OPERATION FOR NON-UNION OF STRESS FRACTURE OF THE TARSAL NAVICULAR

KENNETH D. FITCH, JOHN B. BLACKWELL, WILLIAM N. GILMOUR

From the Royal Perth Hospital, Western Australia

Stress fractures of the tarsal navicular do not heal predictably with conservative treatment, so we recommend operation if the fracture remains symptomatic, and radiographs show wide separation of a complete fracture, extension of an incomplete fracture, delayed healing, or a medullary cyst. An autologous bone graft is inserted after en-bloc resection of the fracture surfaces. It is important that the fracture is fully exposed to its distal limits before the graft is inserted.

We have grafted 19 fractures in 18 patients. Six fractures were complete, 12 incomplete and one had a residual medullary cyst. Of the 15 patients with adequate follow-up, 12 had been able to return to a pre-injury level of activity by five to 12 months.

Since the first description of stress fracture of the tarsal navicular (Towne, Blazina and Cozen 1970), there have been few reports, though several authors have considered that the fracture is under-diagnosed (Goergen et al. 1981; Hunter 1981; Fitch 1982; Torg et al. 1982) and the pitfalls of the radiographic diagnosis have been well described (Pavlov, Torg and Freiberger 1983). Fractures occur in the sagittal plane, usually within the central third of the bone (Torg et al. 1982) and start on the dorsal proximal articular border. Unlike most other stress fractures of the leg which are more commonly seen in athletes in endurance events, navicular stress fractures occur in explosive athletic activities which involve sprinting, jumping and hurdling. Excessive stress in a foot biomechanically unsuited to these activities may be a causative factor.

The initial treatment of tarsal navicular stress fracture is the conventional management of stress-related bone injuries by avoiding the causative stresses, rest with or without a cast, pain control, and the correction of any biomechanical factors. Fitness is maintained by non-weight-bearing aerobic and anaerobic activities.

Even with such managements we have found that navicular stress fractures tend to heal slowly, may proceed to non-union, extend or become complete, and may recur. The uncertainty of conservative management and the length of time before healing can be anticipated are often unacceptable to an athlete whose sporting career is in jeopardy. For the last five years of this study, computerised tomography (CT) has allowed us to assess the progress of incomplete fractures. These often become rapidly asymptomatic and remain so only until the athlete resumes full training. CT has confirmed the unpredictability of healing of these fractures.

Because of this we have adopted a more positive approach to these fractures, and tried to accelerate and augment healing by using autologous bone grafts in the following situations:
1. complete or comminuted fractures,
2. incomplete fractures which extend to become complete or almost complete,
3. incomplete fractures with delayed or non-union as demonstrated by marginal sclerosis,
4. the presence of a medullary cyst,
5. incomplete fractures which do not heal in a non-weight-bearing plaster.

In elite athletes, CT evidence of a fracture extending across half the navicular has been an indication to consider operation. The athlete is offered a definitive plan of treatment which can give a high rate of success and an early return to sport.

Surgical management has been previously reported for only six fractures. Towne et al. (1970) treated a complete fracture with an autologous bone graft supplemented by a staple, but had to remove the staple eight months later. Of the 21 stress fractures in 19 patients reviewed by Torg et al. (1982) three were treated...
surgically, including one previously reported by Hunter (1981). One acutely displaced fracture was reduced and fixed internally with two screws and two un-united fractures were managed by autologous bone grafting, one with the addition of internal fixation. All three had excellent results. This is in marked contrast to three other patients from the same series who had prolonged conservative management for undisplaced incomplete fractures and were still significantly restricted in their physical activity after 16, 24 and 30 months. A recent study from Finland reported good results in a high jumper with a displaced fracture who was treated with two compression screws and in a runner after cancellous bone grafting (Hulkko et al. 1985).

We now report the results of bone grafting in the management of 19 stress fractures of the tarsal navicular in 18 patients, with emphasis upon the delayed union or non-union of incomplete fractures.

**PATIENTS AND METHODS**

From 1971 to 1986, we treated 34 patients with 37 stress fractures of the tarsal navicular. Of the three athletes with bilateral fractures, two required operation; one for both fractures, the other for one fracture.

