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Outcome of conservative and surgical management of navicular stress fracture in athletes

Eighty-six cases proven with computerized tomography

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ABSTRACT

Eighty-two athletes with 86 clinical navicular stress fractures, all imaged with computerized tomography, were followed for an average of 33 months (range, 6 to 108) after diagnosis. Initial treatment consisted of at least 6 weeks of nonweightbearing cast immobilization for 22 fractures, at least 6 weeks of limitation of activity with continued weightbearing for 34 fractures, and a period of less than 6 weeks of conservative treatment for another 19 fractures. Five patients attempted to continue playing sports. Six patients had immediate surgery.

Nineteen of 22 patients (86%) who had initial nonweightbearing cast immobilization treatment returned to sports, compared with only 9 of 34 patients (26%) who initially continued weightbearing with limited activity ($P < 0.001$). After failure of the latter treatment, successful outcomes were seen for 6 of 7 patients (86%) treated with nonweightbearing cast immobilization, while 11 of 15 patients (73%) who had one surgical procedure were able to return to sports.

These results indicate that nonweightbearing cast immobilization is the treatment of choice for navicular stress fractures. Also, this treatment compares favorably with surgical treatment for patients who present after failed weightbearing treatments.

Computerized tomographic appearances of healing fractures do not necessarily mirror clinical union, and postimmobilization management should be monitored clinically.

Navicular stress fracture is a condition that has curtailed many promising athletic careers. Despite the landmark paper by Torg et al.[19] reporting 100% successful outcome for 19 patients with 21 navicular stress fractures that were treated with 6 to 8 weeks of nonweightbearing cast immobilization, a range of navicular stress fracture treatments have been reported.[1,5,12,17,20] Previous studies have used radionuclide scans and tomograms to image navicular fractures because the fracture can rarely be detected in its early stages with plain radiographs.[2,4,15,16,19] In this paper we report a large series of navicular stress fractures that have been imaged using computerized tomography (CT) to enhance accurate diagnosis and aid classification. Serial CTs were performed to permit comparison of clinical and radiographic fracture healing.

Navicular stress fractures generally occur as partial or complete fractures in the sagittal plane. Complete fractures may be displaced or undisplaced. In addition, small fragments or ossicles have been described at the proximal dorsal border of the navicular bone.

Torg et al.[19] have proposed that uncomplicated partial fractures and undisplaced complete fractures of the navicular bone should be treated by 6 to 8 weeks of nonweightbearing cast immobilizaton, that displaced complete fractures should be treated by open reduction and internal

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Figure 1. A CT slice through the axial plane of the proximal navicular bone showing the "Y" type of fracture in a 16-year-old male long jumper.

Figure 2. A CT slice through the axial plane of the proximal navicular bone showing an ossicle and a small partial fracture in a 23-year-old male distance runner.

fixation followed by 6 weeks of nonweightbearing cast immobilization, and that small transverse fragments should be excised. In office practice, however, some practitioners prescribe total rest from sports with continuation of other weightbearing activities (e.g., walking). This occurs particularly for navicular stress fractures that are diagnosed early and appear merely as tiny cortical defects on CT scan. In this paper, this type of treatment is called limited activity with weightbearing.

Fractures complicated by delayed union or nonunion have generally been treated by inlay bone graft surgery.[2,8,13,19] The use of 6 to 8 weeks of nonweightbearing cast immobilization treatment for these fractures has not been reported previously. We report a retrospective multicenter study of 86 stress fractures of the tarsal navicular bone in 82 patients, all of whom had CT scan confirmation of the clinical diagnosis.

MATERIALS AND METHODS

The authors have an ongoing navicular stress fracture data base covering international, national, and recreational athletes treated in five major sports medicine clinics in Melbourne, Australia, since 1981. The data base currently includes patients with 102 clinically confirmed and CT-confirmed navicular stress fractures. Our study group consisted of 82 patients (31 female, 51 male), with an average age of 20.2 years (range, 14 to 39). Only those patients with a minimum of 6 months of followup are included in this paper; the average followup was 33 months since diagnosis (range, 6 to 108). A total of 129 treatments were instituted. After review of the clinical notes and further interview with each patient, the following data were recorded: age, gender, side injured, duration of symptoms before diagnosis, results of radiographs and bone scan (where available), and results of CT scan.

The CT scans were originally reported by numerous radiologists as part of the patients' investigation and management. For this study, all CT scans were then reviewed by two sports physician authors (KMK and PJF) and a radiologist (ZSK). The scans were examined for size and orientation of the defect, cortical defects, sclerosis, vascular markings, signs of resorption, and signs of radiographic union. The majority of the patients had both feet imaged simultaneously on a GE 9800 model CT scanner using bone algorithm and images recorded on a window width of 3000 and a level of 500. Where possible, the extent of the fracture was measured. The sagittal depth of the fracture as seen in slices taken through the axial plane of the bone was measured as a percentage of the total sagittal height of the navicular bone and expressed as the "sagittal percent fractured." The extent of the fracture distally from the talonavicular joint as seen in the horizontal slices was measured as a percentage of the total posteroanterior navicular length and expressed as the "horizontal percent fractured."

