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Arthroscopic Ankle Arthrodesis

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ABSTRACT

***Background*: Arthroscopic arthrodesis has been used mainly for in situ fusion of arthritic ankles without deformity. This paper presents the application of arthroscopic arthrodesis of ankles with marked deformity. *Methods*: The results of 78 consecutive cases of arthroscopic ankle arthrodeses, performed in 74 patients, were retrospectively evaluated. Forty-eight ankles had minor deformity (group A), whereas 30 ankles had a varus or valgus deformity of more than 15 degrees (maximum 45 degrees) (group B). The average hospital stay was 3.8 and 3.4 days in groups A and B, respectively ($p = 0.74$). Postoperative treatment included ankle immobilization for 3 months. Progressive weightbearing was initiated at 2 weeks. Mean followup was 21.1 months. *Results*: Fusion occurred in 47 of 48 (97.9%) ankles in group A at an average time of 13.1 ± 5.8 weeks and in 29 of 30 (96.7%) ankles at 11.6 ± 2.4 weeks in group B ($p = 0.19$). Unplanned operative procedures were required in 11 ankles (14.1%). One superficial wound infection occurred. Symptomatic arthritis from the adjacent joints developed in six ankles (7.7%). Postoperative ankle alignment in the frontal plane averaged 0.7 and 0.4 degrees of valgus ($p = 0.41$), whereas the sagittal plane angle averaged 106 ± 4 degrees and 104.5 ± 7 degrees in groups A and B, respectively ($p = 0.22$). The outcome was graded as very good in 79.2% (38 feet) in group A and 80% (24 feet) in group B, fair in 18.8% (9 feet) in group A and 16.7% (5 feet) in group B and poor in one ankle in each group ($p = 0.68$). *Conclusions*: The arthroscopic technique offered high fusion rates and low morbidity. Deformity correction was achieved with good results.**

Key Words: Ankle; Arthrodesis; Arthroscopic; Deformity

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INTRODUCTION

Ankle arthrodesis is considered to be the "gold standard" treatment for a painful degenerated ankle not responding to conservative treatment. The formal goals of an ankle arthrodesis are to eliminate pain and deformity of the degenerated ankle joint and obtain a plantigrade foot so as to achieve painless mobilization.[23] A variety of arthrodesis techniques have been described, varying in operative approach, use of bone graft, and type and duration of fixation.[3,6,10,12,13–17,23,26,28] Complications associated with ankle arthrodesis include infection, wound-healing problems, fracture, neurovascular injury, malunion, and nonunion.[10,13,23] Long-term complications include secondary arthrosis of the subtalar and talonavicular joints.[5,10,11,20,22,23]

Advantages of the arthroscopic technique over open techniques include low postoperative morbidity and absence of limb-threatening complications, less blood loss, shorter hospital stay, faster rehabilitation and mobilization, a low complication rate, and decreased time to union.[14,16] The arthroscopic technique has the advantage of not compromising the soft-tissue envelope, and it can be done even in patients with both poor skin and wound healing potential which would be a contraindication to the open technique.

Most studies advocate using an arthroscopic technique for only minimally deformed ankles.[8,9,12,16,17,21,26] This was defined as varus or valgus of less than 15 degrees.[12,26] A few authors,[4,27] however, reported occasionally fusing ankles with more severe deformities (up to 28 degrees) arthroscopically. This series includes a group of 30 ankles with deformity of more than 15 degrees (up to 45 degrees) treated with arthroscopic arthrodesis.

MATERIALS AND METHODS

We retrospectively evaluated 78 consecutive arthroscopic ankle arthrodeses performed in 74 patients at our institution between August, 1998, and October, 2005. Surgery was performed by the senior author (SWP) or under his direct supervision. Exclusion criteria were sensory neuropathy and

development of a Charcot joint. During the same period of time, no open ankle arthrodeses were performed in our institution for non-neuropathic ankle joints. All ankles were assessed postoperatively for clinical and radiographic union, complications, presence of significant residual pain, need for metal removal, and other unplanned operative procedures, and subjective clinical outcomes. The study included review of the radiographs and medical records. All preoperative and postoperative radiographic measurements were performed by one blinded observer who was not the surgeon (patient detail labels were covered and preoperative and postoperative radiographs were not reviewed sequentially).

The study cases were divided into two groups, depending on the presence of preoperative ankle deformity. Group A included 48 ankles (47 patients) with less severe deformities (less than 15 degrees of varus or valgus) and group B included 30 ankles (27 patients) with varus or valgus deformities of more than 15 degrees, measured on the anteroposterior ankle radiographs.

The null-hypothesis suggested that the fusion rate, time to fusion, complications, need for unplanned operative procedures, and subjective clinical outcomes were significantly different between the two groups. The alternative hypothesis stated that no difference existed between the two groups regarding the above parameters.

The mean age at operation was 54 ± 14 (range 18 to 81) years. Forty-two patients (45 ankles) were men and 32 (33 ankles) were women. Four patients had bilateral arthroscopic ankle arthrodeses at different times. Forty right ankles were fused and 38 left ankles. The preoperative condition was posttraumatic osteoarthritis in 38 ankles (48.7%), primary osteoarthritis in 30 ankles (38.5%), rheumatoid arthritis in four ankles (5.1%), osteonecrosis of the talus in three ankles (3.8%), an osteochondral defect of the talar dome in one ankle (1.3%) and history of septic arthritis in two ankles (2.6%) (Table 1). Mean followup was 21.1 ± 13.5 (range 6 to 68) months. No procedure performed arthroscopically during the study period was converted to an open arthrodesis intraoperatively.