Thirteen athletes, including one with bilateral fractures, recovered with either plaster immobilisation or rest from stress with continued weight-bearing. They resumed sport after an average of 10 months (range 3 to 32 months). Two fractures have not yet healed, including one patient who has rejected an offer of surgery.

The remaining 18 patients, one with bilateral fractures, all had surgical treatment, either because of failure of conservative treatment, or because of continued pain and disability on activity with radiological evidence of non-union. One fracture required two operations and one was later treated elsewhere by grafting and had a good result.

The results of operation have been evaluated in 15 patients with an average follow-up of 42 months (range 15 to 66 months), three patients with less than six months follow-up having been excluded from this final assessment.

**Clinical features.** The mean age of the 18 patients at time of injury was 21.9 years (range 14 to 45 years) and only four were female (Table I). A wide range of sports was involved, but all included sprinting, jumping or hurdling, and a navicular stress fracture in an endurance competitor was seen only with speed training or with a running gait which used a forefoot footstrike. In jumpers and hurdlers, the take-off leg was always the site of fracture.

![Fig. 1](image1.jpg)

Case 16 - Radionuclide bone scan showing bilateral acute stress fractures in a 15-year-old female sprinter.

![Fig. 2](image2.jpg)

![Fig. 3](image3.jpg)

Figure 2 - Despite a positive radionuclide bone scan and a classical clinical picture, this fracture was repeatedly missed on radiographs until the beam traversed the fracture line after positioning under fluoroscopic control. Figure 3 - Tomogram of a complete fracture in a 16-year-old Australian footballer.

Onset of symptoms was most commonly insidious, with tarsal pain after sprinting or jumping, often associated with a temporary limp and occasionally with significant pain and difficulty on simple weight-bearing. Usually there was rapid improvement within days; return to jogging and slow running was often possible within a week. However, symptoms recurred on resumption of more strenuous activities. Complete fractures produced greater and more prolonged incapacity than incomplete fractures.

On examination, there was point tenderness over the lateral half of the navicular, with pain or inability to hop in the equinus position. We found no correlation with any particular type of foot: fractures were seen in

THE JOURNAL OF BONE AND JOINT SURGERY
patients with mild cavus deformity, normal longitudinal arches and mildly or moderately pronated forefeet.

**Investigations.** Radionuclide bone scanning, using technetium$^{99}$m methylene diphosphonate, has been useful in assessing acute fractures and chronic incomplete fractures exacerbated by athletic activity (Fig. 1). Radiography was diagnostic in major fractures and helped to evaluate the type of foot and other possible antecedent causes. The need for true anatomical anteroposterior views to demonstrate the fracture (Pavlov et al. 1983) needs emphasis (Fig. 2). In our earlier patients tomography was valuable in detecting incomplete fractures or providing additional information on the extent of complete fractures (Fig. 3), but the advent of CT scanning has superseded conventional tomography and is now the most valuable aid in diagnosis and assessment of progress. Examples of this are the demonstration of sclerosis around an incomplete fracture (Fig. 4); of a medullary cyst which is one end result of a navicular stress fracture (Fig. 5); and the extension and aggravation of a fracture in an athlete who had continued sport against medical advice (Fig. 6). Only rarely have postoperative CT scans been indicated or performed.

**Operation.** Through a dorsal transverse incision, the navicular is exposed lateral to the neurovascular bundle. Unless there is wide separation of a complete fracture, the site is difficult to visualise because the dorsal surface of the bone is rarely disrupted. It is frequently necessary to open the talonavicular joint and separate the surfaces by traction. The fracture site is, however, almost always at the junction of the lateral one-third and medial two-thirds of the navicular, and is inclined plantarwards and medially.

A gutter is cut from the dorsal surface to the full depth of the fracture, using a sharp osteotome; this is preferred to a burr because of better appreciation of bone texture. A corticocancellous graft from the iliac crest is then fitted into the defect and the proximal subcortical surface is filled with bone chips. Early experience made it clear that no movement took place at the fracture site and that the use of a compression screw would not help.

After operation cast immobilisation has not been used, but non-weight-bearing is recommended for three to four weeks and running is forbidden for three months. After a gradual return to training and sport, most patients resumed full activity six months after the operation.

