a bone scan or as anterior cortical hypertrophy on x-ray, we focus specifically on the variant that presents with a transverse radiolucency in the anterior tibial cortex—the "dreaded black line," as originally described by Hamilton (9). (Fig. 1). This stress fracture has several unique characteristics that make it difficult to treat and warrant further investigation.

Since Burrows' original description of this fracture in ballet dancers in 1956, several additional studies reporting small numbers of cases have established the clinical nature of the anterior midtibial stress fracture (10-14). It is relatively rare compared to stress fractures of the proximal third and distal third of the tibia. In a Finnish study of 151 tibial stress fractures in athletes over a 7-year period, 7 cases of anterior midtibial fractures were found, comprising 4.6% of the series (13). Furthermore, this lesion has been consistently resistant to treatment. Even with prolonged periods of immobilization or rest, the radiographic healing time can be delayed, if the lesion heals at all. As with other difficult problems, proposed solutions are numerous and often inadequate. Treatment modalities have ranged from simple rest and/or cast immobilization (6,10,11,13), to the addition of electrical stimulation (14), to surgical excision and bone grafting (10,12), to intramedullary nailing (15). The most efficacious form of treatment has not been identified. This is due partly to the relative paucity of cases and small clinical series. The purpose of this article is to discuss the current attitude toward the conservative and surgical treatment of anterior midtibial stress fractures. A national survey of selected orthopedic surgeons who deal with problems

From the Department of Orthopaedic Surgery, University of Texas Medical School at Houston, Rice University, Foot and Ankle Service, Hermann Hospital (T. O. C); Department of Orthopaedic Surgery, University of Texas Medical School at Houston (B. W. S.), and Department of Orthopaedic Surgery, Baylor College of Medicine (D. E. B.), Houston, Texas, U.S.A.

Address correspondence and reprint requests to Dr. T. O. Clanton, 7400 Fannin, Suite 11030, Houston, TX 77054, U.S.A.

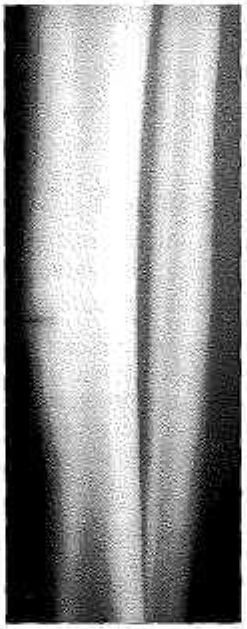

FIG. 1. "The dreaded black line," as originally described by William C. Hamilton (9), denoted the transverse radiolucent line seen in the anterior midtibial cortex of ballet dancers who had a stress fracture that was particularly resistant to treatment. (Radiograph courtesy of W. C. Hamilton, M.D.)

in the lower extremity and sports medicine was conducted to assess more accurately the current trends relating to this entity. After discussing the findings of our survey, we propose recommendations for the treatment of the anterior midtibial stress fracture.

ETIOLOGY

Although the orthopedic literature has established that stress fractures occur as a result of recurrent stress to the bone, many theories have been proposed for the exact mechanism by which this occurs. Bone stress may increase when muscles fatigue and their weakness reduces the relative shock-absorbing capacity of the soft tissue in the lower extremity (2,7,8,16). This theory describes more of a repetitive compression loading effect that results in gradual fatigue of the involved bone. Another theory, proposed by Stanitski et al., points to the highly concentrated muscle forces acting across the bone as the etiologic factor. Subthreshold mechanical insults can result from this rhythmic, repetitive action, leading to a fatigue fracture (6).

The anterior midtibial stress fracture occurs almost exclusively in athletes performing repetitive jumping or leaping activities. Current thought on the etiology of this particular stress fracture centers on the repetitive forceful contraction of the posterior musculature of the leg acting to develop significant tensile forces across the anterior tibial cortex. It is known that a bending force applied to a rod must produce a tensile stress on one aspect and a compressive force on the other. If the distraction force persists, ultimately this may result in a fatigue fracture.

The dynamic metabolic activity of bone enables it to respond to stress in a standard fashion. The histological sequence of stress fracture injury to bone has been characterized by Johnson et al. (17). Osteoclastic resorption predominates the initial response, followed by osteoblastic activity consisting of periosteal and endosteal callous formation. If the stress is discontinued, a fracture line does not develop. If the stressful activity continues, a cortical defect can develop. Cessation of activity allows osteoblastic repair to proceed at a higher level than osteoclastic absorption. This remodeling process is enhanced by a relative decrease in the forces acting across the involved area.