The preoperative and postoperative frontal plane alignment angles are listed in Table 2. Figure 1 illustrates the preoperative and postoperative varus or valgus alignment of the ankles in groups A and B. The average preoperative deformity in group B was 24.7 ± 7.5 (range 15 to 45) degrees. The preoperative and postoperative deformities were measured from the standing anteroposterior radiographs as described by O'Brien et al.,[16] determining the talar shoulders and the long axis of the tibia. Postoperative radiographic measurements in the coronal plane (anteroposterior radiographic view) were performed early postoperatively when the 'arthrodesis line' and the talar shoulders were still observable (Figure 2, A and B). Preoperative and postoperative lateral weightbearing radiographs were used to assess alignment in the sagittal plane (Figure 2, C and D). The 'sagittal alignment angle' was measured by drawing a line 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.[1] The normal mean angle is considered to be 106 degrees, with the ankle in neutral.[16] Furthermore, the anteroposterior tibiotalar alignment was quantified by measuring the tibial-axis-to-talus ratio (T-T ratio: the ratio into which the mid-longitudinal axis of the tibial shaft divides the longitudinal talar length), from the lateral preoperative and postoperative radiographs (Figure 3), as described by Tochigi et al.[24]

The mean age at operation in group A was 51.8 ± 13.5 (range 18 to 81) years and in group B 57.6 ± 14.23 (range 23 to 80) years. These values were not significantly different ($p = 0.08$). The male to female ratio in group A was 1.14, whereas it was 1.7 in group B. The causative factors of arthritis are shown in Table 1.

Five patients smoked at the time of surgery and continued to smoke during the followup period (four in group A, one in group B). Six patients, three in each group, were diabetic, however, without Charcot joint deformity. One patient in group A had recently had chemotherapy treatment for myeloma.

In five ankles with marked symptomatic subtalar arthritis, the subtalar joint was fused arthroscopically during the same

Table 1: Causes of ankle arthritis requiring ankle arthrodesis

Causes of arthritis	All cases ($n = 78$)	Group A ($n = 48$)	Group B ($n = 30$)
Post-traumatic Osteoarthritis	38 (48.7%)	28 (58.3%)	10 (30%)
Primary Osteoarthritis	30 (38.5%)	13 (27.1%)	17 (56.7%)
Osteonecrosis AVN	3 (3.8%)	0	3 (10%)
Septic arthritis	2 (2.6%)	2 (4.2%)	0
Osteochondral lesion	1 (1.3%)	1 (2.1%)	0

Posttraumatic and idiopathic osteoarthritis were the most common causes of disabling ankle pain and affected groups A and B significantly different ($p < 0.001$).

Table 2: Frontal plane alignment of the ankle, measured from the anteroposterior standing radiographs

Tibiotalar alignment in the frontal plane	**All cases ($n = 78$)**	**Group A ($n = 48$)**	**Group B ($n = 30$)**	***p* values group A vs. B**
Preoperative deviation from neutral (varus or valgus)				
(mean degrees)	**13** ± 10.8	**5.6** ± 2.9	**24.7** ± 7.5	<0.0001
(range degrees)	(15–45)	(0–14)	(15–45)	
Postoperative alignment				
(mean degrees)	0.6 *(valgus)* ± 1.7	0.7 *(valgus)* ± 1.7	0.4 *(valgus)* ± 1.8	0.41
(range degrees)	(varus 4-valgus 4)	(varus 4- valgus 3)	(varus 4- valgus 4)	

Postoperative alignment of the fused ankles in the coronal plane, revealed equally good results for groups A and B.

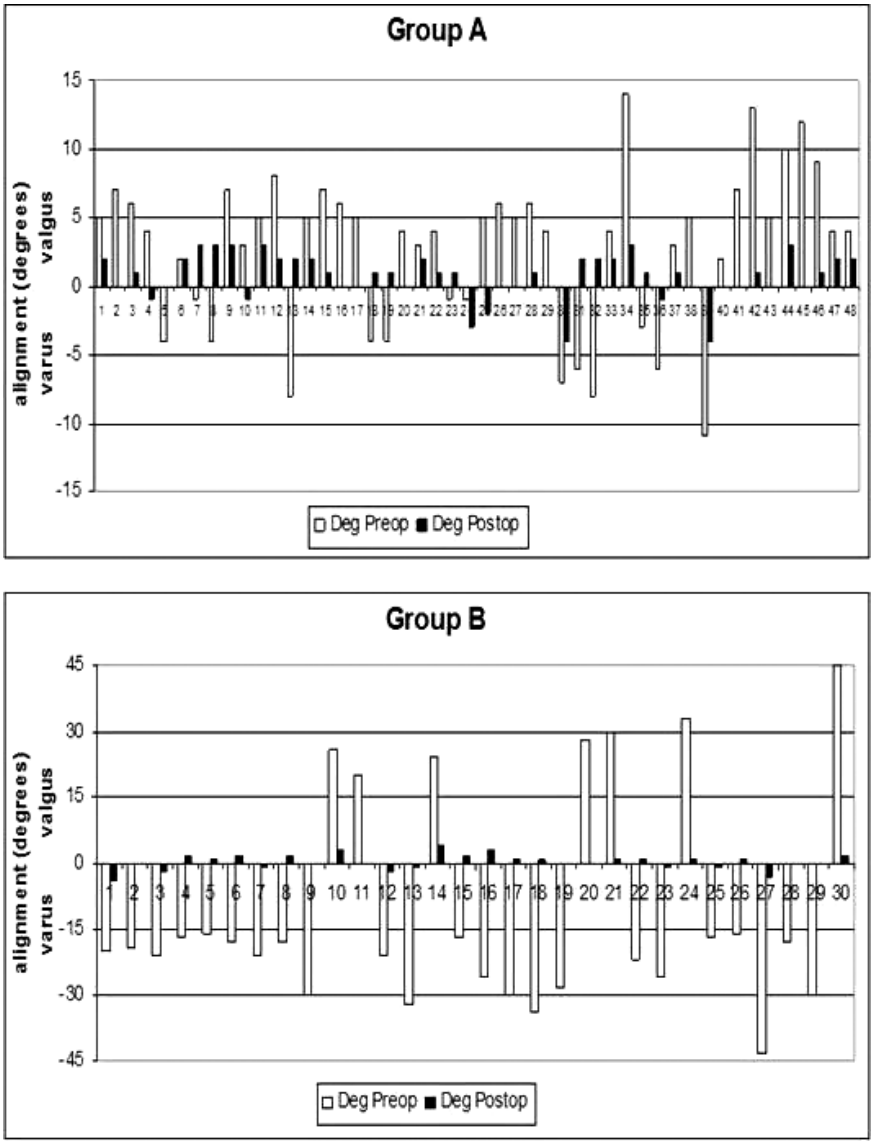

Fig. 1: Comparison of preoperative to postoperative alignment of each individual case (varus or valgus) at the ankle joint.