**Pathology.** Specimens were obtained from 12 patients. The resected bone was a rectangular block from eight patients and multiple bone chips from four, and was decalcified and stained with haematoxylin and eosin, Masson's trichrome and Perl's stain for iron. From one case, half the specimen was processed undecalcified to demonstrate osteoid seams.

A macroscopic lesion was visible in most en-bloc specimens, and convincing pathological changes were

![Figure 4](image1)

![Figure 5](image2)

![Figure 6](image3)

**Figures 4–6** Case 17. CT scan of a 16-year-old National Junior 800 metre title holder, showing an incomplete fracture with surrounding sclerosis. This fracture could not be demonstrated by standard radiographs. Figure 5 – Case 6. A well-defined central cyst is seen in the right navicular of a footballer who did not present for 12 months after developing typical symptoms. No fracture line was visible in the scan; this had presumably healed. Figure 6 – Case 15. The CT scan of a professional tennis player shows destruction of the lateral third of the navicular, a consequence of continuing to play intermittently for nine months despite some pain.
Pattern C (two cases). There was a degenerative cyst containing poorly cellular fibrous tissue (Fig. 8). The adjacent buffer zone consisted of a thin osteosclerotic layer with broad trabeculae of lamellar bone, some lined by plump osteoblasts. The marrow was composed of loose fibrous tissue containing dilated thin walled vessels.

RESULTS

Of the 15 patients assessed for a final result, 12 (80%) were asymptomatic; they had been able to resume a pre-injury level of activity between five and 12 months after operation (mean eight months). One patient who had obtained no initial benefit from surgery, subsequently had two further bone grafts at another centre. He now runs 30 to 40 km a week, but has not regained his pre-injury fitness or ability. One patient, the oldest in the series, with bilateral fractures, has achieved a reasonable result but has retired from his sport. One patient with excessive destruction of the lateral part of the navicular (see Fig. 6) has resumed tennis but not at pre-injury level.

DISCUSSION

Stress fractures of the tarsal navicular have important differences from other stress fractures of the lower limb, which are mostly seen in endurance runners. Navicular fractures may present either with acute displacement or more commonly as an incomplete fracture which may later extend or become complete. Many patients with an incomplete fracture are able to continue to jog or run provided that the forefoot is not used in footstrike. Sprinting and jumping, however, are typically followed by the classical pain and incapacity seen after other stress fractures.

Navicular fractures, unlike other stress fractures, do not seem to follow a sudden increase in the frequency, intensity or duration of training, which may indicate that different biomechanical factors are important. The consistent site of the fracture in the lateral half of the bone appears to correspond with the plane of maximum shear stress, especially during plantar flexion combined with pronation (Fig. 9).

A relatively short first metatarsal or long second metatarsal were common findings in both our series and that of Pavlov et al. (1983). This anatomical variation would tend to accentuate shear stress because of the
Table 1. Details and results in 18 patients, all treated by autologous cortico-cancellous grafting

