Total ankle replacement in association with hindfoot fusion

OUTCOME AND COMPLICATIONS

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We report the clinical and radiological outcome of total ankle replacement performed in conjunction with hindfoot fusion or in isolation. Between May 2003 and June 2008, 60 ankles were treated with total ankle replacement with either subtalar or triple fusion, and the results were compared with a control group of 288 ankles treated with total ankle replacement alone.

After the mean follow-up of 39.5 months (12 to 73), the ankles with hindfoot fusion showed significant improvement in the mean visual analogue score for pain ($p < 0.001$), the mean American Orthopaedic Foot and Ankle Society score ($p < 0.001$), and the mean of a modified version of this score ($p < 0.001$). The mean visual analogue pain score ($p = 0.304$) and mean modified American Orthopaedic Foot and Ankle Society score ($p = 0.119$) were not significantly different between the hindfoot fusion and the control groups. However, the hindfoot fusion group had a significantly lower mean range of movement ($p = 0.009$) and a higher rate of posterior focal osteolysis ($p = 0.04$). Both groups showed various complications ($p = 0.131$) and failure occurring at a similar rate ($p = 0.685$).

Subtalar or triple fusion is feasible and has minimal adverse effects on ankles treated with total ankle replacement up to midterm follow-up. The clinical outcome of total ankle replacement when combined with hindfoot fusion is comparable to that of ankle replacement alone. Thus, hindfoot fusion should be performed in conjunction with total ankle replacement when indicated.

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Malalignment is a major risk factor for early failure in total ankle replacement (TAR), and most authors agree that it needs to be addressed before or simultaneously with any joint replacement.¹⁻⁷ Furthermore, patients with osteoarthritis of the ankle joint frequently have degenerative disease affecting the neighbouring joints.⁸⁻¹⁰ For these reasons, additional procedures are commonly performed, with several papers describing the combination of TAR and subtalar or triple fusion.^{4,11,12}

Subtalar joint or triple fusion are used to correct deformity, relieve pain, achieve a plantigrade foot, and give good results.¹³⁻¹⁸ However, problems arising in adjacent joints are of concern since the loss of mechanism to dissipate forces in the subtalar and midtarsal regions places abnormal stress on the ankle and leads to increased wear or degeneration.^{14,17-21}

If a TAR is implanted in the presence of a fused hindfoot, the prosthesis is theoretically exposed to higher loads. However, how a fused hindfoot affects a TAR and the clinical outcome are poorly understood. Additionally

there are concerns that if the vascularity of the talus is adversely affected, there could be delayed healing and the tolerance for malpositioned components might be affected. Finally, consideration should be given to whether such intervention should be simultaneous or staged, and if isolated, whether subtalar, double or triple fusion should be performed. This study aimed to address the effect of hindfoot fusion on TAR by comparing clinical and radiological outcomes of TARs performed with and without hindfoot fusion.

Patients and Methods

Between May 2003 and June 2008, 362 primary TARs were performed on 347 patients, including 15 patients who underwent bilateral procedures. The indication for surgery was severe pain in an arthritic ankle joint that was refractory to non-operative treatment. The Hintegra (Newdeal SA, Lyon, France) third generation total ankle system was used in all cases. We only included primary replacements, excluding revision procedures and conversion of ankle arthrodesis to TAR. In order to

Table I. Demographic data of the two groups

	Hindfoot fusion group (n = 60 ankles)	Control group (n = 288 ankles)	p-value
Mean (SD) age in years	61.6 (13.6)	61.5 (12.3)	
Male:female ratio	23:37	162:126	< 0.05 [†]
Right:left ratio	31:29	152:136	
Mean (SD) weight in kg	75.7 (19.2)	80.6 (14.9)	< 0.05 [‡]
Mean (SD) height in cm	168.2 (8.6)	171.6 (9.0)	< 0.05 [‡]
Mean (SD) body mass index in kg/m ²	26.7 (6.0)	27.3 (4.1)	
Mean (SD) follow-up in months	36.9 (16.9)	40.1 (18.1)	
Pre-operative diagnosis (%)			
Degenerative OA*	4 (6.7)	16 (5.6)	< 0.005 [†]
Post-traumatic OA	43 (71.7)	253 (87.8)	
Rheumatoid arthritis	8 (13.3)	6 (2.1)	
Other	5 (8.3)	13 (4.5)	
Physical stress at job (%) [¶]			
None	4 (6.7)	4 (1.4)	
Mild	21 (35)	125 (43.4)	
Moderate	26 (43.3)	109 (37.8)	
Hard	9 (15)	50 (17.4)	
Quality of life before operation (%)			
Good	11 (18.3)	78 (27.1)	
Moderate	22 (36.7)	114 (39.6)	
Bad	27 (45)	96 (33.3)	

* OA, osteoarthritis

[†] chi-squared test or Fisher's exact test[‡] two-sample t-test, $p < 0.05$ [¶] quantified with an institutional questionnaire

evaluate the effect of hindfoot fusion, patients who had previously undergone midfoot or forefoot fusion were also excluded. A total of 13 patients (14 ankles) were lost to follow-up: seven patients died, four were from or moved abroad, and two declined to attend for review. The remaining 334 patients (348 TARs) were the basis for the clinical and radiological evaluation of this study, with a mean follow-up of 39.5 months (12 to 73).

These patients were separated into two groups depending on their hindfoot status: hindfoot fusion (TAR with hindfoot fusion; 60 ankles) and a control group (isolated TAR; 288 ankles). Clinical and radiological outcomes, complications and failure rates were compared between the groups. Revision or conversion to arthrodesis was regarded as a failure. The demographic data of the two groups are shown in Table I.

In the hindfoot fusion group, 28 (46.7%) had TAR with isolated subtalar fusion, 29 (48.3%) with subtalar and talonavicular (double) arthrodesis, and three (5.0%) with subtalar, talonavicular and calcaneocuboid (triple) arthrodesis. Hindfoot fusion was performed simultaneously with TAR in 39 ankles (65.0%), while 17 (28.3%) had their hindfoot fused at a mean of 8 years (0.25 to 38) before TAR, and four (6.7%) had hindfoot fusion at a mean of 14.3 months (8 to 23) after TAR. The indications for hindfoot fusion were correction of deformity in 23 ankles

(38.3%, 14 varus and nine valgus malalignment), post-traumatic osteoarthritis in 20 (33.3%), primary osteoarthritis in eight (13.3%), and other causes in nine (15%, six rheumatoid arthritis, two gouty arthropathy, one haemophilia).

Additional surgeries. TAR was performed using a standard surgical technique,^{10,22} and in the presence of malalignment or ligamentous instability, appropriate additional procedures were conducted before or together with TAR as shown in Table II.

Clinical evaluation. All patients were evaluated pre-operatively and at two weeks, six weeks, three months, six months and one year post-operatively and annually thereafter. Clinical evaluations were performed by a research assistant (LZ) who was not involved in the surgery.

Pain was rated using the visual analogue scale (VAS) ranging from 0 (no pain) to 10 (maximum pain). The range of movement (ROM) of the ankle-hindfoot complex was measured using a goniometer along the lateral border of the leg and foot. The American Orthopaedic Foot and Ankle Society (AOFAS) ankle and hindfoot scoring system²³ was used to evaluate the function. We also modified this score¹⁹ by excluding the hindfoot movement (six points) since this is always eliminated after hindfoot fusion. The modified AOFAS score was thus composed of 94 points, allowing us to compare the function status of the two groups without the

Table II. Associated procedures performed together with primary total ankle replacement

	Hindfoot fusion group	Control group	p-value*
Osteotomies (%)	10 (16.7)	24 (8.3)	0.057
Calcaneal osteotomy	7	9	
Supramalleolar osteotomy	0	6	
Medial malleolar osteotomy	0	1	
Metatarsal osteotomy	1	4	
Cuneiform osteotomy	2	2	
Tibial osteotomy	0	1	
Fibular osteotomy	0	1	
Ligament/tendon procedures (%)	14 (23.3)	53 (18.4)	0.372
Medial augmentation	0	1	
Medial and lateral augmentation	1	1	
Peroneus longus transfer	2	6	
Posterior tibialis transfer	0	2	
Flexor digitorum longus transfer	0	1	
Flexor hallucis longus transfer	0	1	
Tendo Achillis lengthening	11	42	

* chi-squared test or Fisher's exact test

Fig. 1

Diagram showing contact point ratio with the foot in neutral position. The apex of the talar component or the point corresponding to the talar dome indicates the central area of contact with the tibial component. The contact point ratio is the ratio of the contact point of the talar component (A) to the length of the tibial loading plate (A+B). The desired contact point is between 40% and 45%.

confounding variable of hindfoot fusion. Patients were also asked to indicate their quality of life as either good, moderate or bad, state their satisfaction with the procedure on a categorical scale of very satisfied, satisfied, satisfied with reservations and dissatisfied, and whether he/she would receive the same operation again in a similar situation.

Radiological evaluation. Weight-bearing true anteroposterior (AP) and lateral views were obtained fluoroscopically at each visit. Serial radiographs were evaluated to determine the position of the components, presence of any loosening defined as a change in position $> 2^\circ$ and for a progressive

radiolucency of > 2 mm in either view,⁴ heterotopic ossification and osteolysis. Angular and linear values were measured using Image Access special metric software (PIC Systems AG, Glattbrugg, Switzerland). In order to evaluate the sagittal balance of the replaced ankle and the relocation of the talus within the mortise, we measured the contact point ratio¹⁰ on standing radiographs immediately after surgery and at the last follow-up. This is a ratio of the contact point of the talar component to the length of the tibial loading plate; the optimal contact point ratio is between 40% and 45% (Fig. 1).¹⁰ The pre-operative varus or valgus angulation of the ankle was measured between the anatomical axis of the tibia and a line perpendicular to the articular surface of the talus.⁵ Malposition of the tibial component was defined as the placement of the component with an angular deviation $> 5^\circ$ to the longitudinal tibial axis.²²

Statistical analysis. Statistical data were analysed by using SPSS version 15.0 software (SPSS Inc., Chicago, Illinois). A paired *t*-test was used to evaluate the clinical changes before and after surgery. For a comparison of the outcomes between the two groups, a two-sample *t*-test for continuous variables and a chi-squared (or Fisher's exact, as appropriate) test for nominal data were used. A *p*-value < 0.05 was considered significant.

Results

Pain in the ankle in the hindfoot fusion group was significantly reduced ($p < 0.001$), and there was no difference in the mean VAS compared to the control group, both pre-operatively ($p = 0.587$) and at final follow-up ($p = 0.304$) (Table III).

Ankles in the hindfoot fusion group showed significant improvement in both the AOFAS ($p < 0.001$) and the modified AOFAS score ($p < 0.001$) (Table III). When compared with the control group, the AOFAS score of the hindfoot fusion group was lower before the operation ($p < 0.001$)

Table III. Clinical assessment (mean, SD) of the two groups

	Hindfoot fusion group	Control group	p-value
Visual analogue scale			
Pre-operative	6.8 (2.0)	6.7 (1.8)	0.587 [†]
Last follow-up	2.5 (2.1)	2.8 (2.4)	0.304 [†]
Improvement	4.4 (2.6)	4.0 (3.0)	0.351 [†]
p-value	< 0.0001 [‡]	< 0.0001 [‡]	
AOFAS [*] score			
Pre-operative	35.5 (16.4)	44.4 (16.5)	< 0.0001 [†]
Last follow-up	66.6 (17.7)	73.4 (18.2)	0.011 [†]
Improvement	31.1 (22.6)	30.2 (23.1)	0.788 [†]
p-value [‡]	< 0.0001 [‡]	< 0.0001 [‡]	
Modified AOFAS score			
Pre-operative	32.0 (16.6)	41.4 (16.7)	< 0.0001 [†]
Last follow-up	66.6 (17.7)	70.7 (17.7)	0.119 [†]
Improvement	34.7 (22.7)	30.3 (22.9)	0.205 [†]
p-value	< 0.0001 [‡]	< 0.0001 [‡]	
Range of movement			
Pre-operative	25.0 (12.8)	30.14 (15.3)	0.007 [†]
Last follow-up	29.5 (10.6)	34.3 (10.6)	0.009 [†]
Improvement	4.1 (17.7)	3.4 (14.9)	0.786 [†]
p-value	0.141 [‡]	0.001 [‡]	
Satisfaction (%)			
Very satisfied	25 (41.7)	105 (36.5)	0.707 [§]
Satisfied	21 (35.0)	120 (41.7)	
Satisfied with reservation	11 (18.3)	41 (14.2)	
Dissatisfied	3 (5.0)	22 (7.6)	
Quality of life (%)			
Good	32 (53.3)	185 (64.2)	0.303 [§]
Moderate	21 (35.0)	79 (27.4)	
Bad	7 (11.7)	24 (8.3)	
Repetition of operation (%)			
Yes	55 (91.7)	267 (92.7)	0.780 [§]
No	5 (8.3)	21 (7.3)	

* AOFAS, American Orthopaedic Foot and Ankle Society

† two-sample *t*-test‡ paired *t*-test, comparing the pre-operative and last follow-up value

§ chi-squared test or Fisher's exact test

and at the final follow-up ($p = 0.011$). However, the modified AOFAS score showed no significant difference with the control group at final follow-up ($p = 0.119$).

The ROM of the ankle of the hindfoot fusion group was significantly less pre-operatively ($p = 0.007$) and post-operatively ($p = 0.009$) compared to the control group, and was not significantly improved after the operation ($p = 0.141$) (Table III). While the ROM of the control group was significantly improved ($p < 0.001$), the mean amount of gained movement of 3.4° (SD 14.9) was similar to the mean gain in the hindfoot fusion group of 4.1° (SD 17.7; $p = 0.786$).

The two groups showed a similar distribution of level of satisfaction ($p = 0.707$), with less than 10% of dissatisfied patients in each group. Likewise, a similar proportion of patients in the hindfoot fusion (88.3%) and control groups

(91.6%) rated their quality of life as good or moderate ($p = 0.303$) (Table III). Over 90% of patients in each group would undergo the same operation again.

The hindfoot fusion group was further analysed to compare the clinical outcomes of isolated subtalar fusion ($n = 28$) with double or triple fusion ($n = 32$). No differences were observed between the two subgroups in all clinical measures, including post-operative VAS ($p = 0.262$), AOFAS score ($p = 0.359$), modified AOFAS score ($p = 0.359$), and range of ankle movement ($p = 0.983$).

Radiologically, focal osteolysis around the posterior tip of the tibial locking plate occurred more often in the hindfoot fusion group than the control group ($p = 0.04$) (Table IV). There was also a tendency towards more bony overgrowth around components in the hindfoot fusion group,

Table IV. Details (mean, SD) of the radiological findings of the two groups

	Hindfoot fusion group	Control group	p-value
α angle (°)	88.6 (2.7)	87.8 (7.9)	0.456*
β angle (°)	87.4 (3.4)	87.2 (6.0)	0.874*
Focal radiolucency (%)	13 (24.1)	35 (12.8)	0.055†
Posterior focal osteolysis (%)	11 (18.3)	26 (9)	0.040†
Heterotopic ossification (%)	8 (14.8)	38 (13.9)	0.832†
Bony overgrowth around component (%)	22 (40.7)	76 (27.7)	0.073†

* two-sample t-test

† chi-squared test or Fisher's exact test

Table V. Relocation of talus; by contact point ratio (mean, SD)

	Hindfoot fusion group	Control group	p-value*
All (n = 348)			
Post-operative	38.8 (6.9)	42.2 (6.4)	0.002
Last follow-up	41.3 (5.6)	43.4 (6.5)	0.051
p-value†	0.002	0.137	
Anterior facing (posterior slope angle‡ < 86°, n = 106)			
Post-operative	37.3 (7.0)	42.7 (5.9)	0.003
Last follow-up	38.6 (4.9)	44.3 (6.1)	0.001
p-value†	0.399	0.076	
Neutral (posterior slope angle: 86° to 90°, n = 191)			
Post-operative	40.3 (6.5)	43.1 (6.1)	0.087
Last follow-up	42.8 (5.6)	43.8 (7.2)	0.549
p-value†	0.027	0.707	
Posterior facing (posterior slope angle > 90°, n = 51)			
Post-operative	37.3 (7.4)	40.2 (7.3)	0.301
Last follow-up	42.6 (5.4)	41.3 (5.9)	0.575
p-value†	0.009	0.301	

* two-sample t-test

† paired t-test, comparing the post-operative and last follow-up value

‡ posterior slope angle, the anterior angle on the lateral view, between the longitudinal axis of the tibia and the articulating surface of the tibial component

but this did not reach statistical significance ($p = 0.073$). Heterotopic ossification was observed in both groups with a similar incidence ($p = 0.832$).

Three ankles (5%) in the hindfoot fusion group and ten ankles (3.5%) in the control group had pre-operative varus or valgus of the ankle of $> 15^\circ$. The pre-operative coronal deformity at the ankle joint did not have an association with the clinical outcome within the hindfoot fusion group (post-operative mean VAS ($p = 0.510$), the mean AOFAS score ($p = 0.471$), the mean modified AOFAS score ($p = 0.471$), mean range of ankle movement ($p = 0.370$)) and the control group (post-operative mean VAS ($p = 0.967$), mean AOFAS score ($p = 0.895$), mean modified AOFAS score ($p = 0.876$), mean range of ankle movement ($p = 0.857$)).

Four ankles (6.7%) in the hindfoot fusion group and 22 ankles (7.6%) in the control group had a malpositioned tibial component. We compared the malpositioned ankles, and found no difference in the mean post-operative VAS of 1.25 (SD 1.89) in the hindfoot fusion group *vs* a mean of 3.05 (SD 2.19) in the control group ($p = 0.139$). Similarly

the mean AOFAS scores of 70.5 (SD 13.0) *vs* 72.7 (SD 20.7) for the two groups respectively were not significantly different ($p = 0.839$), and likewise the mean modified AOFAS scores of 70.5 (SD 13.0) *vs* 69.5 (SD 19.6), respectively, were not significantly different ($p = 0.920$). Four malpositioned ankles in the control group had focal osteolysis around the tibial component, but none of them progressed to failure.

The talus or the hindfoot complex was anteriorly subluxated in the hindfoot fusion group with a mean contact point ratio of 38.8% (SD 6.9) in the first post-operative standing lateral radiograph (Table V). However, the hindfoot complex was relocated within the mortise with a mean contact point ratio of 41.3% (SD 5.6) at final follow-up. Such relocation of the talus was only observed in ankles in the hindfoot fusion group, and especially in those with the posterior slope angle $> 86^\circ$.²²

Complications and revision operations. Various complications developed in both groups, but there was no significant difference in the complication rates ($p = 0.131$) (Table VI).

Table VI. Complications and failures

	Hindfoot fusion group	Control group	p-value*
Overall complications (ankles, %)	14 (23.3)	44 (15.3)	0.131
Painful arthrofibrosis (%)	6 (10)	16 (5.6)	0.239
Bony impingement (%)	3 (5)	13 (4.5)	0.745
Component loosening (%)	3 (5)	7 (2.4)	0.386
Instability/polyethylene dislocation (%)	3 (5)	3 (1)	0.066
Osteolytic cyst formation (%)	1 (1.7)	2 (0.7)	0.434
Malleolar fatigue fracture (%)	0 (0)	2 (0.7)	1.0
Wound healing problems (%)	0 (0)	2 (0.7)	1.0
Intra-articular infection (%)	2 (3.3)	1 (0.3)	0.078
Failure (%)	2 (3.3)	8 (2.8)	0.685
Component revision	1	4	
Ankle arthrodesis	1	4	

* chi-squared test or Fisher's exact test

Table VII. Complications and failures by the timing of hindfoot fusion

	Hindfoot fusion group		p-value*
	Simultaneous fusion (n = 39)	Two-stage fusion (n = 21)	
Overall complications (ankles, %)	6 (15.4)	8 (38.1)	0.061
Prosthesis-related problems	4 (10.3)	3 (14.3)	0.687
Instability/polyethylene dislocation	3 (7.7)	0 (0.0)	
Component loosening	1 (2.6)	2 (9.5)	
Osteolysis	0 (0)	1 (4.8)	
Soft tissue-related or secondary problems	3 (7.7)	6 (28.6)	0.054
Scarring/arthrofibrosis	2 (5.1)	4 (19.0)	
Bony impingement	1 (2.6)	2 (9.5)	
Intra-articular infection	1 (2.6)	1 (4.8)	
Wound healing problems	0 (0)	0 (0)	
Failure (%)	1 (2.6)	1 (4.8)	1.0

* chi-squared test (Fisher's exact test)

We also evaluated the complication rates depending on the timing of hindfoot fusion, whether performed simultaneously with TAR or separately. There was a tendency towards more frequent development of soft-tissue related or secondary problems including scarring and bony impingement in the two-stage fusion group ($p = 0.054$), whereas instability or dislocation of the polyethylene component occurred only in the simultaneous fusion group (Table VII).

No significant difference was observed in the cumulative failure rate between the two groups ($p = 0.685$) (Table VI). A total of two ankles (3.3%) in the hindfoot fusion group and eight ankles (2.8%) in the control group underwent revision (Table VIII). The reason for failure was aseptic loosening in seven ankles, painful arthrofibrosis in two ankles and dislocation of the polyethylene component in one. In five TARs the revision was managed by changing the metallic component, while the other five were converted to an arthrodesis.

Discussion

This study presents, to the best of our knowledge, the first clinical report of TAR performed in conjunction with fusion of the hindfoot. The outcomes in the hindfoot fusion group were generally satisfactory and no worse than those in the control group. Significant improvements were

observed in most clinical parameters in both groups, including VAS, AOFAS score and modified AOFAS score. The modified AOFAS score was significantly lower in the hindfoot fusion group before the operation but improved to a degree comparable to the control group at final follow-up. This revealed that other than hindfoot inversion and eversion, the function of the replaced ankle and the hindfoot complex in the hindfoot fusion group was equivalent to that of the control group. The two groups showed no difference in terms of satisfaction, self-rated quality of life and willingness to undergo the same operation again. The complication rate and the cumulative failure rate in the hindfoot fusion group were not higher than those of the control group. However, a high rate of posterior focal osteolysis was observed in the hindfoot fusion group, suggesting accelerated wear of polyethylene which might prejudice the long-term outcome. Whether this finding is the result of the loss of a compensatory function of the subtalar joint²⁴ such that a slight degree of malalignment can lead to the eccentric transmission of force,²⁵ accelerating polyethylene wear and producing osteolysis,²⁶ could not be confirmed in this series, since focal osteolysis around the malpositioned tibial component was only observed in four (18.2%) of 22 ankles in the control group and none in the hindfoot fusion group.

Table VIII. Details of revised cases

Gender	Age (yrs)	Group	Months to failure	Reason for failure	Primary revision	Prognosis
F	77	Hindfoot fusion	11	Aseptic loosening of the tibial component	Revision of tibial component	Good
M	68	Control	15	Aseptic loosening of the tibial component	Revision of tibial component	Good
F	67	Control	18	Aseptic loosening of the tibial component	Arthrodesis	Good
F	64	Hindfoot fusion	22	Aseptic loosening of the tibial component	Arthrodesis	Good
M	51	Control	24	Painful arthrofibrosis	Arthrodesis	Good
F	59	Control	26	Recurrent polyethylene component dislocation	Arthrodesis	Good
M	72	Control	26	Aseptic loosening of the tibial component	Revision of tibial component	Good
M	59	Control	27	Aseptic loosening of the tibial component	Revision of tibial component	Supramalleolar osteotomy due to valgus malalignment
M	25	Control	50	Aseptic loosening of the tibial and talar components	Revision of tibial and talar components	Converted to arthrodesis due to recurrent loosening
F	48	Control	58	Painful arthrofibrosis	Arthrodesis	Good

We believe that several factors contributed to the finding that the outcome for replaced ankles in the hindfoot fusion group was not inferior to that for the control group. One is the role of the mobile bearing. The function of the subtalar joint in mechanically coupling the foot and the tibia involves transformation of rotation into calcaneal eversion-inversion and vice versa.²⁷ Interestingly, this transfer of movement does not substantially decrease after subtalar fusion as the ankle joint provides a significant part of this transfer of movement.²⁸ In a replaced ankle, the flat surfaces between the polyethylene bearing and the tibial component allow a certain degree of rotation. We speculate that this plays an important role in the transfer of movement between the calcaneum and the tibia in ankles with a fused hindfoot.

