We reviewed 116 patients who underwent 118 arthroscopic ankle arthrodeses. The mean age at operation was 57 years, 2 months (20 to 86 years). The indication for operation was post-traumatic osteoarthritis in 67, primary osteoarthritis in 36, inflammatory arthropathy in 13 and avascular necrosis in two. The mean follow-up was 65 months (18 to 144). Nine patients (10 ankles) died before final review and three were lost to follow-up, leaving 104 patients (105 ankles) who were assessed by a standard telephone interview. The pre-operative talocrural deformity was between 22˚ valgus and 28˚ varus, 94 cases were within 10˚ varus/valgus. The mean time to union was 12 weeks (6 to 20). Nonunion occurred in nine cases (7.6%). Other complications included 22 cases requiring removal of a screw for prominence, three superficial infections, two deep vein thromboses/pulmonary emboli, one revision of fixation, one stress fracture and one deep infection. Six patients had a subtalar fusion at a mean of 48 months after ankle fusion. There were 48 patients with excellent, 35 with good, 10 with fair and 11 with poor clinical results.

Open ankle arthrodesis has been the standard surgical treatment for end-stage ankle arthritis for many years. Since the first description in 1983, arthroscopic ankle arthrodesis has gained in popularity due to increased experience and improved instrumentation. The rate of fusion between the two techniques is comparable, but the arthroscopic method is thought to have a faster time to union, less blood loss, less morbidity, shorter hospital stays and more rapid mobilisation.¹ ² ³ ⁴ The arthroscopic technique also allows fusion in patients with both poor skin and wound healing potential which would previously have been a contraindication to the open technique. Despite the advantages, the technique has been seen as an in situ fusion, with the limitation that it is not possible to correct any significant deformity.

Accelerated osteoarthritic change has been identified following ankle arthrodesis, especially affecting the subtalar joint.⁵ ⁶ ⁷ ⁸ Advances are being made with ankle replacement and the results are improving. Nevertheless at the present time, fusion is accepted as the treatment of choice in young patients and those with high levels of activity. We have analysed the mid- to long-term results of a series by a single surgeon (IGW) to identify the operative indications, optimal post-operative management and reasons for dissatisfaction.

Patients and Methods

Between October 1991 and April 2002, 116 patients underwent 118 arthroscopic ankle arthrodeses. All patients were either operated upon by, or under the direct supervision of, the senior author (IGW) from the start of his experience with the technique. There were 71 men and 45 women; the right side was operated upon in 75 cases and the left in 43 cases and the mean age at operation was 57 years 2 months (20 to 86 years). Pre-operative diagnoses included 67 ankles with post-traumatic osteoarthritis, 36 with primary osteoarthritis, 13 with inflammatory arthropathy and two with avascular necrosis. In those with post-traumatic osteoarthritis, the fracture had occurred at a mean of 15 years 8 months (1 to 47 years) prior to arthrodesis. Mean body mass index was 27 (20 to 38). At the time of operation, 20 patients smoked while 96 were non-smokers. The mean clinical follow-up time was 65 months (18 to 144).

Weight-bearing anteroposterior (AP) pre-operative radiographs were assessed to identify the degree of varus/valgus deformity by measuring the superomedial angle between the anatomical axis of the tibia and a line drawn defining the talar shoulders. The normal mean angle is 93˚. The range of pre-operative deformities is shown in Figure 1. Post-operative lateral radiographs were used to assess plantar/
dorsiflexion fusion position. A line was drawn from the inferior aspect of the posterior tubercle of the talus to the most inferior aspect of the talar neck and intersected with a line drawn along the anatomical axis of the tibia. The anterosuperior angle was then measured (Fig. 2), the normal mean angle being 106˚, with the ankle in neutral.

Pre-operative AP and lateral radiographs were assessed for concomitant osteoarthritis (excluding those with inflammatory arthropathy) of the subtalar, talonavicular and calcaneocuboid joints using the scale of Kellgren and Lawrence (Table I). Union was defined as a clinically stable ankle, painless on manipulation and weightbearing, with radiographic evidence of bridging trabeculae without failure of internal fixation or change in position.