<table>
<thead>
<tr>
<th>Sex and age</th>
<th>Side</th>
<th>Sport and level of activity</th>
<th>Onset to diagnosis (months)</th>
<th>Investigations</th>
<th>Level of activity</th>
<th>Method and period of conservative management (months)</th>
<th>Results of conservative treatment</th>
<th>Period from diagnosis to operation (months)</th>
<th>Pathology pattern (see text)</th>
<th>Length of follow-up (months)</th>
<th>Final result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>M22</td>
<td>R</td>
<td>Long jumper National 5 km</td>
<td>0</td>
<td>None Pos None None</td>
<td>Complete slight separation</td>
<td>NWB*</td>
<td>Cost NWB 2</td>
<td>Walking pain free, running caused pain Osteopenia and medullary cyst Medullary cyst persisted</td>
<td>Nil</td>
<td>12</td>
</tr>
<tr>
<td>1b</td>
<td>R</td>
<td>Able to sprint 10.5 sec 100m</td>
<td>Pos Pos None Pos</td>
<td>L-transected medullary fracture with sclerotic margins, proximal articular border intact</td>
<td>Complete with separation</td>
<td>NWB*</td>
<td>Cost NWB 2</td>
<td>Walking pain free, running caused pain</td>
<td>Nil</td>
<td>36</td>
<td>Minor changes</td>
</tr>
<tr>
<td>2</td>
<td>M16</td>
<td>R</td>
<td>Australian footballer Flute major</td>
<td>2</td>
<td>None Pos None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 5</td>
<td>No functional or radiological change</td>
<td>Nil</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>M21</td>
<td>L</td>
<td>Australian footballer Sette-professional</td>
<td>2</td>
<td>None Pos None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 5</td>
<td>No functional or radiological change</td>
<td>Nil</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>M31</td>
<td>L</td>
<td>Marathon 2h 20min Occurred during speed training</td>
<td>12</td>
<td>None Pos None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 7</td>
<td>Functionally unchanged, non-union medullary cyst</td>
<td>Nil</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>M33</td>
<td>R</td>
<td>Squash A grade</td>
<td>4</td>
<td>None Pos Pos None</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 5</td>
<td>No functional or radiological change</td>
<td>Nil</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>M25</td>
<td>R</td>
<td>Australian footballer</td>
<td>12</td>
<td>None Pos None Pos</td>
<td>Medullary cyst</td>
<td>NWB*</td>
<td>Cost NWB 3</td>
<td>No functional or radiological change</td>
<td>Nil</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>F15</td>
<td>L</td>
<td>100m hurdler Flute major</td>
<td>0</td>
<td>Pos Pos None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 5</td>
<td>Functionally unchanged, non-union</td>
<td>Nil</td>
<td>27</td>
</tr>
<tr>
<td>8</td>
<td>M23</td>
<td>L</td>
<td>National class country and 100m Steeplechase Park after track work</td>
<td>1</td>
<td>Pos Neg Neg Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 5</td>
<td>Functionally unchanged</td>
<td>Nil</td>
<td>24</td>
</tr>
<tr>
<td>9</td>
<td>M23</td>
<td>R</td>
<td>Australian footballer</td>
<td>24</td>
<td>None Pos Pos None</td>
<td>Complete widely separated with central cyst</td>
<td>NWB*</td>
<td>Cost NWB 10</td>
<td>Functionally unchanged</td>
<td>Nil</td>
<td>11</td>
</tr>
<tr>
<td>10</td>
<td>F16</td>
<td>I</td>
<td>Hepatologist</td>
<td>1</td>
<td>Pos Pos None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 10</td>
<td>Functionally unchanged</td>
<td>Nil</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>F16</td>
<td>R</td>
<td>100m hurdler, National junior member &amp; track work</td>
<td>4</td>
<td>None Pos None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 9</td>
<td>Functionally and radiologically unchanged</td>
<td>Nil</td>
<td>9</td>
</tr>
<tr>
<td>12</td>
<td>M45</td>
<td>R</td>
<td>Veteran field hockey player</td>
<td>0</td>
<td>None Pos None Pos</td>
<td>Left complete with slight separation Right almost complete dorsal spurting dorsal</td>
<td>NWB*</td>
<td>Cost NWB 2</td>
<td>Functionally unchanged</td>
<td>Nil</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>M18</td>
<td>R</td>
<td>Australian footballer</td>
<td>0</td>
<td>Pos Neg None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 12</td>
<td>Functionally unchanged</td>
<td>Nil</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>M14</td>
<td>L</td>
<td>Australian footballer, sprinter, high and long jumper</td>
<td>24</td>
<td>Pos Neg None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 1</td>
<td>Continued to play tennis. Finally unable to walk without stick, fracture comminuted</td>
<td>Nil</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>M18</td>
<td>R</td>
<td>Tennis professional</td>
<td>6</td>
<td>Pos Pos None Pos</td>
<td>Complete with large medullary cavity and two lateral fragments</td>
<td>NWB*</td>
<td>Cost NWB 1</td>
<td>Continued to play tennis. Finally unable to walk without stick, fracture comminuted</td>
<td>Nil</td>
<td>5</td>
</tr>
<tr>
<td>16</td>
<td>F15</td>
<td>L</td>
<td>100m sprinter Flute major</td>
<td>0</td>
<td>Pos Neg None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 12</td>
<td>Functionally unchanged</td>
<td>Nil</td>
<td>27</td>
</tr>
<tr>
<td>17</td>
<td>M16</td>
<td>R</td>
<td>800m National age champion</td>
<td>0</td>
<td>Pos Neg None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 12</td>
<td>Functionally unchanged</td>
<td>Nil</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>M24</td>
<td>L</td>
<td>100m State champion</td>
<td>2</td>
<td>None Pos None Pos</td>
<td>Incomplete dorsal proximal articular border</td>
<td>NWB*</td>
<td>Cost NWB 12</td>
<td>Functionally unchanged</td>
<td>Nil</td>
<td>2</td>
</tr>
</tbody>
</table>