Fig. 2: A and B, Deformity correction in the frontal plane in an 80-year-old woman with a varus deformity of 18 degrees. The ankle was reduced to neutral. **C and D,** The ankle 'sagittal plane angle' measured from the lateral radiograph was 105 degrees postoperatively, representing an acceptable sagittal plane alignment.

operation. Four of them had significant ankle deformity preoperatively (group B).

Operative Technique

The patient was placed supine with a tourniquet applied to the thigh, and a support was placed under the hip on the operating side. A noninvasive mechanical device was used for joint distraction, acting through a sling on the foot, with a connection to a lever and screw thread to control the distracting force. The joint was filled with 20 ml saline. After the anteromedial portal had been established, just lateral to the anterior tibial tendon,[2] the anterolateral portal was created under direct vision. A 4.5-mm 30-degree arthroscope was used.

Extensive removal of the distal tibia and the upper joint surface of the talus was performed. The remaining articular cartilage was removed with a combination of a 4.5-mm soft-tissue debrider and curettes. Cheilectomy of anterior osteophytes was performed, and the medial malleolar articular surfaces were removed. The lateral gutter also was cleared enough to allow compression of the joint or reduction of deformity. A bony burr was then used to remove bone down to a healthy cancellous base, demonstrating

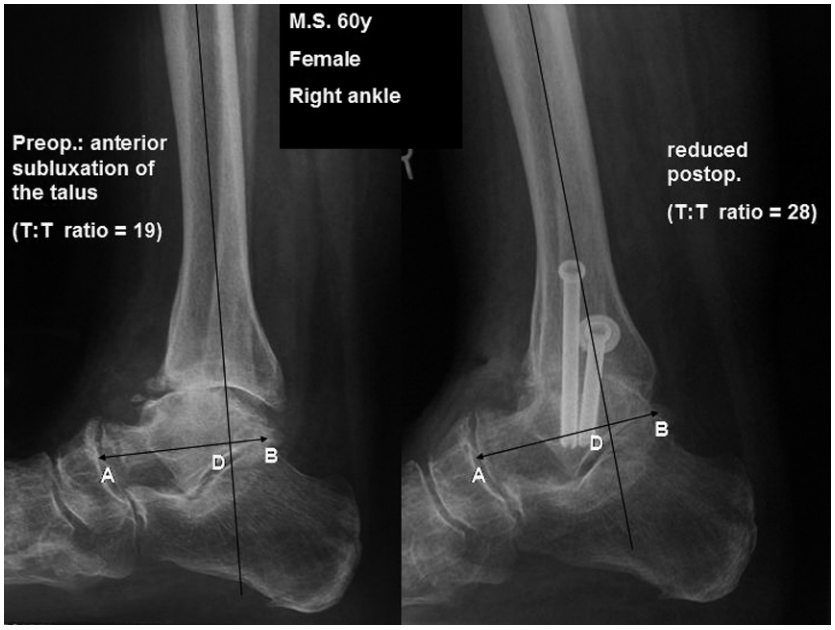

Fig. 3: Anterior extrusion of the talus was reduced with the hindfoot well aligned underneath the tibia. The tibial-axis-to-talus ratio (T:T = AD/AB × 100)[24] quantifies sagittal tibiotalar alignment.

punctate bleeding, which was readily demonstrated if the suction for the burr was maximal. After removal of anterior tibial osteophytes it was easiest to initially pass from anterior-to-posterior on the talar dome, then posterior-to-anterior on the tibia. Approximately 20 minutes before the tourniquet was released an ankle block with local anesthetic (20 to 30 ml of bupivacaine 0.5%) was performed. At the end of the arthroscopic joint-surface debridement, the tourniquet was deflated.

After adequate preparation of the joint surfaces, the foot was manipulated and positioned sagittally in neutral, 0 to 5 degrees hindfoot valgus and external rotation equal to the opposite side if normal, or approximately 5 to 10 degrees if abnormal.[1,8,23,27] In cases of moderate to severe malalignment more subchondral bone from the tibial surface (medially in cases of valgus deformity and laterally in cases of varus) was excised to achieve congruency of the upper talar and lower tibial surfaces, although without complete contact. No form of graft or bone substitute was used.

Under image intensifier control, two or three cannulated percutaneous 6.5-mm titanium cannulated screws (ASNIS screws, Stryker, UK) were placed over guidewires medially from the distal tibia into the body and neck of the talus. The screws should ideally be placed parallel on both anteroposterior and lateral views if possible. During guidewire and screw insertion, an assistant provided controlled pressure on the hindfoot against the tibia through a flat surface placed on the plantar aspect of the foot. The position was checked with the image intensifier intraoperatively (anteroposterior and lateral views) (Figure 4, B, C and F). A gap usually was seen at the arthrodesis site on the intraoperative films, but despite this, screw fixation was at maximal compression. In ankles in which bone quality was very poor, washers were used. Care was taken to avoid penetration of the subtalar joint, which was checked by clinical examination and radiographs. The aim was to achieve a clinically well aligned, plantigrade foot.