Nine patients (ten ankles) died before final review and three were lost to follow-up, leaving 104 patients (105 ankles) who were reviewed by telephone with a retrospective assessment of radiographs and post-operative complications. Subjective clinical outcome was graded into four groups: excellent, no pain, limp or occupational restriction, fused; good, mild pain, occasional limp or occupational restriction, fused; fair, moderate pain, limp and occupational restriction, fused; and poor, nonunion or severe pain. Patient satisfaction was graded into three groups: 1), satisfied without reservation; 2), satisfied with reservation; 3), dissatisfied.

Operative technique. The patient is placed supine with a tourniquet and a bolster under the thigh to flex the hip 30˚. A soft-tissue distractor is applied and the table end dropped to apply tension. The joint is filled with 20 ml saline. After the anteromedial portal has been established the anterolateral portal is created under direct vision. The remaining articular cartilage is removed with a combination of a 4.5 mm soft-tissue debrider and curettes. The medial malleolar articular surfaces are removed but the lateral gutter is only cleared enough to allow compression of the joint or reduction of deformity, the articular surfaces are not addressed. A bony burr is then used to remove bone down to a healthy cancellous base demonstrating punctate bleeding which is readily demonstrated if the suction for the burr is maximal. After removal of anterior tibial osteophytes it is often easiest to initially pass from anterior to posterior on the talar dome, then posterior to anterior on the tibia. Following adequate preparation of the joint surfaces the foot is positioned correctly in neutral flexion, 0˚ to 5˚ hindfoot valgus and external rotation equal to the opposite side if normal, or 5˚ to 10˚ if abnormal.

However, when assessing whether an arthroscopic arthrodesis is technically possible due to the degree of varus/valgus deformity, the primary consideration is whether the forefoot can be balanced without fixed pronation or supination rather than whether the ankle itself can be corrected in the coronal plane. If the forefoot cannot be corrected then we would opt for an open arthrodesis and may extend this to other joints. Under image intensifier control, two cannulated percutaneous ACE 6.5 mm screws (DePuy

<table>
<thead>
<tr>
<th>Varus (%)</th>
<th>Valgus (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>25</td>
<td>30</td>
</tr>
</tbody>
</table>

The pre-operative deformity measured from the standing AP radiographs. The mean coronal deformity was 3˚ varus but was from 22˚ valgus to 28˚ varus. Of 118 ankles, 94 (80%) were within 10˚ varus/valgus, 14 (12%) were varus > 10˚ and 10 (8%) were valgus > 10˚.

We measured angle X on the post-operative radiograph to record the plantar/dorsiflexion fusion position.

<table>
<thead>
<tr>
<th>Table I. Kellgren and Lawrence score used for assessing osteoarthritis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>
International Ltd, Leeds, UK) are placed medially from the tibia into the talus. We aim to place the screws parallel on both AP and lateral views where possible. Care is taken to avoid penetration of the subtalar joint which is checked by clinical examination and radiographic screening. If following arthroscopic arthrodesis the heel is in excessive varus/valgus, an os calcis osteotomy is performed. Surrounding joints often have a degree of arthritis. The history and clinical assessment are used to decide whether these are a major source of symptoms and, if necessary, steroid or local anaesthetic injection is used for pain relief.

A gap is usually seen at the arthrodesis site on the intraoperative films (Fig. 3) but despite this screw fixation is at the maximal compression allowed by the quality of the bone. If this is very poor then washers are used. All wounds are closed with nylon and a below-knee backslab is applied. A complete cast is applied at 24 to 48 hours after which the patient is mobilised non-weight bearing for two weeks, then partial weight-bearing for six weeks. After that a removable boot is applied and the patient is allowed full weight-bearing for a final four-week period, until 12 weeks after operation, or until clinical and radiological union.

**Results**

The mean hospital stay was four days (1 to 21). Those patients who had extended stays usually had poly-arthritis and mobilisation non-weight-bearing was difficult. The mean time to union was 12 weeks (6 to 20), but union may have occurred earlier because in the latter part of the series, radiographs were not taken until 12 weeks after operation. Nonunion occurred in nine cases (7.6%), seven have been successfully fused by an open technique, one awaits open fusion and one elected to be treated conservatively. Four cases of nonunion occurred within the first eight operations performed. The patients had been immobilised for between seven and 11 weeks after surgery. Following a review of the first 12 cases, we initiated a policy of at least 12 weeks of immobilisation. Since then there have been five of 106 (4.7%) cases of nonunion. Three of the nine patients with nonunion (33%) smoked peri-operatively compared with non-union patients.
with 17 of the 109 whose arthrodeses united (16%). Age and body mass index were not associated with nonunion. The primary diagnosis for those with nonunion was post-traumatic osteoarthritis in five, primary osteoarthritis in three and avascular necrosis in one. One of the cases of nonunion was because of deep infection which presented as an abscess around a screw head. The screws were removed; the holes drilled out followed by a six-week course of antibiotics, prior to successful open fusion without recurrence of infection. Other complications included 22 cases requiring removal of screws due to prominence, three superficial infections which resolved with antibiotics, two deep vein thromboses with non-fatal pulmonary emboli confirmed by ventilation/perfusion scans. One case required revision of fixation due to positioning in equinus and one stress fracture occurred at the level of the proximal screw head. This was successfully treated by plaster immobilisation.

Six patients have subsequently undergone subtalar fusion (primary diagnosis was post-traumatic osteoarthritis in four, primary osteoarthritis in one and avascular necrosis in one). One patient with rheumatoid arthritis has undergone triple fusion and one patient a talonavicular fusion. The mean time between ankle fusion and subsequent subtalar fusion was 48 months (10 to 84). The mean Kellgren and Lawrence scores in those with osteoarthritis were subtalar 2.35, talonavicular 1.46 and calcaneocuboid 0.86. With respect to subtalar osteoarthritis, of those patients that have subsequently undergone fusion the mean Kellgren and Lawrence score was 2.8 (2 to 4). There were six patients classified as grade 4 pre-operatively and only one has undergone subtalar fusion. There were 28 patients classified as grade 3 of whom two have undergone subtalar fusion. Of the 13 cases with inflammatory arthropathy, all united and were satisfied without reservation. They often had significant involvement of other joints although only one has undergone a triple fusion.

The mean position of fusion in the sagittal plane, as seen on the lateral radiograph, was 103˚ (99 to 112), representing 3˚ of ankle dorsiflexion; 76% of cases were within 106˚ ± 5˚.

Four cases required intra-operative osteotomy of the os calcis to realign the hindfoot following ankle fusion and two required lengthening of the tendo Achillis.

During the same time period it was necessary to perform ten primary open arthrodeses because of the pre-operative coronal deformity (representing 8% of all isolated ankle arthrodeses performed). We found that if the ankle deformity was of such a severe degree, the subtalar joint was often also deformed or caused symptoms which required a combined ankle and subtalar fusion using a hindfoot nail. During this period, we performed 60 such procedures.

Assessment of clinical outcome showed excellent results in 48 patients, 35 good, ten fair and 11 poor. Of the 11 poor results, there were nine cases of nonunion and two that united but later required a subtalar fusion and still had continuing pain.

In the 95 patients followed up without nonunion, there were 60 who were satisfied without reservation, 29 satisfied with reservations and six were dissatisfied. Of the six patients who were dissatisfied, two have subsequently undergone subtalar fusion, three have symptoms attributable to the subtalar joint and one has undergone a talonavicular fusion for osteoarthritis. In those patients who have undergone further fusions, hindfoot pain persists.

Discussion

In order to perform an arthroscopic ankle arthrodesis, the surgeon must be an experienced ankle arthroscopist with the ability to change technique to an open fusion if necessary. The potential advantages of the arthroscopic technique have been well described.1,2

Initially arthroscopic ankle arthrodesis was felt to be an in situ fusion and no, or only minimal deformity could be corrected. With greater experience, increasing deformities have been attempted and currently an upper limit of 10˚ to 15˚ deformity is accepted. We have arthroscopically fused patients with deformities of 25˚ and greater based on the pre-operative ability to place the forefoot square to the ground and then dealing with residual hind-foot deformity by means of a calcaneal osteotomy.

Because of this we feel that the indications for the procedure can be extended after experience has been gained with minimally deformed ankles. We were able to perform arthroscopic fusion in more than 90% of cases requiring an isolated ankle arthrodesis. Most reports of arthroscopic ankle arthrodesis have recommended preparation of both tibial and fibular articular surfaces and the use of two crossed transmalleolar screws.1,8-13 We feel that there is no requirement to fuse the talofibular aspect of the joint and we only clear the lateral gutter enough to allow apposition of the tibiotalar surfaces. We have not seen symptoms post-operatively in any patient that can be ascribed to the unfused portion of the joint.

There is a decreased time to union. This is probably because periosteal stripping was not necessary and therefore the local circulation is intact. Following arthroscopic fusion, the mean time for union may be as short as 8.7 weeks.2 After our initial 12 cases, we decided to leave all patients immobilised for 12 weeks before we reviewed them. We recognise that the initial high rate of nonunion affecting four of the first eight cases may have been partly related to the period of immobilisation but probably a more significant factor was the experience of the surgeon. Other studies have found that the procedure can be done as an outpatient/overnight stay, but we had longer mean stays primarily because the group with inflammatory arthropathy was more difficult to mobilise post-operatively.

When performing an open ankle fusion, posterior displacement of the talus on the tibia has been recommended to produce a more normal pattern of gait and reduce stress on the knee.5 Anterior displacement leads to increased extension of the knee during walking. Although the arthro-
scopic technique does not allow active displacement, posterior placement of the screws from the posteromedial corner of the tibia will bring the talus back under the tibia in the majority of cases.

Although almost 19% of patients required removal of their screws due to prominence, it is a simple daycase procedure and did not lead to any complications. All patients are warned pre-operatively of the frequent need for the removal of screws.

It has been suggested that compensatory increase in movement of the surrounding joints of the foot occurs after ankle fusion. Subtalar degenerative change is commonly seen in patients following ankle fusion, less commonly talonavicular and only rarely calcaneocuboid. Coester et al followed 23 patients with post-traumatic osteoarthritis who underwent fusion for 22 years and found that 21 had moderate to severe subtalar osteoarthritis but only one patient had pre-operative radiographs. Nevertheless, 67% remained happy with the outcome, 88% would repeat the operation and 92% would recommend it to a friend. Fuchs remained happy with the outcome, 88% would repeat the procedure and did not lead to any complications. All patients were warned pre-operatively of the frequent need for the removal of screws.

Thus, it is clear that arthritis of the hindfoot is common following ankle fusion but we have shown that it is also very common before fusion and that in this series there were 45 grade 3 or 4 subtalar joints but only three have subsequently required subtalar fusion. However, the patients who were dissatisfied with their operations were generally those who had ongoing symptoms attributable to arthritis of the hindfoot. It is difficult to decide which patients will develop progressive worsening of their symptoms following ankle fusion. Unfortunately, we have not been able to identify those who fall into this category and who would be better served by an alternative procedure, whether that be total ankle replacement alone or combined with a subtalar fusion or a pantalar fusion.

The results of total ankle replacement continue to improve but still suggest that survivorship falls below that of hip or knee replacement. With the high incidence of soft-tissue problems and the young age of onset of post-traumatic arthritis, arthrodesis will remain the treatment of choice in many cases.

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