* NWB non-weight bearing, WBR Weight-bearing test
greater force being transmitted through the second metatarsal and the intermediate cuneiform. Shear stress would be further increased by metatarsal adduction and pronation during weight-bearing and lift off. For this reason patients with recent fractures may benefit from the provision of a custom-made neutral orthosis.

Since most stress fractures of the lower limbs in healthy young athletes usually heal (Stanitski, McMaster and Scranton 1978) it is necessary to examine the factors involved in the poor healing of the tarsal navicular. In the absence of any metabolic or systemic disorder, only poor vascularity and faulty immobilisation seems to be important. Microangiographic studies in fresh cadavers have shown that the central one-third of the navicular is relatively avascular, and the common site of fracture appears to correspond to this area of poor vascularity (Torg et al. 1982).

Our 12 histological specimens came from patients with from 4 to 36 months of symptoms before surgery (mean 13 months), so all were examples of delayed or non-union. Fibrous tissue and cartilage survive and grow better than bone in a poorly oxygenated environment; these tissues predominate where vascularity is poor, either originally or as a result of excessive mobility. Review of our histological findings confirmed that in the eight patients with Patterns A or B, fibrocartilage predominated. Evidence of active bone remodelling was seen in most of these specimens and appeared to correlate with continued weight-bearing prior to surgery.

One long-term result is a pseudarthrosis and an attempt to form a synovial lining (Collins 1966); this was the trend in both Pattern C specimens. These patients had radiographic symptoms for more than 12 months, and had tried to continue their sport. But only one of these patients had a complete fracture which would allow excessive mobility, and an incomplete dorsal fracture could hardly be compatible with the movement necessary to produce pseudarthrosis.

The need to extend surgical guttering to the most distal part of the fracture was demonstrated in Case 1. After the first operation he was improved and able to sprint at a national level, but symptoms persisted and CT scans showed the persistence of a deep medullary cyst; this became asymptomatic only after a second graft had been inserted into the cystic region.

The failure to heed symptoms and continue sport had unfortunate results in Cases 13 and 15. In the latter patient, gross destruction of the lateral half of the navicular was seen at operation, with major disruption of the articular cartilage of the talonavicular joint.

Uncertainty about the result of conservative management was shown in Cases 7 and 16. Both were seen early and had positive bone scans. Acute symptoms settled rapidly, and both patients appeared to have healed on return to athletics. In Case 16, serial CT scans showed that bilateral incomplete fractures which had not extended far into the medulla had virtually healed. Despite a gradual return to training and competition, refracture necessitated bone grafting 27 months after the first injury.

Many of our patients were not treated initially by prolonged periods of non-weight-bearing in a cast. This was because of the uncertain results in early patients who were treated in this manner, the rapid loss of acute symptoms (often before presentation) and the healing of fractures, albeit slowly, in patients who were treated by relative rest with normal weight-bearing. In association with the probable aetiological factors of avascularity and mobility, these findings are parallel with those for traumatic fractures of the carpal navicular (Cooney, Dobyns and Linscheid 1980).

Autologous bone grafting has been demonstrated to be an effective method of management, but non-weight-bearing cast immobilisation for six to eight weeks has been shown to be successful for incomplete fractures (Torg et al. 1982). After reviewing these results, we now treat recent fractures with eight to 10 weeks of non-weight-bearing in a cast, but we still encounter examples of delayed union or non-union. Although we have had no experience, electrical bone stimulation using surface electrodes has produced promising results (J. Taunton, personal communication), and implanted electrodes could be used (Connolly 1981). We still consider that an autologous bone graft is the treatment of choice for complete fracture and those which develop a medullary cyst.

The authors wish to thank Mr Philip Noble (now at the Methodist Hospital, Houston, Texas) for his contribution to the biomechanical aspects of this study, and Mr Alan Skirving, of the Department of Orthopaedic Surgery, University of Western Australia for reviewing the manuscript.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES