INJURIES OF THE TARSO-METATARSAL JOINTS

Etiology, Classification and Results of Treatment

D. W. WILSON, LONDON, ENGLAND

From the Royal Free Hospital, London

Dislocations of the tarso-metatarsal joints are uncommon. Twenty-two injured feet of twenty patients treated at five centres have been reviewed and dissections of cadaveric feet have been done to study the possible mechanisms of injury.

CLASSIFICATION

Analysis of the clinical cases (Figs. 1 to 27) suggested that the injuries could be classified into five types (Table 1). This classification was confirmed by experiment (Figs. 28 to 40).

A review of sixty radiographs previously published showed that all but three could be classified within this scheme. Cases 15 and 17 in the present series are not typical, but a reasonable approximation could be found (Figs. 16 and 18). The fifth group of plantar-flexion injuries may escape detection unless the radiographs are studied closely (Figs. 26 and 27).

Quénu and Küss (1909) pointed out that the medial cuneiform and navicular bones and the talus form parts of the same anatomical column as the first metatarsal bone. Displacement of the latter with all or part of the former (Fig. 18, Case 17) represents the same basic injury as dislocation of the first metatarsal bone alone. Similarly, on the lateral border of the foot, fractures of the cuboid bone (Figs. 1, 5, 11 and 12; Cases 1, 5, 11 and 12 (right)) could be included with first or second degree supination and second degree pronation injuries.

Fracture of the proximal metatarsal shafts could replace dislocation of its base (Figs. 9 and 10, Cases 9 and 10). Chip fractures of the metatarsal and tarsal bones were common (82 per cent). The distinction between pure dislocation and fracture-dislocation is not fundamental.

First and second metatarsal diastasis, stressed by Quénu and Küss (1909), is only a stage in both inversion and eversion injuries and is not important in classification, although it may have a bearing on injury to the dorsalis pedis vessels.

EXPERIMENTS ON MECHANISM OF INJURY

The anatomy of the region has been well described elsewhere (Collett, Hood and Andrews 1958; Jeffreys 1963; Wiley 1971).

Experiments were done on eleven preserved feet, each cleared down to the intact tarso-metatarsal region. Manual strains were applied to the forefoot while the hindfoot was held fixed. Mechanical force was used only in crushing experiments. Jeffreys (1963) has shown that inversion and evasion forces cause different dislocations.

Inversion—Forced inversion of the forefoot ultimately caused dorsolateral dislocation of all five metatarsal bones, as Jeffreys (1963) described, but in two stages. Dorsolateral dislocation of the four lesser bones took place first, beginning laterally and progressing medially. Little displacement of the lateral three metatarsal bones was seen until after the second had given way (Figs. 28 and 29). With further force, dorsolateral dislocation of the first metatarsal was added (Fig. 30).

Eversion—Forcible eversion of the forefoot caused medial dislocation of the first metatarsal (Figs. 31 and 32) at first, but with further eversion, dorsolateral subluxation or fracture of the shafts of the lesser metatarsal bones occurred, starting laterally (Figs. 33 and 34).
Plantar-flexion—Forced plantar-flexion without rotation produced variable results. Three feet showed merely dorsal gaping of the tarso-metatarsal joints, which hinged on the plantar tissues without true dislocation. In one foot, initial rupture of the dorsal ligaments of the second and third joints was followed by a coronal fracture of the base of the first metatarsal bone (Figs. 35 and 36). Further strain displaced the bases of the second and third metatarsal bones dorsally followed by the lateral two (Fig. 37). There was no lateral shift of the bones. The distal fragment of the first metatarsal bone trapped the dissected dorsalis pedis artery on the cuneiform. This was the only dissection showing any obvious vascular involvement.

With another foot, the first lesion was a dorsal subluxation of the second metatarsal bone alone (Fig. 38). Further force then displaced the remainder (Figs. 39 and 40). Chip fractures from the tarsal and metatarsal bones were invariable in all the dissections.