Conservative treatment was recorded in the following categories: 1) continued sporting activity; 2) nonweightbearing cast for at least 6 weeks; 3) limitation of activity with weightbearing (including weightbearing cast) for a minimum of 6 weeks; and 4) periods of conservative treatment for less than 6 weeks, either weightbearing or nonweightbearing.

Surgical treatment varied depending on the type of fracture. Symptomatic, radionuclide-positive ossicles were ex-

TABLE 1
Success of different types of first treatments

Treatment type	No. of cases	No. of successes	Percent success	Average time of return to sports (months)	Significance cf. NWBC
Nonweightbearing cast (≥6 weeks)	22	19	86	5.6	
Nonweightbearing cast (2–5 weeks)	13	9	69	3.7	
Limitation of activity (≥6 weeks)	34	9	26	5.8	$P < 0.001$
Limitation of activity (3–5 weeks)	6	3	50	3.7	
Continued sporting activity	5	1	20	0	$P < 0.02$
All conservative excluding nonweightbearing cast	58	22	38	9.3	$P < 0.001$
Surgery	6	5	83	3.8	NS

TABLE 2
Effectiveness of nonweightbearing cast (NWBC) as first or second treatment

Treatment	No. of cases	No. of successes	Percent success	Average time of return to sports (months)	Significance cf. NWBC
First	22	19	86	5.6	
Second	10	9	90	6.9	NS

cised. Saggital plane stress fractures were generally treated either by autogenous bone graft or internal fixation, or a combination of these.

Postinjury activity was recorded as the same as, or lower than, preinjury activity. All patients gave a subjective rating of their ability to return to sports as well as pain and discomfort during activity or at rest. The rating was categorized as excellent (no symptoms whatsoever), good (pain or discomfort occasionally), moderate (pain during or after exercise but not at rest), and poor (activity ceased due to persistent pain and or discomfort).[7] In those patients who were able to return to the preinjury activity level, the time from the beginning of treatment to unrestricted return to activity was recorded.

A successful outcome of treatment was defined as one that allowed the patient to return to sports within 12 months from the beginning of treatment and without recurrence of symptoms at the time of followup. Forty-six fractures were treated successfully. Forty fractures prevented patients from being able to return to sports within 12 months or required more than one treatment.

Statistical analysis was performed using the chi-square test for nonparametric data sets with small number correction (Fisher) as necessary. Two by two tables were established using the nonweightbearing cast immobilization group (at least 6 weeks) as a standard against which the groups for limitation of activity with weightbearing (at least 6 weeks), continued sporting activity, and surgery were compared. Similarly, the outcome of the group using nonweightbearing cast immobilization as a first treatment was compared against the group using it as a second treatment.

RESULTS

There were 48 recreational, 15 state level, and 19 national level (elite) athletes. The mean time from the onset of symptoms to diagnosis was 4 months (range, 3 days to 5 years). Three patients had suffered a navicular stress fracture in both feet and one had a second, separate fracture on the same foot. At the time of diagnosis, examining clinicians noted limitation of ankle dorsiflexion or subtalar joint motion or both in a large number of patients. Foot types ranged from pes planus with excessive pronation through normal feet to rigid pes cavus.

Initial plain radiographs were available for 77 of the 86 fractures and were positive in 14 cases (18%). Seventy-eight fractures had been imaged by radioisotope scan and all were markedly positive. All fractures were demonstrated on CT scan.

With two exceptions the fractures were in the sagittal plane and involved the central third of the navicular bone. Two fractures consisted entirely of dorsal fragments that were clearly positive on isotope scan and which we refer to as "ossicles." At the time of diagnosis there were 83 partial fractures and 3 complete fractures. Four partial fractures were described as "Y" type (Fig. 1). Five partial fractures

TABLE 3
Results of the first surgical treatment undertaken by patients[a]

Treatment	No. of cases	No. of successes	Percent success	Average time of return to sports (months)
Excision of small fragment alone	8	7	89	5.1
Internal fixation alone	11	6	55	4.8
Bone graft alone	6	4	67	6.8
Bone graft and internal fixation	3	2	67	5.0
Total/average	28	19	68	5.4

[a] Six cases where surgery was the first treatment of the fracture and 22 cases of the first surgical treatment following failed conservative treatment.