Arthroscopic subtalar arthrodesis was done at the same setting in five ankles, with concomitant severe symptomatic subtalar arthritis, after the tibiotalar arthrodesis was completed. Talocalcaneal joint debridement was done arthroscopically through two lateral portals, level with the sinus tarsi. The sinus tarsi was denuded, and a small laminar spreader was used to arthroscopically assist in excision of the posterior and anterior subtalar joints. Fixation was with one or two 6.5-mm cannulated titanium screws, inserted over guide-wires under fluoroscopic control, from the heel to the talus and in some cases to the distal tibia, or alternatively from the talus to the os calcis. All wounds were closed with nylon sutures and a below-knee back-slab was applied.

Postoperative Protocol

All patients were given one daily dose of low-molecular-weight heparin while in the hospital. They were mobilized nonweightbearing for 2 weeks. The postoperative followup consisted of examination in the outpatient clinic at 2 weeks at which time the wound was checked and the cast changed. At this stage, partial weightbearing was allowed. At 6 weeks, when a radiograph was obtained, patients were put into a walking boot and full weightbearing was allowed. Three months postoperatively a radiograph was obtained. If radiographic fusion had occurred, patients were allowed to walk bearing full weight without any support. A routine

followup was arranged at 6 months. In those ankles in which fusion was not evident on radiographs, further protection in a walking boot was required and further followup was arranged at 6 weeks.

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.[15]

Grading of Outcomes

Subjective clinical outcome was categorized into three groups. The outcome was graded as (1) very good, if no or only mild pain was present and no limp or restriction in activities was present and the joint was fused successfully, (2) fair, if significant pain was present requiring additional operative procedures, or if a limp or restriction in activities was present with the joint fused, and (3) poor, when nonunion occurred or severe pain was present.

Statistical Analysis

Statistical analysis of data was performed to compare values obtained on several parameters between groups A and B. The SPSS soft-ware, version 11.0 for Windows (SPSS, Inc., Chicago, IL), was used. The Pearson correlation coefficient and Student t-test were calculated to find the degree of correlation and the respective p values (to detect any statistically significant differences), comparing the numeric variables of the patients' ages, durations of the procedures, hospital stays, times to fusion and followup periods between groups A and B. The chi-square test and the Fisher Exact test were performed to compare nominal variables (hardware removal [yes or no] and the need for additional unplanned procedures [yes or no]), in independent groups (A and B) to assess the level of significance of differences. The Fisher Exact test was used to compute the p values for all 2×2 tables. For nonparametric ordinal variables (clinical outcome [very good, fair, or poor]), the Mann-Whitney test was used. A 95% confidence interval was set to assess statistical significance of observed differences.

RESULTS

None of the 78 arthroscopic procedures had to be converted into an open ankle arthrodesis intra-operatively. Mean age difference between the two groups did not prove to be significant ($p = 0.08$). Similarly the followup period was equivalent for groups A and B ($p = 0.41$). None of the patients were lost to followup. An overall 97.4% (76 of 78 ankles) fusion rate was achieved as shown in Table 3. Two nonunions occurred (2.6%). A 56-year-old man (group A) had a history of septic arthritis of the same ankle. The arthrodesis failed to unite and was revised successfully with an open procedure. A 23-year-old lady had an open IIIb fracture according to the Gustillo-Anderson classification, resulting early in disabling ankle joint degeneration and deformity (group B). Five years after the arthrodesis, consolidation of the fusion site had not occurred, and she developed a stable fibrous union. She currently is having subtalar pain but does not wish to have further surgery.

Overall time to union was 12.5 ± 4.9 (range 6 to 32) weeks. Radiographic union in group A ($n = 47$) occurred at an average of 13.1 ± 5.8 weeks and in group B ($n = 29$) at 11.6 ± 2.4 (range 8 to 18) weeks. No statistically significant difference between the two groups was detected ($p = 0.19$) (Table 3).

The operating time averaged 104 ± 35 (range 55 to 225) minutes. It was 99 ± 34 (range 55 to 165) minutes in group A and 112 ± 37 (range 60 to 190) minutes in group B ($p = 0.13$).

The average number of cannulated screws used for arthrodesis was 2 ± 0.5 (range 2 to 3) in group A and 2.53 ± 0.8 (range 2 to 5) in group B ($p = 0.09$).

The average time of the hospital stay was 3.7 ± 4.1 days (range 1 to 27, median 3 days). It was 3.8 ± 4.5 days (range

Table 3: Outcome of arthroscopic fusions

	All cases ($n = 78$)	Group A ($n = 48$)	Group B ($n = 30$)	p values
Fusion rate	76/78 (96.7%)	47/48 (97.9%)	29/30 (97.4%)	0.77
Time to fusion (weeks)	12.5	13.1	11.6	0.19
Unplanned procedures	11 (14.1%)	7 (14.6%)	4 (13.3%)	0.71
Outcomes:				
Very good	62 (79.5%)	38 (79.2%)	24 (80%)	0.68
Fair	14 (17.9%)	9 (18.8%)	5 (16.7%)	
Poor	2 (2.6%)	1 (2.1%)	1 (3.3%)	

No significant differences were obtained between groups A and B, in terms of fusion rate, time to fusion, additional not planned operative procedures and clinical outcome.

Table 4: Alignment in the sagittal plane

	Sagittal alignment angle			
	All cases	**Group A**	**Group B**	***p* values Group A vs. B**
Preoperative				
(mean degrees)	**104.4** ± 5	**105** ± 4.5	**103.4** ± 5.6	0.19
(range degrees)	(95–118)	(96–118)	(95–116)	
Postoperative				
(mean degrees)	**105.6** ± 5.4	**106** ± 4.3	**104.5** ± 7.1	0.22
(range degrees)	(94–115)	(100–115)	(94–115)	
***p* values preop vs. post-op.**	0.12	0.15	0.44	

The 'sagittal alignment angle' was close to the considered as 'normal' angle of 106 degrees.[1] No significant differences were detected between groups.