This same process seems to exist for the anterior midtibial stress fracture, with a slight variation—the break through the anterior cortex is usually incomplete and may persist even with cessation of activity. Histologically, the anterior midtibial stress fracture appears more like a nonunion than a fracture. Compact cortical bone surrounds the fracture defect. At biopsy, the fissure or fracture line is filled with fibrous or granulation tissue without notable callous (10). This cortical bone has been found to have empty lacunae (11). It appears that the tensile forces across the anterior tibial cortex supplied by its shape and the pull of the posterior leg musculature are sufficient to overload the reparative forces.

While these biomechanical factors are ultimately to blame for the midtibial stress fractures, other intrinsic and extrinsic variables are important in etiological considerations. These have been enumerated in detail elsewhere, so only the most pertinent ones are reviewed here (18-21). Simkin and coworkers have shown that the high arched foot is more at risk of tibial stress fractures than the flat foot (22). Empirically, one would expect leg length discrepancy, excessive body weight, and lower extremity malalignment to be important as well. This has not been demonstrated in the few studies that have examined these variables (23-25). On the other hand, weekly running mileage (over 40 mi or 64 km per week) has been consistently demonstrated to be a factor in running injuries, including stress fractures (26-28). Recent changes in the training regimen, prior injury, and participation on hard or high friction surfaces are among the additional considerations when evaluating athletes with these injuries (19).

DIAGNOSIS

In general, stress fractures present with a characteristic history, physical examination, and radiographic findings that allow an accurate diagnosis to be made. The anterior midtibial stress fracture is no exception. The pain is located at the middle of the tibial crest. It may have an insidious onset or present with an acute complete fracture. The pain can be confined to certain activities such as jumping or running and may be absent during routine daily activities. Symptoms are typically relieved with rest. The duration of symptoms may be weeks, months, or even years and delay in diagnosis is common due to similarities with other chronic lower extremity overuse syndromes. Due to the pain and the radiographic appearance in the midtibial stress fractures, these patients may be misdiagnosed as an osteoid osteoma or Brodie's abscess. Most studies of anterior midtibial stress fractures list patients in their late teens or early twenties, with males in the majority. Participation at a high level of competition in jumping or leaping sports such as basketball, ballet, gymnastics, and football is the most common presentation. The physical examination is characterized by bony tenderness and swelling over the anterior midtibia. However, the clinician should not be misled by the absence of pain or tenderness when only a bony mass is palpable in the proper setting (29). A limping gait pattern is also variable. A palpable bony enlargement is often felt. Other aspects of the physical examination focus primarily on factors of potential etiological significance. These include leg length discrepancy, cavus deformity, muscle imbalance, lower extremity malalignment, and use of inadequately cushioned or nonsupportive shoewear.

Radiographs

Anteriorposterior and lateral radiographs are usually adequate to establish a diagnosis. A small transverse cortical fissure or wedge-shaped defect in the middle third of the anterior or anterolateral cortex of the tibia is diagnostic (Fig. 1). This is often surrounded by hypertrophic or sclerotic anterior tibial cortex, which is best seen on the lateral projection. This differs from the hazy sclerosis or periosteal callous seen with proximal or distal tibial compression-type stress fractures.

Bone scintigraphy

Bone scanning has traditionally been helpful in patients whose history and physical findings are compatible with a stress fracture but whose radiographs are negative or atypical. Technetium scans have been proven to be a highly sensitive method of detecting stress fractures early in their course. In the presence of a stress fracture, the bone scan will show intense localized uptake at the affected site. For the "dreaded black line" lesion, the literature does not denote any additional benefit of bone scanning for diagnosis, but an absence of uptake around the cortical defect may be associated with a poor prognosis for healing (19).

TREATMENT

The treatment of stress fractures in general is rest and avoidance of the offending activity. Stress fractures of the tibia usually respond to restricted activity and cross training to maintain fitness for the athlete. Return to activity may require 4 to 6 weeks, according to the length and severity of symptoms. A gradual progression of load during retraining is necessary to prevent reoccurrence of symptoms.

Based upon a review of the literature, the anterior midtibial stress fracture does not follow the normal healing patterns of a stress fracture. The nature of this fracture poses a challenging management problem. Early recognition and treatment are desirable since the development of a cortical radiolucency seemingly increases the risk of delayed union or complete fracture.

The nonoperative treatment of the anterior midtibial stress fracture has met with variable success. Several recurrent themes have been elucidated from the literature. One is the prolonged duration of disability associated with this stress fracture. Studies have shown a delay in the diagnosis of the injury and also resistance to conservative treatment through restriction of activity or immobilization (11–13). While rest may bring about early clinical improvement, a high incidence of reoccurrence is noted when the athlete returns to full activity. In the standard situation, clinical healing precedes radiologic healing. In the nonstandard situation of the midtibial stress fracture, a radiographic defect persists in spite of clinical improvement or apparent healing. In Burrows' examination of five ballet dancers, three patients had continued radiological evidence of the defect, including one at 6 years following the onset of symptoms (10). The classic radiographic appearance can be present in asymptomatic individuals as seen in some of Burrows' follow-up patients. The potential for late fracture in asymptomatic patients, even years after their stress fracture, has been demonstrated by Brahms and coworkers (29). They describe a football player for the National Football League with an apparently well-healed, stable stress fracture of the anterior lateral cortex of the midshaft tibia. After three successful asymptomatic seasons as a kickoff return specialist and running back, he developed a noncontact comminuted fracture while running.

The success of nonoperative treatment has been difficult to document because of the inconsistent definition of healing in the reported studies. Some have reported follow-up until athletes have returned to athletic competition without documenting radiographic union, while others report radiographic union but do not comment on the athlete's ability to return to symptom-free competition. These deficiencies in reporting have made it difficult to determine the rate or average time of true clinical and radiographic union in these fractures or the average time for return to sports. This makes it literally impossible to properly counsel athletes and dancers as well as their coaches and employers.

The orthopedic literature clearly reflects a limited ability of conservative treatment to heal the midtibial stress fracture in a timely fashion (6,10–12,14, 29). Of the 30 cases reported, only 5 were treated with rest or immobilization alone. One of these was lost to follow-up, and the other four improved sufficiently to resume activities. Unfortunately, no follow-up radiographs were performed to confirm radiographic union. The remaining 25 patients failed rest and/or immobilization and required additional intervention. For eight patients, electrical stimulation was added, and six healed with this alone at an average of 7.5 months (range, 5-11 months). In the cases treated with electrical stimulation to union, the average time from symptom onset to return to activity averaged 11.9 months (range, 10-18 months). The addition of electrical stimulation to the nonoperative treatment regimen appears to offer substantial benefit.

The basic premise of nonoperative treatment is to place the bone in a situation in which the natural healing process can take place without further injury. Electrical stimulation may augment the healing environment, but it does not change the overall biochemical situation that produced the lesion originally, nor does it bring in new bone healing potential. Because of the high failure rate of nonoperative treatment and its prolonged duration, more effective treatment through surgical means has been pursued.

OPERATIVE TREATMENT

The rationale for surgical treatment of the anterior midtibial stress fracture is based on two basic precepts. One is removal of the nonunion area, with or without the addition of bone grafting, to eliminate the pathological tissue and stimulate new bone ingrowth. This was the treatment of choice after a period of rest for three of five ballet dancers in Burrows' study (10). Friedenberg biopsied both patients in his series at 7 and 10 months, respectively, after failed nonoperative treatment (11). He described symptomatic recurrence of the defect 18 months postbiopsy in one patient, while the second had continued symptoms and a persistent radiolucent line at 17 months postbiopsy. Green et al. performed excision and bone grafting in three patients in their study, when they failed 3 to 8 months of preoperative cast immobilization (12). Postoperatively, these patients were reported to have healed in a three to five month period. Rettig et al. described a basketball player requiring biopsy and bone grafting for a midtibial stress fracture that failed treatment by rest, casting, and electrical stimulation (14). The lesion finally healed with postoperative electrical stimulation, but not before the athlete had missed two basketball seasons.

Excision or biopsy of the nonunion site has been a popular choice after a course of conservative treatment has failed. Biopsy or excision alone has an unacceptably high failure rate. Without simultaneous bone grafting, biopsy does serve to confirm the diagnosis, remove the nonhealing tissue, and stimulate a vascular or inflammatory response in the area. It does not, however, change the biomechanical stresses that cause the lesion any more than rest and immobilization.

Surgical stimulation of a healing response can also be accomplished by transverse drilling of the nonunion site as described in five cases by Orava and Hulkko (5). The athletes were restricted in weight bearing and activity for 4 to 5 months after surgery to allow adequate healing prior to return to sports at an average of 10 months (range, 7-14 months). One complication occurred—a complete fracture through the biopsy site, which required bone grafting. We have treated an additional two ballet dancers with open drilling and bone grafting. Both healed at 10 and 12 months, and both returned to professional ballet careers (Figs. 2A-C and 3A and B). The potential for drilling to stimulate a healing response seems to exist, but the small number of cases and the lack of radiographic follow-up in Orava and Hulkko's series point to the need for further investigation.

Case reports

Case 1. A 19-year-old female ballet dancer was seen 18 months following onset of left midthird anterior tibial pain. Her symptoms were worsened by activity and improved by rest and had persisted in spite of rest from dance and cast immobilization for 6 weeks. Her radiograph showed hypertrophy of the anterior midtibial cortex, with a transverse radiolucent line partially through the anterior cortex (Fig. 2A). In January 1993, the patient underwent open drilling of the defect and autologous bone grafting from the proximal tibia as an outpatient (Fig. 2B). She was on crutches in a splint for 1 week before being converted to a removable walking boot. She wore this for 6 weeks before commencing ballet class at alow stress level at approximately 2.5 months after surgery, It was September 1993 before

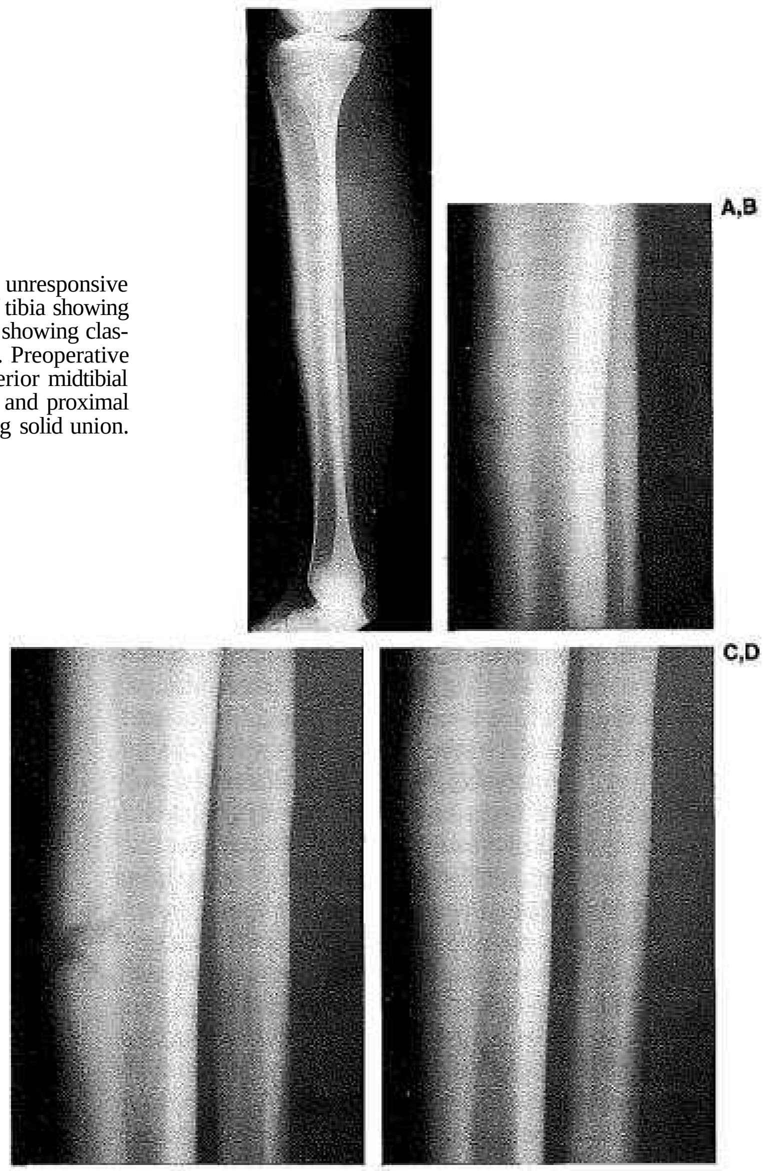

FIG. 2. Ballet dancer with anterior midtibial stress fracture unresponsive to rest and immobilization. A: Preoperative lateral x-ray of tibia showing hypertrophy of anterior cortex. **B:** Closeup of lateral x-ray showing classical transverse radiolucent line in anterior midtibial cortex. Preoperative x-ray showing classical transverse radiolucent line in anterior midtibial cortex. C: Postoperative x-ray showing drilling of defect and proximal tibial bone graft donor site. D: Postoperative x-ray showing solid union.

A,B

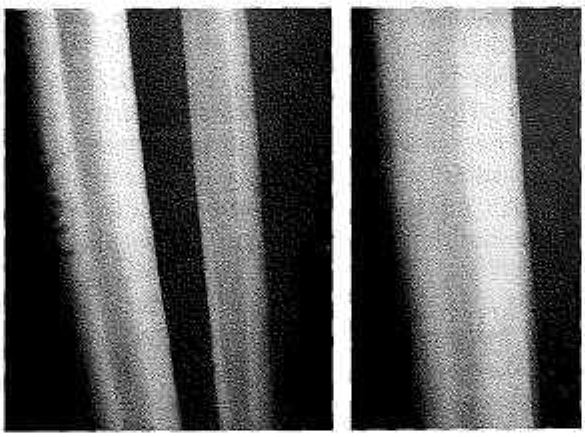

FIG. 3. Ballet dancer with anterior midtibial stress fracture. A: Postoperative x-ray showing drilling of defect in anterior cortex. B: Postoperative x-ray demonstrating solid union.

jumping was included in classwork, and performances started in November. Radiographs taken in July 1994 showed complete union but persistent anterior cortical hypertrophy (Fig. 2C). She was recently hired to dance professionally.

Case 2. A 19-year-old female professional ballet dancer complained of anterior midtibial pain and swelling for 17 months despite treatment with limited activity and a short leg walking boot. At this point, she was treated with open drilling and bone grafting (Fig. 3A). She was immobilized for 6 weeks postoperatively in a short leg walking boot. Light exercise began at 7 months following surgery, and performance dancing resumed at 10 months postoperatively. Her follow-up radiograph showed complete union (Fig. 3B). She remains asymptomatic while continuing her professional dance career at 4.5 years following surgery.

A final surgical approach is based upon the second precept of altering the biomechanical stresses across the fracture site. The advantage of a load-sharing device to reduce tensile stresses of the anterior tibial cortex is appealing. Unfortunately, only two cases have been reported. Green et al. had a college football player treated initially with rest for his midthird tibial stress fracture, but a completion of the fracture occurred with resumption of sports (12). This was treated with a long leg cast for 3 months, and 9 weeks later jogging commenced. At 5 months following the complete fracture, the patient refractured through the tibia while wrestling. An unreamed intramedullary nail was inserted along with bone grafting. Healing occurred in approximately 7 months both clinically and radiographically, and the patient resumed college football. Barrick and Jackson have reported the use of prophylactic intramedullary nailing in a professional football player after failure of varying periods of rest, and failure of a limited bone grafting procedure (15). The intramedullary nailing was performed ~2 years following the onset of symptoms. Radiographic healing was present at 6 weeks postoperatively, the athlete returned to running at 3 months, and he resumed professional play at 10 months. The ability to improve the biomechanical situation while simultaneously providing an autologous internal bone graft (with a reamed nail) makes intramedullary nailing attractive (Fig. 4A and B). Furthermore, it seems to provide more certain union and a quicker return to sports participation. There are specific risks that should be considered as well. These include infection and blood clots as well as increased expense in comparison to nonoperative treatment or even bone grafting. This is particularly true when removal of the nail is included in the consideration.

