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John S. Lewis Jr., MD[1], Samuel B. Adams Jr., MD[1], Robin M. Queen, PhD[1], James K. DeOrio, MD[1], James A. Nunley, MD[1], and Mark E. Easley, MD[1]

Abstract

Background: Ipsilateral hindfoot arthrodesis in combination with total ankle replacement (TAR) may diminish functional outcome and prosthesis survivorship compared to isolated TAR. We compared the outcome of isolated TAR to outcomes of TAR with ipsilateral hindfoot arthrodesis.

Methods: In a consecutive series of 404 primary TARs in 396 patients, 70 patients (17.3%) had a hindfoot fusion before, after, or at the time of TAR; the majority had either an isolated subtalar arthrodesis (n = 43, 62%) or triple arthrodesis (n = 15, 21%). The remaining 334 isolated TARs served as the control group. Mean patient follow-up was 3.2 years (range, 24-72 months).

Results: The SF-36 total, AOFAS Hindfoot-Ankle pain subscale, Foot and Ankle Disability Index, and Short Musculoskeletal Function Assessment scores were significantly improved from preoperative measures, with no significant differences between the hindfoot arthrodesis and control groups. The AOFAS Hindfoot-Ankle total, function, and alignment scores were significantly improved for both groups, albeit the control group demonstrated significantly higher scores in all 3 scales. Furthermore, the control group demonstrated a significantly greater improvement in VAS pain score compared to the hindfoot arthrodesis group. Walking speed, sit-to-stand time, and 4-square step test time were significantly improved for both groups at each postoperative time point; however, the hindfoot arthrodesis group completed these tests significantly slower than the control group. There was no significant difference in terms of talar component subsidence between the fusion (2.6 mm) and control groups (2.0 mm). The failure rate in the hindfoot fusion group (10.0%) was significantly higher than that in the control group (2.4%; $p < 0.05$).

Conclusion: To our knowledge, this study represents the first series evaluating the clinical outcome of TARs performed with and without hindfoot fusion using implants available in the United States. At follow-up of 3.2 years, TAR performed with ipsilateral hindfoot arthrodesis resulted in significant improvements in pain and functional outcome; in contrast to prior studies, however, overall outcome was inferior to that of isolated TAR.

Level of Evidence: Level II, prospective comparative series.

Keywords: total ankle replacement, hindfoot arthrodesis, arthritis

To maximize outcome after total ankle replacement (TAR), it is imperative to achieve a stable, neutrally aligned, plantigrade, weight-bearing position of the ankle and hindfoot postoperatively.[10] Malalignment is major risk factor for early failure of TAR,[12,14,15,29] and most authors agree that it must be corrected either prior to or at the time of joint replacement.[8,10,12,14-16] Furthermore, patients who develop osteoarthritis in the tibiotalar joint often have degenerative disease in neighboring joints.[16] Subtalar or triple fusion is sometimes performed in the setting of TAR to correct deformity and/or address degenerative joint disease in the hindfoot.[13,15,25] When performing a TAR in combination with a hindfoot fusion, Frigg et al[11] showed the optimal position of the hindfoot to be neutral or in minimal varus in relation to the mechanical axis of the tibia as determined by a hindfoot alignment view radiograph.

Although hindfoot fusion can be a powerful tool to correct deformity and eliminate pain, the manner in which a fused hindfoot affects the survivorship and function of a TAR remains unclear.[13] There is concern that loss of motion

[1]Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC, USA

Corresponding Author:
John S. Lewis Jr., MD, Department of Orthopaedic Surgery, Duke University Medical Center, 200 Trent Dr, Box 3000, Durham, NC 27710, USA.
Email: john.lewis@duke.edu

Table 1. Patients With Total Ankle Replacement and Ipsilateral Hindfoot Arthrodesis.

	Timing of Arthrodesis in Relation to Total Ankle Replacement (TAR)		
Type of Arthrodesis	Prior to TAR	Simultaneous to TAR	Subsequent to TAR
Subtalar (n = 43; 62%)	9	28	6
Triple (n = 15; 21%)	14	1	—
Talonavicular (n = 10; 14%)	1	8	1
Talonavicular/calcaneocuboid (n = 1; 1%)	1	—	—
Subtalar/calcaneocuboid (n = 1; 1%)	1	—	—
Total (n = 70)	26	37	7

in the hindfoot and/or talonavicular joint places abnormal stress on the ankle joint and will thus lead to increased early wear or degeneration of an ankle prosthesis.[7,9,16,19,22] Furthermore, any compromise of the vascularity of the talus could lead to early component subsidence and malposition.[16] Finally, there is no consensus as to the timing of these procedures, either staged or synchronous, or whether triple arthrodeses confer a greater risk of adverse events than less complete hindfoot fusions.[16]

One series has shown that at midterm follow-up, hindfoot fusion in association with ipsilateral TAR has minimal adverse effects with clinical and radiographic outcomes similar to that of primary TAR alone.[16] This investigation, however, used components not available in the United States. There are currently no published series evaluating the outcome of implants in this setting that include prostheses available in the United States. This study compares the clinical and functional outcome of primary TAR in patients with hindfoot arthrodesis to that of patients who had a primary TAR without hindfoot fusion using components commercially available in the United States and approved or cleared for use by the Food and Drug Administration (FDA).