1 to 27, median 2.5 days) in group A and 3.4 ± 3.2 days (range 1 to 21, median 3 days) in group B ($p = 0.75$).

Postoperative alignment in the frontal plane measured from anteroposterior radiographs was brought to neutral (Figures 2, A and B and 4, A through D) in both groups as shown in Figure 1 and Table 2.

The 'sagittal alignment angle' measured from the lateral preoperative and postoperative radiographs, as described in the Materials and Methods section, is shown in Table 4.

Anterior subluxation of the talus relative to the tibia, defined as a T:T ratio[24] less than 27%,[25] was present in the preoperative lateral radiographs in eight ankles (3 in group A and 6 in group B). In this subgroup (n = 8) the mean preoperative T:T ratio was 23.1 ± 2.7 (range 19 to 26), whereas the respective postoperative values were 30.9 ± 3.0 (range 28 to 36) ($p = 0.0002$). Thus, reduction of the talus underneath the tibia to obtain optimal alignment (Figure 4), quantified as a T:T ratio within the 'normal' limits 27% to 42%,[25] was achieved (Figure 3). Mild posterior extrusion of the talus was present in two severely deformed ankles with coexisting valgus deformities of 26 and 33 degrees. Respective T:T ratio values were 45 and 47, remaining unchanged postoperatively. In the remaining 68 ankles mean preoperative T:T ratio was 34.9 ± 3.3 and postoperatively 37.5 ± 3.9 ($p = 0.006$).

Preoperative equinus of more than 10 degrees of fixed plantarflexion was present in three ankles (one in group A, two in group B) and was also reduced to neutral.

Delayed union at 6 months was observed in three patients (all in group A). One smoked, one had recently had chemotherapy, and one had a history of septic arthritis of the same ankle. Patients who smoked had a significant delay in consolidation of the fusion site; five in our series had a time to union of 20.4 ± 7.4 weeks, compared to 12 ± 4.3 weeks in nonsmokers (n = 73) ($p < 0.0001$).

Skin necrosis, wound dehiscence, deep infection, compartment syndrome, and neurovascular compromise of the leg did not occur. A diabetic patient developed a superficial wound infection that resolved with local care and antibiotics. One patient developed postoperatively superficial peroneal nerve distribution paresthesia. No lower limb deep vein thrombosis was documented; however, a pulmonary embolism complicated one case.

Six ankles (four in group A and two in group B) developed symptomatic subtalar joint arthritis during the followup period at 6, 15, 18, 24, 40, and 50 (average 25.5) months after the ankle arthrodesis. Three ankles have had a triple arthrodesis. Type I complex regional pain syndrome complicated three procedures in our series. Mild pain arising from the lateral gutter, which was not fused, was present in one ankle in group A, without the need for additional operative procedures.

Additional, unplanned operative procedures were required in 11 ankles (14.1%) during the follow-up period. Seven in group A (14.6%) and four (13.3%) in group B ($p = 0.73$). Removal of hardware was required overall in seven ankles (9%). Three ankles in group A (6.3%) and four in group B (13.3%) required removal of screws ($p < 0.001$). Hardware removal was required at an average of 29.8 (5 to 54) months postoperatively. Additional procedures carried out in group A included three triple arthrodeses, one revision of a nonunion with an open technique, and three hardware removals. In group B, unplanned operative procedures included four hardware removals. Table 5 summarizes early and late complications that were documented during the followup period, indicating an insignificant difference between groups A and B.

All patients returned at least to the prearthrodesis level of activities. Three young patients in group B had already diminished levels of activities preoperatively, one of them being hemiparetic and two as a result of compound distal tibial fractures requiring multiple operative procedures.

Fig. 4: A through G, Excessive ankle varus (30 degrees) malalignment **(A)** was corrected with the arthroscopic technique. More bone was resected from the lateral tibial plafond. Intraoperative fluoroscopy was used to check alignment and guide wire and screw positioning **(B, C, and F).** Signs of consolidation of a well aligned fusion site were already present at 6 weeks **(D and G)**.

The outcome according to the subjective grading we proposed earlier was very good in 62 ankles (approximately 80%) of all cases. Poor results accounted for only 2 ankles (2.5%). The subjective outcome grading in groups A and B was almost identical without any statistically significant difference as shown in Table 3.

Thus, the null-hypothesis was rejected, and the alternative hypothesis was accepted, stating that no significant difference was present between the two groups, regarding fusion rate, time to fusion, complication rate, and clinical outcome.

Figures 2, A through D and 4, A through G illustrate examples of two cases with marked preoperative deformities and their radiographic postoperative outcome.

DISCUSSION

With the high incidence of soft-tissue problems and the young age of onset of post-traumatic arthritis, arthrodesis remains the treatment of choice for end-stage ankle arthritis.[26] More than 40 types of procedures involving open incisions

Table 5: Complications and painful conditions

Complications	All cases ($n = 78$)	Group A ($n = 48$)	Group B ($n = 30$)	p values group A vs. group B
Nonunion	2 (2.6%)	1 (2.1%)	1 (3.3%)	0.70
Paresthesia (superficial peroneal n.)	1 (1.3%)	1 (2.1%)	—	0.74
Subtalar pain	6 (7.7%)	4 (8.3%)	2 (6.7%)	0.75
Painful hardware	7 (9 %)	3 (6.3%)	4 (13.3%)	0.61
CRPS-type I	3 (3.8%)	3 (6.3%)	—	0.79
Minor lateral gutter pain	1 (1.3%)	1 (2.1%)	—	0.74
Minor wound problems	1 (1.3%)	—	1 (3.3%)	0.67
Psychiatric disorder	1 (1.3%)	1 (2.1%)	—	0.74
Allergic reaction	1 (1.3%)	1 (2.1%)	—	0.74
Pulmonary embolism	1 (1.3%)	—	1 (3.3%)	0.67
Total of cases affected	**24 (30.8%)**	**15 (31.3%)**	**9 (30.0%)**	0.84

Complications (early or late) following ankle arthrodesis were documented in about a third of cases, without any significant difference between groups A and B.

Table 6: Results of published studies in the English literature, regarding fusion rate and time to fusion

Authors	Fusion rate	Time to fusion
Myerson & Quill, 1991[14]	94% (16/17)	8.7 weeks
Ogilvie-Harris et al, 1993[17]	89% (17/19)	11 weeks
Corso & Zimmer, 1995[6]	100% (16/16)	9.5 weeks
Glick et al, 1996[12]	97% (33/34)	9 weeks
Cameron & Ullrich, 2000[3]	100% (15/15)	11.5 weeks
Zvijak et al, 2002[28]	95% (20/21)	8.9 weeks
Cannon et al, 2004[4]	100% (36/36)	All at 4 months
Saragas, 2004[18]	96% (33/34)	10.5 weeks
Winson et al, 2005[24]	92% (105/112)	12 weeks
Ferkel & Hewitt, 2005[8]	97% (34/35)	11.8 weeks
Current study (Gougoulias et al.)	97% (76/78)	12.5 weeks

have been used for more than a century.[12] The most frequent complications were infection and pseudarthrosis sometimes exceeding 40%.[6,12] Minimally invasive techniques in ankle reconstruction were developed because they minimize the risks of open incisions in this region with tenuous healing capacity. Arthroscopic arthrodesis offers fusion rates of over 90%[3,4,6–8,12,14,16,18,21,26–28] that are comparable or superior to open procedures,[16,28] with an acceptably low complication rate and a short time to union.[3,4,6–8,12,14,16,18,21,26–28] This is probably because periosteal stripping is not necessary, and the local circulation remains intact. Table 6 illustrates fusion rates and time to fusion reported by different authors in the published literature.

Crosby et al.[7] reported earlier complications rates up to 55%, stating, however, that in most cases they were minor and manageable. In our series, including any condition preventing an uneventful early and late postoperative period, complications or painful conditions resulted in about a third of the treated ankles (Table 5). Absence of deep infection, wound dehiscence, limb-threatening complications and rarity of pseudarthrosis (2.6%) significantly reduced the postoperative morbidity. Furthermore, an overall fusion rate of 97.4% was obtained at an average time of 12.5 weeks, with 80% very good clinical results.

We accepted an ankle as successfully fused if it was clinically stable on examination, pain-free on weightbearing and when radiographic signs of bridging trabeculation were present. Although consolidation over the arthrodesis site can take several months to complete, we accepted the presence of trabeculation as the radiographic marker of a consolidated

union.[4] It is likely that the fusion mechanism resembles a process of secondary bone healing; an intermediate connective tissue or fibrocartilage is initially formed within the fracture gap and secondarily replaced by bone. Radiographic characteristics are callus formation, temporary widening of the fracture gap by osteoblastic resorption, and a relatively slow disappearance of the radiolucent fracture line caused by fibrocartilage mineralization and bone formation.[27]

In our series, 61 ankles (78%) consolidated within three months and 73 ankles (94%) within 6 months. Three cases, however, with compromised local (previous septic arthritis) or general healing potential (chemotherapy, smoking) (3.8%) developed a delayed union and showed definite signs of union at 8 months postoperatively.

The senior author (SWP) has been using the anteromedial arthroscopic portal, as described in the Materials and Methods section, routinely for many years because it allows a wide field of view and facilitates passage of the instruments in the anteroposterior direction. The safety of this portal and its anatomic relation to adjacent structures has been reported by other authors.[2] In our series (78 ankles), no neurovascular damage was detected from the use of this portal. It should not serve, however, as a recommendation to specifically use the anteromedial portal to correct deformities with the arthroscopic technique.

Hardware removal often was needed. Other authors following their patients for an average of 72[8] and 65[27] months recorded hardware removal in 33% and 19% of cases, respectively. In our study, at an average follow-up of 21 months hardware removal was required in 7 ankles (9%) at an average of 30 months postoperatively.

Postoperative alignment in the frontal plane was brought to neutral. We measured the angle between the long axis of the tibia and the 'arthrodesis line' indicated by the upper surface of the cartilage-denuded talus, from the immediate postoperative radiographs (Figure 2, B). As long as consolidation had not occurred and the arthroscopic technique did not produce complete contact of the lower tibia and the upper talar surface, the arthrodesis line was visible. According to our measurements, the fused ankle was brought into normal alignment in both groups, without significant difference (Table 2).

Radiographic position of the fused ankles in the sagittal plane was satisfactory with a mean sagittal plane ankle of 106 ± 5.4 (range 94 to 115) degrees, without any significant difference between the two groups and close to the normal ankle of 106 degrees[1] (Table 4). Similar results also were reported by other authors.[27]

Furthermore, the arthroscopic technique allowed correction of the sagittal tibiotalar alignment where needed. Eight ankles with anterior extrusion of the talus, five of which had severe malalignment in the frontal plane, were reduced into a satisfactory position. In 68 ankles, not associated with tibiotalar malalignment in the sagittal plane, the mean T:T ratio was altered from 34.9 to 37.5 ($p = 0.006$), indicating significant posterior translation of the talus and foot relative to the tibia. This is desirable as it has been shown to create a plantigrade foot aligned with the mechanical axis of the limb, also reducing the anterior lever arm of the foot on the arthrodesis site and improving ground clearance of the foot during gait.[1]

Our immobilization and weightbearing regime consisted of keeping all ankles immobilized in a cast for at least 12 weeks, irrespective of the presence of radiographic signs of successful fusion a lot earlier in some cases. We allowed partial weightbearing at 2 weeks. As reported by Winson et al.,[27] early allowance of weightbearing without any immobilization device after 7 to 11 weeks in their early cases was complicated by four nonunions in eight ankles. An immobilization scheme of 12 weeks thereafter resulted in only 4.7% nonunions in their subsequent 106 ankles. Cannon et al.,[4] however, suggested that it was safe to allow weightbearing during the early postoperative period. In practice, this usually entailed partial weightbearing on crutches in the initial 2 weeks increasing to full weightbearing by 4 to 6 weeks. They compared two demographically equivalent groups of patients undergoing arthroscopic ankle arthrodesis (excluding diabetic patients and patients with Charcot joints) who followed different postoperative mobilization regimes and found that no difference existed between the two groups regarding their outcomes.