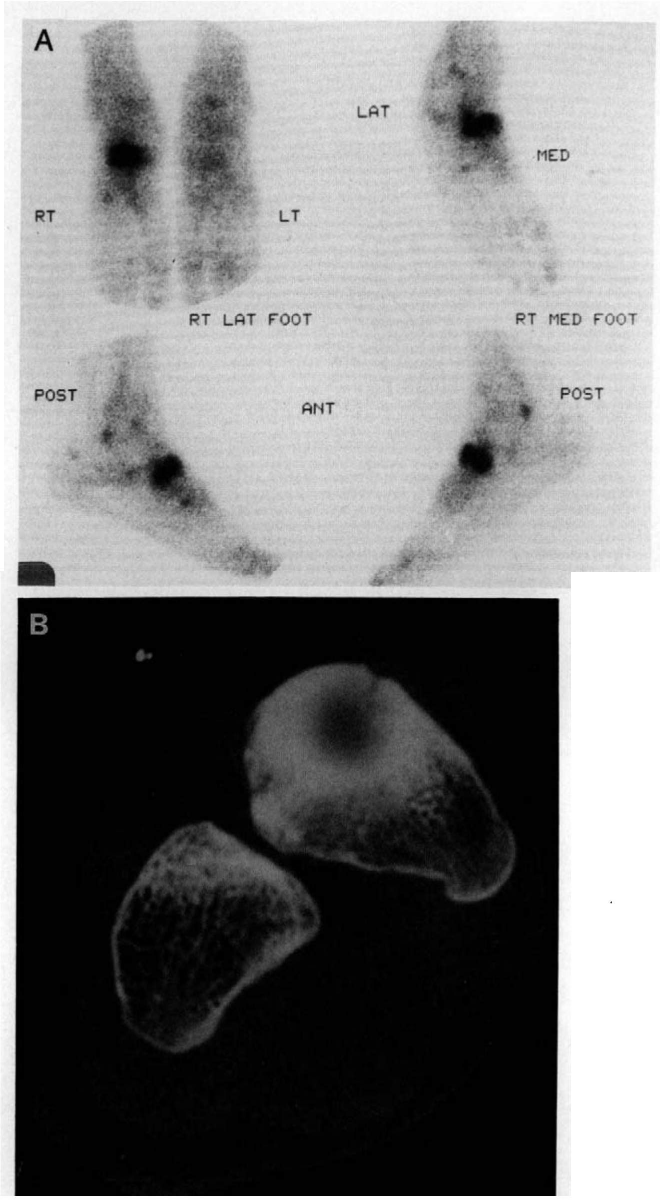

Figure 3. A, a positive radionuclide scan clearly outlining the right navicular bone of a 20-year-old elite male middle distance runner. B, a CT slice through the axial plane of the proximal navicular bone showing a relatively small navicular partial fracture. This fracture was evident on three axial slices, each 1.5 mm apart.

were associated with ossicles (Fig. 2). Ossicles were noted on the CT scans of the asymptomatic feet of some patients, but the corresponding isotope scans were normal.

Continued sporting activity at previous level

There was only one successful outcome with this treatment method (Table 1). Five patients continued to train at their previous intensity after a 2-week period of limitation of activities with weightbearing. Three of these athletes extended their partial fractures to complete navicular fractures. One stopped because of increasing pain and a repeat CT showed extension of the fracture. One recreational distance runner continued despite pain on activity and eventual permanent diminution of his level of activity.

Limited activity with weightbearing

Despite the previously documented incidence of nonunion of navicular stress fractures with this treatment,[14,19] this was still the most frequently used method of treatment in this retrospective study (Table 1). Thirty-four athletes had between 6 and 100 weeks of limitation of activity as their first treatment. Only 5 of 34 athletes (15%) with at least 6 weeks of this treatment began their return to sports by 6 months; another 4 returned by 12 months. One was able to continue sports for a season after having limited activity with weightbearing, but subsequently required further treatment.

Of the 25 patients who failed with this treatment, successful outcomes were obtained for 6 of 7 patients (86%) who had nonweightbearing cast immobilization as a second treatment. Eleven of 15 patients (73%) returned to sports after one surgical procedure. The other three patients persisted with limited activity with weightbearing and returned to sports 2 years after diagnosis.

Nonweightbearing cast immobilization

Six to eight weeks of nonweightbearing cast immobilization was employed either as first treatment (22 patients) (Table 1) or as second treatment (10 patients) (Table 2). With the advent of water-proof underwrap (W.L. Gore, Melbourne, Australia) and fiberglass casting material, it is possible for patients in a cast to maintain aerobic fitness by swimming, and this has been encouraged.

Nineteen of 22 patients (86%) with nonweightbearing cast immobilization as first treatment had a successful outcome, with a mean time of return to sports of 5.6 months (range, 3 to 12) (Table 1). Three patients failed to return to sports with this method as first treatment. One, a 17-year-old female sprinter, was diagnosed after 1.5 months of pain. At that time she already had a complete fracture and was suffering athletic amenorrhea with low serum estrogen. The athlete received hormone replacement therapy and her fracture healed clinically and this was confirmed radiographically. She was able to return to full sports participation by 18 months (see Fig. 8). An Australian Rules footballer, diagnosed after 4 months of pain, had a large fracture associated with an ossicle. After cast immobilization he continued to have mild but persistent symptoms and was referred for surgical removal of the ossicle.

Nine of 13 patients (69%) with a shorter duration of cast immobilization (2 to 5 weeks) had successful outcomes.