Figs. 1 to 11
Figure 1—Case 1. An S.1 injury to the right foot which was trapped under a girder and the patient fell backwards. Figure 2—Case 2. An S.1 injury to the right foot in a road traffic accident (motor-cycle) details unknown. Figure 3—Case 3. An S.1 injury to the right foot in a road traffic accident to a front seat passenger, car. The foot was in plantar-flexion on sloping floor. Figure 4—Case 4. An S.1 injury to the left foot caused by falling at tennis and sitting on the inverted foot. Figure 5—Case 5. An S.1 injury to the left foot in a road traffic accident (motor-cycle) details unknown. Figure 6—Case 6. An S.2 injury to the right foot from falling downstairs. Figure 7—Case 7. An S.2 injury to the left foot in a road traffic accident (motor-cycle) details unknown. Figure 8—Case 8. An S.2 injury to the right foot in a road traffic accident to a front seat passenger, car. The foot was in plantar-flexion on sloping floor with pressure on the toes. Figure 9—Case 9. An S.2 injury to the right foot to a pedestrian in a road traffic accident. Figure 10—Case 10. An S.2 injury to the right foot in a road traffic accident on a motor-cycle, details unknown. Figure 11—Case 11. An S.2 injury to the left foot in a road traffic accident to a front seat passenger, car.
Dorsiflexion—Attempts to produce dislocation by strong dorsiflexion of the forefoot were unsuccessful.

Crushing force—Two feet were crushed in a vice, with dorsi-plantar compression between a board beneath the sole (representing the ground) and a jaw of the vice on the dorsum of the

tarsus. Bones were splintered, joints sprung open and the arch flattened completely, but no true dislocation was seen. When released the bones returned to their original positions.

Side-to-side compression of another specimen in the vice produced multiple fractures but again no dislocation, and in particular no dorsal extrusion of the second metatarsal base in the way that a fruit pip is squeezed between the fingers ("mécanisme du noyau de cerise", Quéné and Küss 1909a).
DISCUSSION ON ETIOLOGY

In this series, road accidents accounted for 64 per cent of the injuries. Clear histories obtained from nine patients suggested that the usual mechanism was one of forced plantar-flexion and rotation. Occasionally, forcible plantar-flexion alone may have been responsible (Fig. 22, Case 20).

Most authors have agreed that the foot must be in plantar-flexion at the time of injury (Quénu and Küss 1909a, Aitken and Poulson 1963, Wiley 1971). In dorsiflexion, strains fall on the ankle (Lauge-Hansen 1950). Forced plantar-flexion can occur in three ways: by longitudinal compression (Ashhurst 1926, Aitken and Poulson 1963, Wiley 1971), by backward
TABLE I
CLASSIFICATION AND INCIDENCE OF EACH TYPE

<table>
<thead>
<tr>
<th>Type</th>
<th>Typical displacement</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forefoot inversion (pronation)</td>
<td>Medial dislocation of first metatarsal bone alone</td>
<td>4 18</td>
</tr>
<tr>
<td>First stage P.1</td>
<td>Medial dislocation of first metatarsal bone and</td>
<td></td>
</tr>
<tr>
<td>Second stage P.2</td>
<td>dorsilateral dislocation of the four lesser metatarsal</td>
<td>2 9</td>
</tr>
<tr>
<td>Forefoot inversion (supination)</td>
<td>Dorsal dislocation of up to four lesser metatarsal bones</td>
<td>5 23</td>
</tr>
<tr>
<td>First stage S.1</td>
<td>Dorsilateral dislocation of all five metatarsal bones</td>
<td>7 32</td>
</tr>
<tr>
<td>Second stage S.2</td>
<td>Dorsal subluxation of base of second metatarsal and/or</td>
<td></td>
</tr>
<tr>
<td>Plantar-flexion alone</td>
<td>coronal fracture-dislocation of base of first metatarsal</td>
<td>4 18</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>22 100</td>
</tr>
</tbody>
</table>

falls with the forefoot entrapped and by falls on to the point of the toes. In simulating falls
down stairs and from capsizing stools, when the plantar-flexed leading foot met the ground,
it often rolled on to the dorsum of the toes (Chavasse 1884), increasing the plantar-flexion
still more. Plantar-flexion strains probably cause the isolated subluxation of the second
metatarsal (Novotny 1953) seen thrice in this series (Figs. 19, 20 and 22; Cases 18, 19 (right) and 20).

Fig. 28
Diagrams showing an experimental foot subjected to forcible forefoot inversion (supination). Rupture of the
dorsal ligaments of the cubo-metatarsal joints has occurred (1 in Fig. 28), followed by subluxation of the fifth
metatarsal bone, fourth metatarsal bone and the third metatarsal bone (2 in Fig. 28). There is then rupture of
the dorsal ligament of the intermediate cuneiform metatarsal joint (3 in Fig. 29) and a dorsilateral dislocation
of all the lesser metatarsal bones (4 in Fig. 29). Finally there is dorsilateral dislocation of the first metatarsal
bone with its base rotated away from the medial cuneiform (5 in Fig. 30).

In car accidents people in front seats have their feet fixed in plantar-flexion on the sloping
floor (Aitken and Poulson 1963, Wiley 1971) and are vulnerable so far as these injuries are
concerned.

Pure abduction strain has been incriminated (Collett et al. 1958, Wiley 1971), but this
cannot account for all the patterns of injury found, particularly medial dislocation of the first
metatarsal bone (seen in pronation injuries), or sparing of this bone (as in first degree
supination injuries). In contrast, quite minor rotational force easily produces all the typical
patterns of dislocation seen clinically (Easton 1938, Gissane 1951, Novotny 1953, del Sel 1955,
Jeffreys 1963).
Diagrams showing an experimental foot subjected to forcible forefoot eversion (pronation). Figure 31 is a diagram showing how the rotatory medial displacement of the first metatarsal bone occurs. The sequence of the joint injuries is first a medial dislocation of the first metatarsal bone (1 in Fig. 32) then subluxation of the fifth metatarsal bone and fourth metatarsal bone (2 in Fig. 33) and finally fracture of proximal shafts of the third metatarsal bone and the second metatarsal bone (3 in Fig. 34). Dorsilateral dislocation of the fifth metatarsal bone and the fourth metatarsal bone was now possible.

Diagrams showing an experimental foot subjected to forcible plantar-flexion. There has been rupture of the dorsal ligaments of the intermediate and lateral cuneiform metatarsal joints (1 in Fig. 35) followed by a coronal fracture of the first metatarsal bone (2 in Fig. 35). The lateral view shows the coronal slice fracture of the base of the first metatarsal bone, extending into the joint, with dorsal displacement of the shaft fragment (2 in Fig. 36). There was later dorsal subluxation of the second metatarsal bone and the third metatarsal bone and of the other lesser metatarsal bones (3 and 4 in Fig. 37).

Diagrams showing an experimental foot that was subjected to forcible plantar-flexion. There was dorsal subluxation of the second metatarsal bone (1 in Fig. 38), followed by dorsal subluxation of the medial cuneiform, the first metatarsal bone and the third metatarsal bone (2 in Fig. 39) and later by a fracture of the proximal shaft of the fifth metatarsal bone and dorsal subluxation of the fourth metatarsal bone (3 and 4 in Fig. 40).
Injuries of the Tarso-Metatarsal Joints

In Case 12 of this series (Figs. 12 and 13) the different dislocation in each foot suggests that the trunk was thrown to one side, rotating the feet in opposite directions.

Pure crushing was seen in only one instance (Fig. 19, Case 18). It is suggested that, to sustain dislocation in the crushed foot, some element of rotation or hyperplantar-flexion is also needed. This is added only if the patient’s body falls to the ground (Fig. 43).

TREATMENT

The definitive methods of treatment adopted and the results are shown in Table II. The numbers were small and full details were not available for each factor considered, but some conclusions could be drawn.

Quality of reduction—The quality of the reduction was assessed from radiographs of twenty feet immediately after definitive treatment. Two had had no significant initial displacement (Cases 18 and 19 (left)) and were excluded from analysis. Four of the eighteen feet remaining had been subjected to operation (Fig. 41), and in three reduction was anatomical or nearly so. Of fourteen feet treated conservatively, in only one was anatomical reduction obtained: in seven there was residual displacement of five millimetres or more.

Pain—If residual pain was complained of, it was assessed as slight or moderate. No patient complained of severe pain. Of four feet treated by operation, three were painless and the other had only slight pain. Of fifteen feet treated conservatively, only two were free from pain and five caused moderate pain. Of six feet with anatomical reduction, four caused no pain but two gave slight pain. Of six feet with marked residual displacement (5 millimetres or more), five caused moderate pain.
TABLE II
RESULTS OF TREATMENT

<table>
<thead>
<tr>
<th>Final treatment adopted</th>
<th>None</th>
<th>Plaster cast only</th>
<th>Manipulation and plaster</th>
<th>Soft-tissue closure</th>
<th>Open reduction</th>
<th>Metatarsals not fixed</th>
<th>Metatarsals fixed internally</th>
<th>Totals</th>
<th>Number of feet reviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiological reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anatomical or &lt; 2 millimetres</td>
<td>2+</td>
<td>1</td>
<td>1</td>
<td></td>
<td>2</td>
<td>6</td>
<td></td>
<td></td>
<td>20*</td>
</tr>
<tr>
<td>Residual displacement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 to 4 millimetres</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 to 10 millimetres</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 10 millimetres</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1+</td>
<td>1</td>
<td>1</td>
<td></td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Slight</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Slight</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11</td>
</tr>
<tr>
<td>Marked</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Deformity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>2+</td>
<td>2</td>
<td>1</td>
<td></td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Slight Valgus</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Slight Cavus</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Marked Valgus</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Marked Cavus</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Bony bosses</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td></td>
<td>2</td>
<td>13</td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Movement Foot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over half</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>Half or less</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metatarsophalangeal joint</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over half</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>Toes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half or less</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>10</td>
<td>1</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>22</td>
</tr>
</tbody>
</table>

* The radiographs of two feet after operation were not available for review.
† Case 19 (left) had no displacement.
‡ Case 18 had less then 2 millimetres displacement which was left unreduced.
§ Case 14 had a pre-existing bilateral pes cavus which remained unchanged.