The issue of persistent hindfoot pain, arising mainly from subtalar arthritis, as a cause of patient dissatisfaction after an ankle arthrodesis has been discussed in the literature.[5,11,20,25] Altered biomechanics cause a compensatory increase in movement of the surrounding joints of the hindfoot and midfoot.[13,22,23] Long-term results of ankle fusion showed that subtalar degenerative changes were seen in 10% to 60% of patients, whereas this occurred less commonly in the talonavicular and only rarely calcaneocuboid joints.[5,11] However, despite development of adjacent joint arthritis patients were satisfied with their ankle fusion outcomes and only had minor restrictions with everyday activities.[11]

All our patients were evaluated clinically and radiographically for subtalar and midfoot arthritis, preoperatively. Five (four in group B) were significantly symptomatic and had ankle and subtalar joint arthrodesis during the same operation. During the relatively short followup period, we found that in six ankles (7.7%), patients developed symptomatic subtalar arthritis. This occurred at an average of 25.5 months postoperatively. The early presentation could possibly represent pre-existing degeneration,[20] which becomes symptomatic after the hindfoot biomechanics have changed after tibiotalar arthrodesis.[23]

In our series, the indication for subtalar joint arthrodesis was painful subtalar arthritis. Subtalar joint arthrodesis was not used as an aid to obtain alignment correction. In four ankles in group B, severe deformity was accompanied by both ankle and subtalar joint destruction. In those cases, the

preoperative planning included arthrodesis of both joints. In all patients, arthrodesis of the ankle joint was undertaken first. The authors do not believe that alignment correction through the subtalar joint would be possible to a great extent unless the accumulation of experience improved the operative technique.

It does not seem, however, that there are clear preoperative indications on when to fuse additional joints instead of the tibiotalar joint alone. The authors believe that it is worth preserving the adjacent joint motion and proceed to further arthrodesis procedures at a later stage if needed. Accurate preoperative patient information is, thus, very important. The treating surgeon should make his patients aware of the likelihood of pain in the future arising from the adjacent joints and the need for hardware removal.

Initially, arthroscopic ankle arthrodesis was thought to be performed only as an *in situ* fusion, unable to correct significant deformity.[8,12,14,16–18,21,23,26] With greater experience, increasing deformities have been attempted[4,27] and currently an upper limit of 10- to 15-degree deformity is accepted.[27] The current study showed that marked ankle deformity, (previously reported as a contraindication for an arthroscopic technique), can be corrected arthroscopically, depending on the surgeon's familiarity with this procedure. Arthroscopic ankle arthrodeses were successfully performed in patients with severe varus or valgus deformities (Figure 1, A and B), without the need to convert to an open procedure in any of the ankles. We did not need to perform additional procedures to correct residual deformity, such as a calcaneal osteotomy. Furthermore, this series of consecutive patients does not include any kind of patient selection, apart from the fact that patients with neuropathic feet or Charcot joints were not included. Clinically well-aligned, plantigrade feet with the ability to be placed onto a flat surface, was achieved in all patients. Technically, correction of ankle joint malalignment can be achieved by completely resecting soft-tissue connections of both the medial and lateral gutters, between the talar body and the malleoli. This allows manipulation of the ankle joint in the coronal and sagittal planes, to obtain an optimal arthrodesis position. In some patients with coexisting subtalar arthritis, arthrodesis across the subtalar joint could further help to reduce the deformity.

Radiographic alignment measurements can be criticized as inaccurate as rotational differences on the anteroposterior views could interfere with the results. Ideally, hindfoot alignment views as described by Saltzman and el Khoury[19] should be obtained. However, as long as this retrospective study focuses on the comparison of results between in situ ankle fusions (group A) and deformed ankle fusions (group B) the same method limitations were present in both groups. Our results clearly showed that ankle alignment of greatly deformed ankles (group B) was corrected to normal in both the frontal (Figure 1, Table 2) and sagittal planes (Table 4), without any significant differences compared to well aligned (group A) arthritic ankles (Tables 2 and 4).

A limitation of the present study is the short followup period (average 21.1 months, range 6 to 68 months). This limits the ability to detect any long-term problems arising from degeneration of the adjacent joints (subtalar, talonavicular, tarsometatarsal). The aim of our study, however, was to assess the efficacy of arthroscopic arthrodesis in deformed arthritic ankles in comparison to arthritic ankles without significant deformity in terms of fusion and complication rate.

Four significantly deformed ankles required an arthroscopically assisted subtalar joint arthrodesis during the same operative setting. Fusion was obtained at the subtalar joint level in all patients. No big series of results of arthroscopic subtalar joint arthrodesis have been published so far. The recognition and enhancement of this technique as well as the development of more advanced technology will certainly allow this arthroscopic subtalar joint arthrodesis technique to mature even further over time.