Nine of 10 patients (90%) with nonweightbearing cast immobilization as second treatment had successful outcomes. This treatment was employed after the failure of limited activity with weightbearing (7 cases), short-term

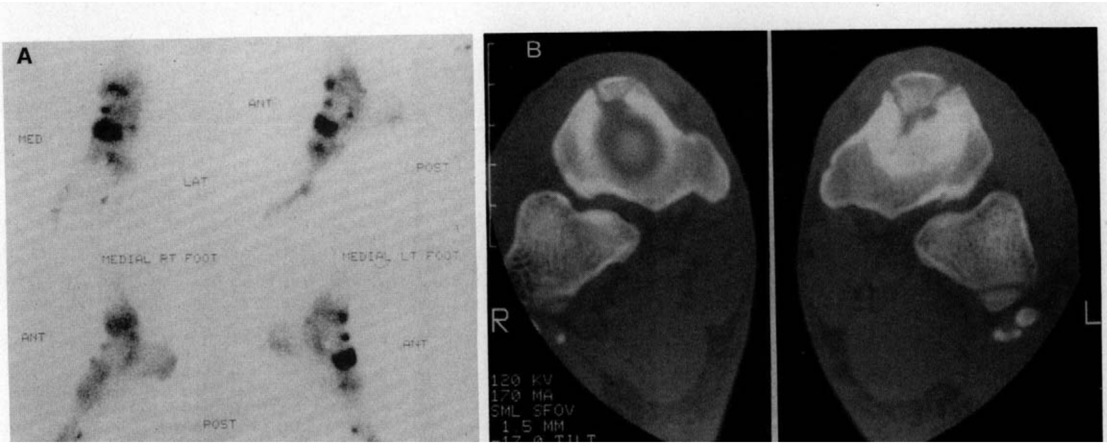

Figure 4. A, a positive radionuclide scan clearly outlining the left navicular bone of a 24-year-old male international long jumper. B, a CT slice through the axial plane of both navicular bones taken on the same day as A. There is a large, symptomatic left navicular fracture, with a large fragment. Note that the right foot is asymptomatic and negative on the radioisotope scan.

limited activity with weightbearing (1 case), continued sporting activity (1 case), and internal fixation surgery (1 case).

Surgery

Of the six patients who had surgery as the first treatment of the fracture, two had complete fractures, two had small ossicles that were excised, one had an ossicle associated with a small partial fracture, and one had internal fixation of a partial fracture. Five of six patients (83%) had successful outcomes (Table 1).

Surgery was used as a second or subsequent treatment for 22 fractures: after 15 cases of failed limitation of activity with weightbearing, 1 case of failed nonweightbearing cast immobilization, 3 cases of failed continued sporting activity, and 3 cases of failed conservative treatment of less than 6 weeks. When patients had not had surgery previously, the percentage of surgical success was 68% (Table 3). When a second surgical procedure was undertaken, 2 of 5 patients (40%) had a successful outcome. The 3 patients in whom the second surgical procedure was unsuccessful opted for further surgery; 2 of them required more than 4 operations.

Bone grafting and screw fixation were the most commonly performed procedures. Complications of bone grafting included incorrect positioning of the graft, nonunion of the graft, and sequestra. Complications of screw fixation included incorrect placement of the screw, breakage of the screw in situ, and breakage of the screw during extraction. There were no cases of infection, wound breakdown or deep vein thrombosis in this series.

DISCUSSION

Delayed diagnosis

The diagnosis of navicular stress fracture is often not made immediately.[4,6,10,16,19,20] In this study, the average time from the onset of pain to diagnosis was 4.0 months (range, 3 to 60 months). This delay occurred for a number of reasons. First, athletes were not aware of the potential seriousness of a diffuse foot pain that would often disappear with a few days of rest from running. On occasion, the diagnosis was overlooked by physicians because of the vague nature of the pain. Because the talonavicular joint is supplied by the medial plantar nerve, the pain may radiate along the medial arch of the foot and not directly over the talonavicular joint. Sometimes the pain radiated distally, causing the practitioner to suspect a Morton's neuroma or metatarsalgia. Even using special views,[15] radiographs of small navicular stress fractures commonly appear normal.

Interpretation of radioisotope scans

Positive isotope scan in the asymptomatic patient. A radioisotope bone scan is the most sensitive indicator of the presence of a fracture. The scan may even show marked activity in the navicular bone before an athlete has foot pain. Matheson et al.[9] described the concept of "bone strain" where a radionuclide scan is positive in an asymptomatic region. There were four patients (three female, one male) in this study who fit the description of bone strain before developing frank navicular stress fractures. All four were investigated with radionuclide scans for medial shin pain before they developed navicular pain. Each had a scan with markedly increased navicular uptake, as well as having signs of tibial stress. These athletes did not have navicular tenderness on examination at the time of the scan; one underwent CT scanning and was shown not to have a navicular fracture. All four continued full training and developed clinically and CT-confirmed navicular stress fractures 2 to 5 months later.

Moderately positive isotope scan in the symptomatic patient. In athletes with clinical features of navicular stress fracture, a moderately positive radionuclide scan must be

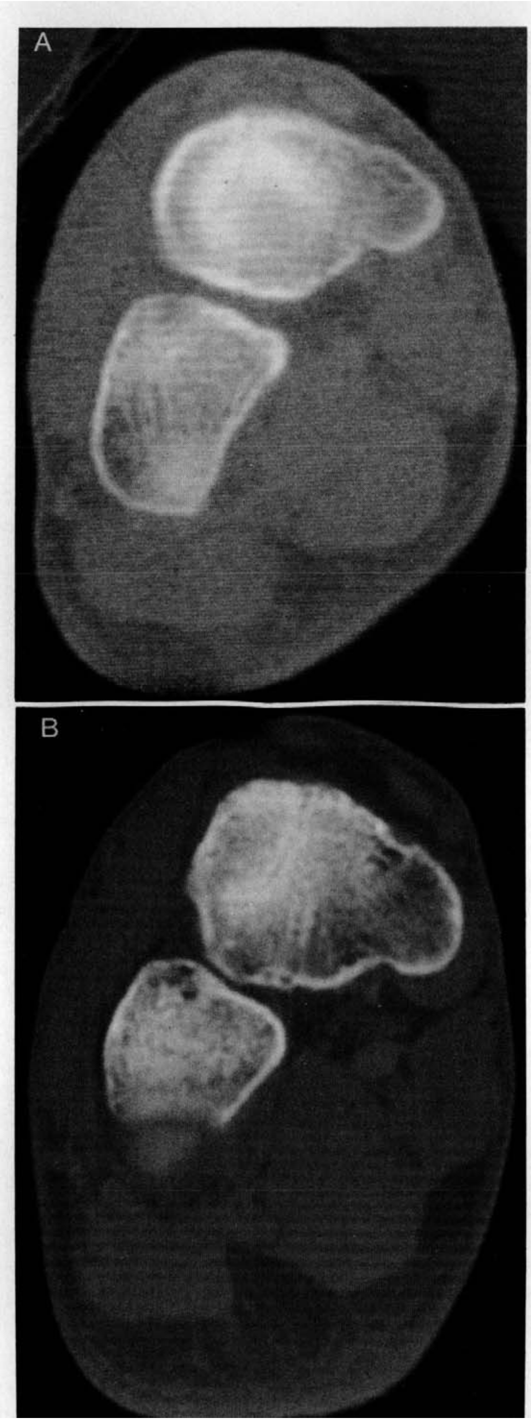

Figure 5. A, a CT slice through the axial plane of the proximal navicular bone at diagnosis shows a typical partial fracture in an 18-year-old female hurdler. B, a CT slice through the axial plane of the proximal navicular bone after 3 weeks of nonweightbearing cast immobilization. The fracture line appears slightly more obvious than at diagnosis; the normal navicular sclerosis is less evident. The patient had a further 3 weeks of nonweightbearing cast immobilization followed by an uneventful return to sports.

interpreted with care since there may be interoperator variability with regard to labeling such a scan as "stress reaction" or "stress fracture" if relying purely on intensity of uptake.[3,9] Therefore, in the course of this study, we reserved the diagnosis of stress reaction for symptomatic patients with positive isotope scans and normal CT scans on a high-quality scanner. Since we do not consider these patients to have true stress fractures, they have been excluded from the data base. Patients with stress reaction by these criteria do not require cast immobilization and have been managed successfully with 6 weeks of strict limitation of activity with weightbearing (eight patients; Khan and Fuller, unpublished data, 1992).

Stongly positive isotope scan in the symptomatic patient. Patients with clinical features of navicular stress fracture and positive isotope scans that are very similar in intensity can have a variety of CT appearances. The CT scans in our study ranged from being almost normal to demonstrating a small partial fracture (Fig. 3), a large partial fracture with a large fragment (Fig. 4), and a complete fracture.

Interpretation of initial CT scans

In this study, errors in the initial reporting of the CT scans occurred in 6 of 86 cases (7%). Five scans were originally reported as being normal, when on review of the films the fracture line could be seen by the authors. In one case, the reporting radiologist used an arrow to point to a normal cleft and missed the fracture present in the typical position. In other cases, small fractures (1 to 2 mm) in the proximal articular surface have been read as being small vessels. An angiographic study of the tarsal navicular bone shows that vessels enter the navicular surface through a narrow central waist.[19] These vessels can sometimes be seen on axial CT scan slices distal to the sclerotic proximal articular surface. Vessels have not been seen in the proximal articular surface in any of the scans examined in this study.

Tomograms not obtained in the proper plane often fail to demonstrate navicular fractures[15]; similarly, if CT slices do not include the dorsal proximal cortical surface, small fractures will be missed. Furthermore, if the slices are taken too far apart (axial slices >1.5 mm apart) or if the CT scanner has inadequate resolution, misdiagnosis can occur.

The CT appearance after conservative treatment

During cast immobilization, plain radiographs of navicular fracture margins become less well defined and there is often apparent radiographic widening due to bone resorption. "Notching" of the proximal articular margin and intramedullary cyst formation have been seen on radiographs of clinically healed fractures.[15,19]

Union shown by CT lags behind clinical union of navicular fractures and after several weeks of nonweightbearing cast immobilization, patients may not show obvious CT changes (Fig. 5). Nonweightbearing causes the navicular bone to temporarily lose its normal sclerosis (Figs. 5 and 6). Subtle

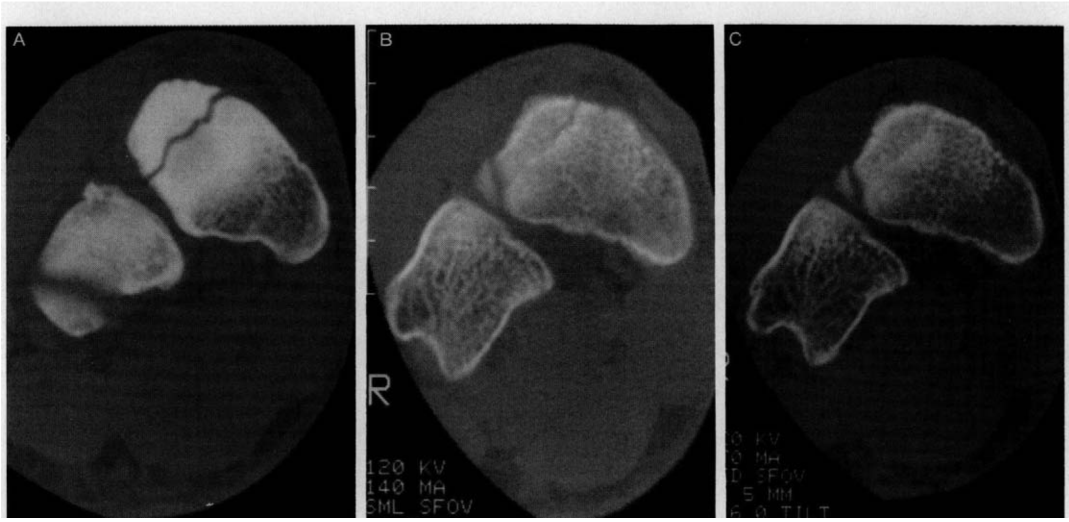

Figure 6. The CT scans of a 19-year-old male sprinter with a complete fracture that occurred 2 weeks after he first noticed mild foot pain while running. A, CT slice through the axial plane of the complete navicular fracture. The patient was treated with 6 weeks of nonweightbearing cast immobilization. B, in the repeat CT scan 3 months after injury, the patient was pain-free and nontender over the navicular bone and beginning to jog again. C, a repeat CT scan 6 months after injury shows further radiographic union. The patient was training fully without pain at this point.

significant changes that may be evident with excellent quality scanners at 3 months include blurring of the fracture line (Fig. 6) and cortical bridging (Fig. 7). The obvious, but normal, proximal navicular sclerosis (Figs. 1, 2, 3B, 4B, 5A, 6A, 7A, 8, and 9) must not be considered as evidence of nonunion when it surrounds the still-evident fracture line, as such an interpretation could cause a patient to have unnecessary further immobilization or surgery.

Intramedullary cysts (Fig. 8A) and notching of the proximal articular surface (Fig. 8B) can sometimes be seen on CT scans of the healing navicular stress fracture. The notching, usually seen best on horizontal slices, is more common and is sometimes seen on plain radiographs.[19] In this study there were patients who were asymptomatic and playing sports at the elite level with a persistent fracture line (Fig. 9) or an internal navicular cleft on CT (Fig. 8A) up to 6 years after initial treatment. Interestingly, patients who have treatment that allows limited activity with weightbearing may show apparent closure of the fracture during the period of rest from activity, but this often reverses quickly once patients return to sports.

Parameters used to follow fracture healing in this study

1. After 6 weeks of nonweightbearing cast immobilization, tenderness to palpation at the fracture site (the dorsal proximal region of the navicular) is the best guide to fracture healing. Patients with persistent tenderness at that site (the "N" spot) require a further 2 weeks of the same treatment before reassessment.

2. If the fracture site is not tender after cast immobilization, patients may begin weightbearing. They will often feel some diffuse foot pain at first, different from their original pain. This may be due to stiffness of the crural, subtalar, and midtarsal joints. As long as the navicular bone is not tender, mobilization of the joints involved and weightbearing activity is the appropriate treatment.

3. As plain radiographs are often not sensitive enough to detect the original fracture, it is clear that they do not provide a reliable indicator of fracture healing.

4. Radioisotope scan is not useful for monitoring fracture healing because the scan remains positive long after clinical union.[11]

5. Repeat CT scans 3 months from the commencement of nonweightbearing cast immobilization usually show blurring of the fracture line and cortical bridging. However, the CT will not necessarily show complete obliteration of the fracture at that stage even though the patient is, and will remain, asymptomatic.