Another factor is the compensatory increase in ROM at the knee. The loss of the dynamic function of the subtalar and transverse tarsal joints results in a rigid mid- and hindfoot and reduces the ROM of the ankle.^{29,30} However, gait analysis has revealed that reduced movement of the ankle is compensated by increased flexion of the knee and greater knee extension moments.^{29,30} Fixation of the tibial component independently of the fusion of the syndesmosis can also contribute to the low failure rate by minimising the effects of hindfoot fusion. Hindfoot fusion increases the displacement across the anterior tibiofibular ligament, and can cause failure of designs that rely on syndesmosis fusion such as the Agility system (DePuy, Warsaw, Indiana).³¹ Therefore, preserving the normal anatomy of the syndesmosis can be important if TAR is combined with hindfoot fusion.

We had conflicting results concerning the timing of any hindfoot fusion on the outcome of TAR. Soft-tissue related or secondary problems, including scarring and bony impingement, tended to develop more frequently with two-staged fusion ($p = 0.054$), whereas instability or dislocation of the polyethylene were observed only in the simultaneous fusion group. Concerning the extent of fusion, isolated talonavicular fusion was not performed despite its effec-

tiveness in the correction of deformity³² either because most of our cases with endstage osteoarthritis of the ankle had associated adjacent arthritis primarily involving the subtalar joint, or because they had deformities requiring isolated subtalar or combined subtalar and talonavicular fusion.³³ Fusion of the calcaneocuboid joint was added only when there was arthritis of this joint because sparing the joint has advantages in reducing operative time, risk of nonunion,^{15,34} and further adjacent joint arthritis.^{33,35} TAR with isolated subtalar fusion and double or triple fusion showed similar results. This can be related to the similar gait patterns after isolated subtalar *vs* triple fusion as fusion of the subtalar joint also decreases the movement of the talonavicular and calcaneocuboid joints.^{35,36} We were also concerned about the possible development of osteonecrosis of the talus and subsequent loosening of the talar component in the hindfoot fusion group due to aggressive denuding and devascularisation up to the sinus tarsi during subtalar fusion. Fortunately, osteonecrosis of the talus did not occur, and the one case (0.3%) of loosening of the talar component was in the control group.

It was interesting to note in the hindfoot fusion group that the hindfoot complex was anteriorly displaced immediately after surgery, but was relocated to the mortise at the last follow-up. This change in the contact point ratio < 40 can be explained by a small amount of shortening that occurs in the process of fusion. The relocation of the talar component is mainly due to the realignment of the ligaments that help to restore the normal axis of rotation as described by Wood et al.⁶ Furthermore, this restoration in the sagittal plane is blocked when the tibial component is placed facing anteriorly. Therefore, the surgeon should take care not to increase the posterior slope, especially in patients undergoing subtalar fusion.

Our results should be interpreted with caution. Firstly, there were some differences in the demographics of the two groups with the mean height and weight being lower in the hindfoot fusion group, as there were more women in this group compared with the control group ($p = 0.015$). How-

ever, the body mass index was similar between the groups. Furthermore the different gender distribution seemed to be related to the aetiology of the arthritis, with the proportion of rheumatoid arthritis being higher in the hindfoot fusion group, and we believe that this is partially related to the characteristics of rheumatoid arthritis involving multiple joints. Since the results of TAR in rheumatoid patients are reported to be good³⁷ or not inferior to those in patients with osteoarthritis,³⁸ we assumed that the different distribution of aetiology would not seriously compromise our findings. Another important limitation is that the pre-operative status of the two groups was different. Thus, comparing the outcomes of the two groups could be questioned. However, since it is apparent that ankles requiring simultaneous hindfoot fusion had more complex problems and worse pre-operative function, improvement to a level equivalent to the control group is meaningful. Furthermore, the modified AOFAS score¹⁹ has been used to account for the loss of movement in the subtalar joint but we accept this has not been validated and may not be ideal for the assessment of the ankle and fused hindfoot complex.

In conclusion, hindfoot fusion is feasible, even simultaneously with TAR, and has minimal adverse effect on TAR up to midterm follow-up. The clinical outcomes of TAR with hindfoot fusion are comparable to those of TAR alone. Thus, hindfoot fusion should be performed in conjunction with TAR when indicated.

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