THE JOURNAL OF BONE AND JOINT SURGERY
Deformity—Deformity was graded into slight (six feet) or marked (four feet). Valgus deformity, seen in six feet, was associated with the supination (four feet) or plantar-flexion (two feet) types of injury. Cavus deformity (four feet) followed pronation type injuries in two feet. No foot treated by operation was more than slightly misshapen. All four feet with marked deformity had been managed conservatively, two with manipulation. However, the remaining eight feet in this group were of normal shape or had only slight deformity.

Of five feet with poor reduction (5 millimetres or more displacement), four had marked deformity. With no more than 4 millimetres of residual displacement, a normal shape resulted in four feet, or only slight deformity in five feet. Three of the four patients with badly misshapen feet had to change their occupations and to give up active hobbies and sports because of their feet.

Thirteen of fifteen feet seen personally showed bony bosses around joints, representing either residual bony displacements or osteophytes.

Stiffness—Stiffness was found in all but two feet reviewed. Of thirteen feet, six had half or less of the normal tarsal movement. The quality of reduction influenced this stiffness but the treatment by which it was obtained did not. Of five feet with more than 5 millimetres residual displacement, four had less than half the normal tarsal movement, whereas of seven feet with no more than 4 millimetres of displacement only two were as stiff. Also, stiffness of the metatarso-phalangeal joints of the toes often occurred, eight of thirteen feet having half or less of the normal range of movement in the great toe. Again, this was related to quality of reduction. Among five feet with 5 millimetres or more displacement four had half or less of normal movement, while of six feet with better reduction than this, only two were as stiff.

Limp—Limp was noted in twelve of sixteen patients. There was no correlation with either pain or stiffness. No patient used a stick.

Degenerative arthritis—Degenerative joint changes were always present in radiographs taken some time after the accident. Even cases with anatomical reduction by operation were not exempt (Fig. 42).

Conclusions—In general, the least active conservative treatment gave poor reduction and consequent pain. Successful reduction by manipulation or operation with anatomical or good position on radiographs, gave more comfortable, better shaped feet. This agrees with the results of Granberry and Lipscomb (1962). If open reduction is undertaken, transfixion of the replaced joints with Kirschner wires (del Sel 1955, English 1964) is simple and effective (Fig. 41). The wires are removed after six weeks, and before the patient bears weight on the foot. Bony bosses, minor joint stiffness and late degenerative changes were almost universal.

VASCULAR COMPLICATIONS

Gissane (1951) emphasised the risk of arterial damage in these injuries when the space between the first and second metatarsal bones was involved. Three patients in this series had impaired circulation to the toes. The patient in Case 1, with a compound first degree supination injury, suffered gangrene of the little toe, probably from severe local trauma to the lateral aspect of the foot. At review the dorsalis pedis pulsation was preserved. In Cases 17 (second degree pronation) and 20 (plantar-flexion), toe ischaemia was followed by spontaneous recovery but the first intermetatarsal space had been deranged and the dorsalis pedis pulse was permanently lost.

SUMMARY

1. Twenty-two feet injured at the tarso-metatarsal level are reviewed.
2. Experiments with eleven cadaveric feet are reported.
3. The injuries are caused by forced plantar-flexion combined with rotation in most cases. Crushing of the foot alone often does not produce dislocation.
4. A classification is suggested.
5. The results of various treatments in this small series are presented. It is concluded that anatomical reduction is important, achieved if necessary by operation and internal fixation.
I am indebted to the following surgeons for permission to quote their cases and for their considerable help and encouragement: Mr. A. Benjamin and Mr. K. I. Nissen (Watford General Hospital), Mr. A. S. Dawson (Queen Elizabeth II Hospital, Welwyn), Mr. C. Gray and Mr. J. C. R. Hindenach (Royal Free Group of Hospitals, London), Mr. W. Herschel and Mr. R. H. Maudsley (Heatherwood Hospital, Ascot), Mr. D. Walker and Mr. F. G. Ward (Ashford Hospital, Middlesex). I am grateful to Professor R. Bowden (Royal Free Hospital Medical School) for access to the material for dissection, and to the Department of Clinical Photography (Royal Free Hospital) for the illustrations.

REFERENCES