Our results were consistent with the previously reported low complication rates, absence of limb-threatening complications, and high fusion rates.[3,4,6,8,16–18,26–28] Deformity correction was possible with the arthroscopic technique, and arthroscopic subtalar joint arthrodesis was undertaken when needed. Clinical and radiographic results were equally good, compared to the in-situ arthrodesis group. We advocate the use of the arthroscopic technique for disabling ankle arthritis, including those with marked deformity.

REFERENCES

1. **Buck, P; Morrey, BF; Chao, EY:** The optimum position of arthrodesis of the ankle: a gait study of the knee and ankle. J. Bone Joint Surg. **69-A**:1052–1062, 1987.
2. **Buckingham, RA; Winson, IG; Kelly, AJ:** An anatomical study of a new portal for ankle arthroscopy. J. Bone Joint Surg. **79-B**:650–652, 1997.
3. **Cameron, SE; Ullrich, P:** Arthroscopic arthrodesis of the ankle joint. Arthroscopy **16**:21–26, 2000.
4. **Cannon, LB; Brown, J; Cooke, PH:** Early weight bearing is safe following arthroscopic ankle arthrodesis. Foot Ankle Surg. **10**:135–139, 2004.
5. **Coester, LM; Saltzman, CL; Leupold, J; Pontarelli, W:** Long-term results following ankle arthrodesis for post-traumatic arthritis. J. Bone Joint Surg. **83-A**:219–228, 2001.
6. **Corso, SJ; Zimmer, TJ:** Technique and clinical evaluation of arthroscopic ankle arthrodesis. Arthroscopy **11**:585–590, 1995.
7. **Crosby, LA; Yee, TC; Formanek, TS; Fitzgibbons, TC:** Complications following arthroscopic ankle arthrodesis. Foot Ankle Int. **17**:340–342, 1996.
8. **Ferkel, RD; Hewit, M:** Long-term results of arthroscopic ankle arthrodesis. Foot Ankle Int. **26**:275–280, 2005.
9. **Fitzgibbons, TC:** Arthroscopic ankle debridement and fusion: indications, techniques and results. Instr. Course Lect. **48**:243–248, 1999.
10. **Frey, C; Halikus, NM; Vu-Rose, T; Ebramzadeh, E:** A review of ankle arthrodesis: Predisposing factors to non-union. Foot Ankle **15**:581–584, 1994.
11. **Fuchs, S; Sandmann, C; Skwara, A; Chylarecki, C:** Quality of life 20 years after arthrodesis of the ankle: a study of adjacent joints. J. Bone Joint Surg. **85-B**:994–998, 2003.

12. **Glick, JM; Morgan, CD; Myerson, MS; Sampson, TG; Mann, JA:** Ankle arthrodesis using an arthroscopic method: long-term follow-up of 34 cases. Arthroscopy **12**:428–434, 1996.
13. **Mann, RA; Rongstad, KM:** Arthrodesis of the ankle: a critical analysis. Foot Ankle Int. **19**:3–9, 1998.
14. **Myerson, MS; Quill, G:** Ankle arthrodesis: a comparison of an arthroscopic and an open method of treatment. Clin. Orthop. **268**:84–95, 1991.
15. **Monroe, MT; Beals, TC; Manoli, A:** Clinical outcome of arthrodesis of the ankle using rigid internal fixation with cancellous screws. Foot Ankle Int. **20**:227–231, 1999.
16. **O'Brien, TS; Hart, TS; Shereff, MJ; Stone, J; Johnson, J:** Open versus arthroscopic ankle arthrodesis: a comparative study. Foot Ankle Int. **20**:368–374, 1999.
17. **Ogilvie-Harris, DJ; Lieberman, I; Fitsialos, D:** Arthroscopically assisted arthrodesis for osteoarthritic ankles. J. Bone Joint Surg. **75-A**:1167–1174, 1993.
18. **Saragas, NP:** Results of arthroscopic arthrodesis of the ankle. Foot and Ankle Surg. **10**:141–143, 2004.
19. **Saltzman CL, el-Khoury GY**: The hindfoot alignment view. Foot Ankle Int. **16**:572–576, 1995.
20. **Sheridan, BD; Robinson, DE; Hubble, MJW; Winson, IG:** Ankle arthrodesis and its relationship to ipsilateral arthritis of the hind- and midfoot. J. Bone Joint Surg. **88-B**:206–207, 2006.
21. **Tasto, JP; Frey, C; Laimans, P; et al.:** Arthroscopic ankle arthrodesis. Instr. Course Lect. **49**:259–280, 2000.
22. **Thomas, R; Daniels, TR; Parker, K:** Gait analysis and functional outcomes following ankle arthrodesis for isolated ankle arthritis. J. Bone Joint Surg. **88-A**:526–536, 2006.
23. **Thordarson, DB:** Fusion in posttraumatic foot and ankle reconstruction. J. Am. Acad. Orthop. Surg. **12**:322–333, 2004.
24. **Tochigi, Y; Suh, JS; Amendola, A; Pedersen, DR; Saltzman, CL:** Ankle alignment on lateral radiographs. Part 1: sensitivity of measures to perturbations of ankle positioning. Foot Ankle Int. **27**:82–87, 2006.
25. **Tochigi, Y; Suh, JS; Amendola, A; Saltzman, CL:** Ankle alignment on lateral radiographs. Part 2: reliability and validity of measures. Foot Ankle Int. **27**:88–92, 2006.
26. **Wasserman, LR; Saltzman, CL; Amendola, A:** Minimally invasive ankle reconstruction: current scope and indications. Orthop. Clin. North. Am. **35**:247–253, 2004.
27. **Winson, IG; Robinson, DE; Allen, PE:** Arthroscopic ankle arthrodesis. J. Bone Joint Surg. **87-B**:347–343, 2005.
28. **Zvijac, JE; Lemak, L; Schuhoff, MR; Hechtman, KS; Uribe, JW:** Analysis of arthroscopically assisted ankle arthrodesis. Arthroscopy **18**:70–75, 2002.