These findings suggest that after nonweightbearing cast immobilization of navicular stress fractures, routine CT scan is not indicated, and that clinical examination of tenderness of the navicular bone at the "N" spot should be used to monitor gradual return to sports. Most importantly, post-immobilization CT findings should never be used as an indication for surgery when the patient is pain-free.

A hypothetical progression from bone strain to navicular stress fracture

Athletes who show significant radioisotope uptake over the tarsal navicular bone several months before they develop foot pain could be considered to be suffering bone strain.[9] We believe if this is ignored, the athlete may develop navicular pain and tenderness, which, with a positive isotope scan and a normal CT, might be termed stress reaction.[9] Navic-

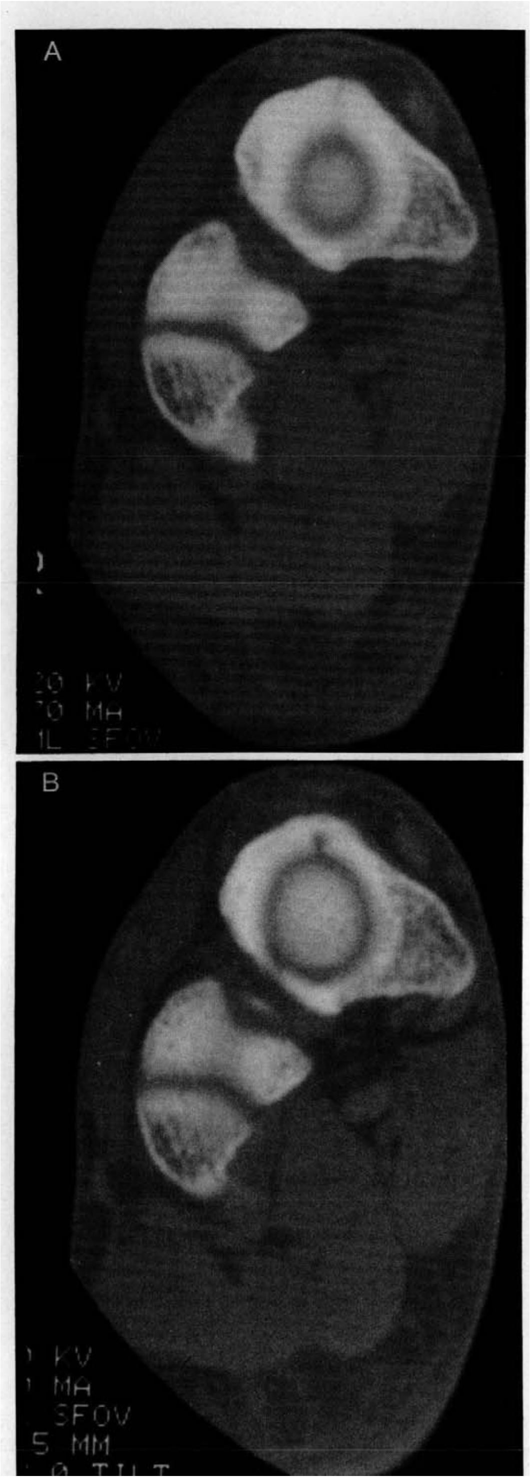

Figure 7. A, a CT slice through the axial plane of the proximal navicular bone of a 16-year-old female hurdler showing partial fracture. B, the patient was treated for 6 weeks in a non-weightbearing cast. This axial CT was taken 10 weeks after the commencement of treatment. The fracture is clinically healed; the CT shows cortical bridging and the central cleft remains.