From this discussion of the treatment alternatives, it should be clear that no single method has gained preeminency. One reason for this is the infrequency with which these patients are encountered. Even those physicians with subspecialty

A,B

FIG. 4. Professional basketball player with anterior midtibial stress fracture who required intramedullary nail after failed drilling of anterior cortex. A: Postoperative x-ray showing multiple drill holes through anterior tibial cortex. B: Postoperative x-ray after intramedullary nailing. (Radiographs courtesy of J. C. DeLee, M.D.)

practices in sports medicine may go through a career without seeing the "dreaded black line" lesion. It is for this reason that we surveyed a large group of orthopedists whom we thought might have seen this entity.

SURVEY

A survey was distributed to 287 noted authorities in the field of sports medicine. A 58% response rate was obtained. The survey specifically targeted the anterior midtibial stress fracture with the classic radiographic findings. A radiographic example accompanied the survey. The goals of the questionnaire centered on developing a consensus for the treatment of anterior midtibial stress fractures. Requested information included the method of treatment, the average time to clinical union and radiographic union for each treatment method, and any complications of treatment. The results of our survey demonstrate not only a lack of consensus for treatment of this entity, but also a large group of physicians with no experience with the anterior midtibial stress fracture with a transverse radiolucent line. Most respondents chose nonoperative treatment, with a small subgroup advocating the more aggressive approaches of intramedullary nailing or drilling and bone grafting. Some of the responses suggested a difference in interpretation in the type of stress fracture being analyzed and possibly did not deal specifically with the type of stress fracture we are considering. For this reason, a more controlled multicenter study is being developed.

DISCUSSION

Relatively few cases of midtibial stress fractures with a transverse radiolucent line have been discussed in the literature since Burrows' first description in 1956 (10). With these small study groups, no consensus has been formed regarding treatment of this specific lesion. However, the characteristics of the anterior midtibial stress fracture have been well defined. It is resistant to traditional means of treatment, and complications can occur such as completion of the fracture and persistent nonunion. The latter is manifested by a radiolucent line even after treatment, whether operative on nonoperative. Therefore, a prolonged disability for the patient may result, possibly terminating his/her athletic career.

From the available information in the literature, no statement with statistical validity can be made regarding the proper method of treatment for the anterior midtibial stress fracture. Based upon review of the literature and our own experience, together with the experience of other practicing orthopaedists that have been surveyed, we make the following recommendations. In the recreational athlete, a conservative approach is indicated. This includes restriction of activity with immobilization and the addition of electrical stimulation. The patient must be counseled on the nature of this stress fracture and can generally be told to expect healing within a 1-year period. In the professional athlete whose livelihood depends on competitive sport participation, a more aggressive plan is warranted. This can occur in one of two ways. The more conservative route is percutaneous drilling and bone grafting. This has limited potential complications and results in healing within 1 year for the large majority of patients. Intrameduallary nailing of the tibia (barring complications) provides a quicker return to athletics. As with all major surgery, a careful explanation is essential, with an open discussion of the risks and benefits to the athlete. We feel that intramedullary nailing is biomechanically sound and provides a better healing environment for the stress fracture. The risk of complications is obviously higher than nonoperative treatment and must be considered carefully. We agree with Barrick and Jackson's recommendations not to remove the rod until the athletic career is completed (15). The use of an unlocked, large-diameter, reamed nail appears best to satisfy the biomechanical requirements for healing.

Between the recommendations for these two groups of patients is a large gray area consisting of competitive high school- and college-level athletes. These athletes often have high-intensity, competitive attitudes and lack the patience to deal with prolonged conservative treatment. Each of these patients must be considered individually and all related physical, emotional, and environmental factors weighed to determine the best approach to treatment. More definitive answers will be forthcoming only with larger controlled series of patients using different treatment modalities.

In conclusion, we feel that treatment of the anterior midtibial stress fracture should begin immediately. The typical behavior of this fracture is well documented, and we can usually predict a lengthy disability with conservative treatment. Surgical methods should use sound biomechanical and physiologic principles and be individualized to the athlete. A more in-depth study of this entity is necessary before more conclusive statements can be made.

REFERENCES

1. Clement DB. Tibial stress syndrome in athletes. *J Sports Med* 1974;2:81-5.
2. Orava S, Puranen J, Ala-Ketola L. Stress fractures caused by physical exercise. *Acta Orthop Scand* 1978;49:19-27.
3. Matheson GO, Clement DB, McKenzie DC, Taunton JE, Lloyd-Smith DR, Mcintyre JG. Stress fractures in athletes: a study of 320 cases. *Am J Sports Med* 1987;15:46-58.
4. McBryde Jr AM. Stress fractures in athletes. *Am J Sports Med* 1975;3:212-7.
5. Orava S, Hulkko A. Stress fractures in the athlete. *Int J Sports Med* 1987;8:221-6.
6. Stanitski CL, McMaster JH, Scranton PE. On the nature of stress fractures. *Am J Sports Med* 1978;6:391–6.
7. Belkin SC. Stress fractures in athletes. *Orthop Clin North Am* 1980;11:735-42.
8. Devas MB. Stress fractures of the tibia in athletes of "shin soreness." *J Bone Joint Surg* 1985;40B:227-39.
9. Hamilton WC. Injuries in dancers. Presented at the Midwinter Trauma Society Meeting, Vail, CO, Dec. 5, 1984.
10. Burrows HJ. Fatigue in fraction of the middle of the tibia in ballet dancers. *J Bone Joint Surg [Br]* 1956;38:83-94.
11. Friedenberg ZB. Fatigue fractures of the tibia. *Clin Orthop* 1971;76:111-5.
12. Green NE, Rogers RA, Lipscomb AB. Nonunions of stress fractures of the tibia. *Am J Sports Med* 1985;13:171-6.
13. Orava S, Hulkko A. Stress fractures of the mid-tibial shaft. *Acta Orthop Scand* 1984;55:33-7.
14. Rettig AC, Shelbourne KD, McCarroll JR, Bisesi M, Watts J. The natural history and treatment of delayed union stress fractures of the anterior cortex of the tibia. *Am J Sports Med* 1988;16:250-5.
15. Barrick EF, Jackson CB. Prophylactic intramedullary fixation of the tibia for stress fracture in a professional athlete. */ Ortho Trauma* 1992;6:241–4.
16. Orava S. Stress fractures. *Br J Sports Med* 1980;14:40-4.
17. Johnson LC, et al. Histogenesis of stress fractures: Proceedings of the American Academy of Orthopaedic Surgeons. *J Bone Joint Surg* 1963;45A:1542.
18. Baxter DE. The foot in running. In: Mann RA, Coughlin MJ, eds. *Surgery of the foot and ankle.* St. Louis: Mosby, 1993: 1229.
19. Clanton TO, Schon LS. Athletic injuries to the soft tissues of the foot and ankle. In: Mann RA, Coughlin MJ, eds. *Surgery of the foot and ankle.* St. Louis: Mosby, 1993;1095-224.
20. Clanton TO. Etiology of injury to the foot and ankle. In: DeLee JC, Drez D, eds. *Orthopaedic sports medicine: principles and practice.* Philadelphia: W. B. Saunders, 1994: 1642-704.
21. Frankel VH. Fatigue fractures. *J Bone Joint Surg [Am]* 1972; 54:1345.
22. Simkin A, Leichter I, Giladi M, et al. Combined effect of foot arch structure and an orthotic device on stress fractures. *Foot Ankle* 1989;10:25–9.
23. McNeal AP, Watkins A, Clarkson PM, et al. Lower extremity alignment and injury in young, preprofessional college and professional ballet dancers. II. Dancer reported injuries. *Med Probl Perform Arts* 1990;5:83-8.
24. Soloman RL, Trepman E, Micheli LJ. Foot morphology and injury patterns in ballet and modern dancers. *Kinesiol Med Dance* 1989;12:20-40.
25. Walter SD, Hart LE, Mcintosh JM, et al. The Ontario cohort study of running related injuries. *Arch Intern Med* 1978; 6:75-98.
26. Macera CA, Pate RR, Powell KE, et al. Predicting lower-extremity injuries among habitual runners. *Arch Intern Med* 1989;149:2565-8.
27. Marti B, Vader JP, Minder CE, et al. On the epidemiology of running injuries. The 1984 Bern Grand-Prix study. *Am J Sports Med* 1988;16:285-94.
28. Powell KE, Kohl HW, Casperson CJ, et al. An epidemiological perspective on the causes of running injuries. *Phys Sports Med* 1986;14:100-4.
29. Brahms MA, Funnich RM, Ippolito VD. Atypical stress fracture in a professional athlete. *Am J Sports Med* 1980;8: 131-2.