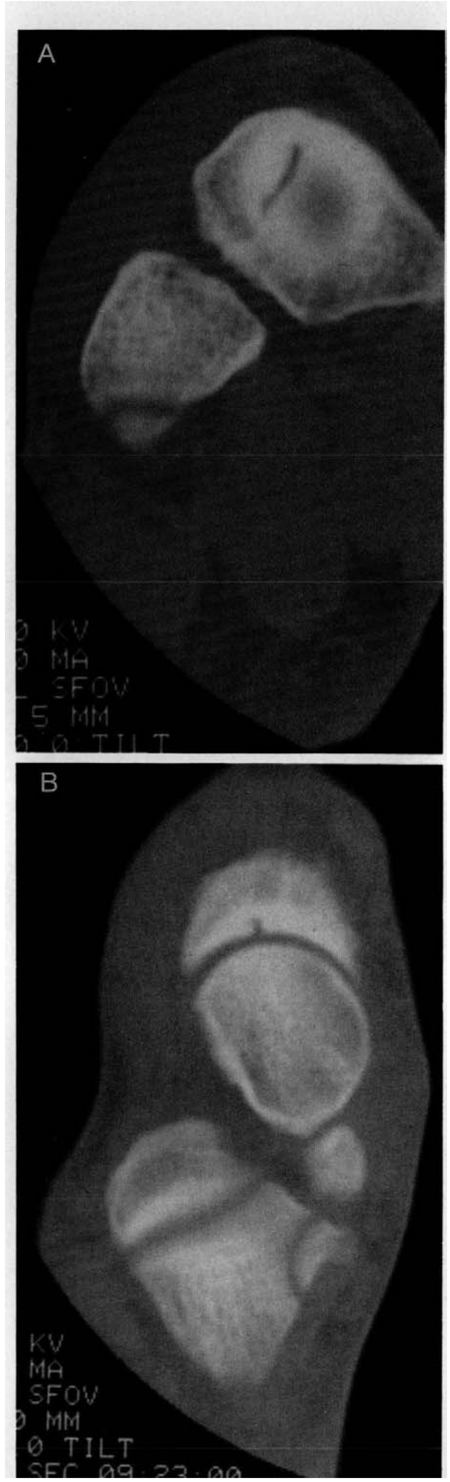

Figure 8. A, a CT slice through the axial plane of the proximal navicular bone of a 17-year-old female sprinter after 18 months showing a clinically healed fracture with persistent central cleft. The patient was running without pain at this time. B, a horizontal CT taken at same time as A demonstrates proximal notching in the articular surface, which is often seen on horizontal slices of healed fractures.

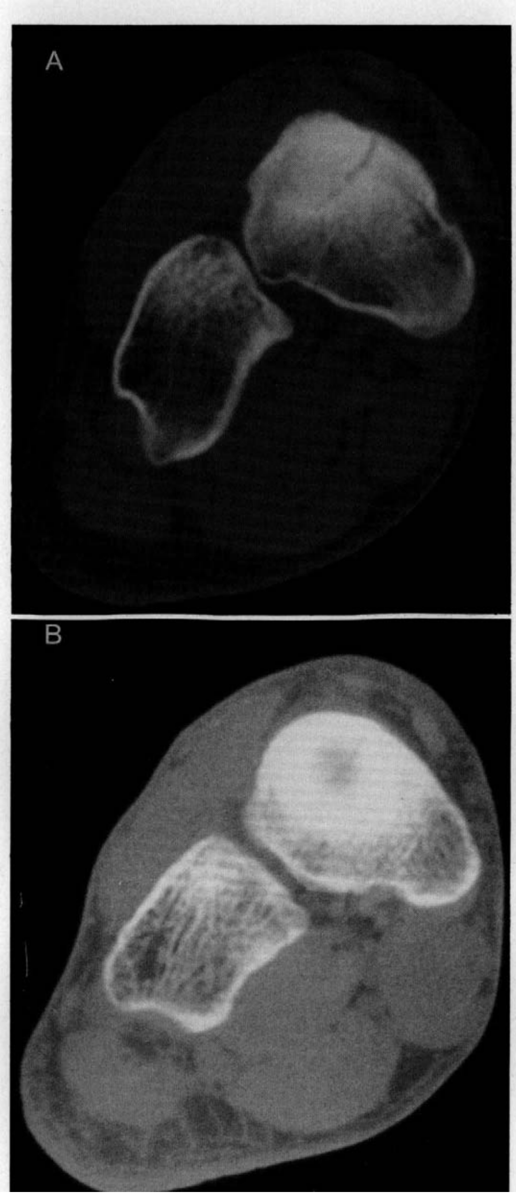

Figure 9. A, an axial CT scan of a navicular stress fracture in a 17-year-old male distance runner at presentation in 1984. The patient had 6 weeks of nonweightbearing cast immobilization and made an uncomplicated return to running. B, an axial CT scan taken while the patient was asymptomatic 6 years later shows that cortical bridging has taken place. There is a persistence of the central part of the fracture line.

ular stress fractures appear to begin in the cortical surface of the highly sclerotic dorsal proximal articular surface[21] of the tarsal navicular bone (Fig. 3B). Sagittal fractures then extend distally (thus visible on more of the axial slices) and plantarward with a varying degree of curvature, usually laterally (Fig. 5A). When the fracture is recent, the CT shows an irregular fracture line with occasional sites of bridging (Fig. 5A). When the patient's fracture remains untreated for several months it widens, the margins become smoother (Fig. 4B), and it may extend to become a complete fracture.

CONCLUSIONS

The condition of bone strain is particularly significant when seen in the tarsal navicular bone because patients with this condition who do not modify their athletic training have been seen to develop frank navicular stress fracture.

We feel that clinical evidence of navicular stress fracture with a positive radioisotope scan is insufficient evidence to justify a diagnosis of navicular stress fracture. A CT scan is necessary to distinguish between stress reaction and stress fracture.

The authors concur with published evidence documenting the high failure rate of treatment using limitation of activity with weightbearing. Nevertheless, this study shows that this form of treatment for CT-positive navicular fracture is still prevalent.

Our results indicate that all clinically, radioisotopically, and CT-confirmed navicular stress fractures, partial or complete, should be treated with 6 to 8 weeks of nonweightbearing cast immobilization.

After failed weightbearing treatments, nonweightbearing cast treatment compares favorably with surgical treatment.

The CT scan appearance of navicular stress fracture is variable. Radiographic expertise is required to obtain appropriate images to aid in early diagnosis. After appropriate treatment, however, fractures should be monitored clinically.

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