Methods

After receiving appropriate Institutional Review Board approval, we prospectively identified a consecutive series of 404 primary TARs in 396 patients that occurred between June 2007 and June 2011 and were followed for a minimum of 2 years. All surgeries were performed at a single institution by orthopaedic foot and ankle surgeons with previous TAR experience. The indication for surgery was severe pain in an arthritic tibiotalar joint that had failed appropriate nonoperative management. All patients signed informed consent prior to study initiation. The INBONE (Wright Medical, Arlington, TN, USA), Scandinavian Total Ankle Replacement (STAR; Small Bone Innovations, Morrisville, NJ, USA), and Salto-Talaris (Tornier, Bloomington, MN, USA) third-generation total ankle prostheses were implanted at the discretion of the operating surgeon. Only primary arthroplasty procedures were included; patients were excluded from the study if they were undergoing revision procedures or conversions of prior ankle arthrodeses to TAR. As in the study by Kim et al,[16] to evaluate the effect of hindfoot fusion on TAR, all patients who had undergone prior midfoot or forefoot fusions were also excluded.

Table 2. Patient Characteristics.

	Control Group	Fusion Group	*P* Value
Patients	334	70	
Follow-up (months)	37.5 ± 15.2	38.4 ± 15.8	.648
Mean age (years)	62.8 ± 11.3	61.5 ± 12.6	.252
Body mass index (kg/m^2)	29.5 ± 5.5	28.7 ± 4.7	.256
Male:female ratio	1.00:0.96	1.00:1.06	.706
Primary diagnosis			<.001
a. Posttraumatic arthritis	74.0%	50.0%	
b. Osteoarthritis	16.4%	17.1%	
c. Rheumatoid arthritis	3.6%	14.0%	
d. Other	5.7%	18.5%	
Right:left ankle affected	1.00:0.78	1.00:0.52	.143
Prosthesis			.001
a. STAR	103 (30.8%)	19 (27.1%)	
b. INBONE	163 (48.9%)	48 (68.6%)	
c. Salto-Talaris	68 (20.4%)	3 (4.3%)	

Of the 404 ankle replacements performed, we identified 70 (17.3%) that had an ipsilateral hindfoot arthrodesis (Table 1): 43 (62%) had an isolated subtalar arthrodesis, 15 (21%) had a triple arthrodesis, 10 (14%) had an isolated talonavicular (TN) arthrodesis, 1 had a combined TN/calcaneocuboid arthrodesis, and 1 had a combined subtalar/calcaneocuboid arthrodesis. The remaining 334 isolated TARs served as the control group. Clinical and functional outcomes, gait analyses, complications, radiographic outcomes, and failure rates were compared. Revision arthroplasty requiring removal of one or more metallic components or conversion to ankle arthrodesis was regarded as a failure for the purposes of this study.

Mean patient follow-up was 3.2 years (range, 24-72 months), with average patient age in the control group 62.8 years compared to 61.5 in the fusion group (Table 2). Age, mean follow-up, and body mass index (BMI) were not

significantly different between the 2 patient groups. The most common primary diagnosis in the control group was posttraumatic arthritis of the ankle (74%), followed by osteoarthritis (16.4%) and rheumatoid arthritis (3.6%), with the remainder composed of a variety of other etiologies (5.7%). Similarly, posttraumatic arthritis was the primary diagnosis in 50.0% of the patients in the hindfoot fusion group, followed by osteoarthritis (17.1%), rheumatoid arthritis (14.0%), and other etiologies (18.5%). Prosthesis choice in the fusion group included 19 (27.1%) STAR, 48 (68.6%) INBONE, 3 (4.3%) Salto-Talaris; in the control group, the distribution was 103 (30.8%) STAR, 163 (48.9%) INBONE, and 68 (20.4%) Salto-Talaris.

TARs were performed using a standard operative technique for each respective implant.[1,6,10,23] At the time of arthroplasty, any additional procedures required to achieve a balanced prosthesis and plantigrade foot, including osteotomy, arthrodesis, tendon transfer, or heel cord lengthening, were performed as deemed necessary by the operating surgeon. All patients were evaluated preoperatively at 3 weeks, 6 weeks, and 3 months postoperatively; clinical outcome assessments were made at 6 months and 1 year postoperatively, and annually thereafter.

Patient-Reported Outcomes

Pain was rated using the Visual Analog Scale (VAS), ranging from 0 (*no pain*) to 100 (*maximum pain*). The American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot-ankle scoring system[17] was used to evaluate function. The Short Form–36 (SF-36) was used to assess overall patient health, and the Foot and Ankle Disability Index (FADI) and Short Musculoskeletal Function Assessment (SMFA) questionnaires were used to assess patient-reported functional limitations.[26] The FADI asks 26 questions about activities of daily living and has previously been reported in an ankle arthritis population.[15] The SMFA is a 46-item questionnaire divided into the Dysfunction (or Function) index, which assesses patient function, and the Bother index, which evaluates how much patients are bothered by functional limitations; the metric has been validated for use in patients with musculoskeletal disease or injury.[26]

Functional Outcomes

The functional assessments that were completed were a 5 repetition sit-to-stand, timed get up and go, the 4-square step test, and walking speed. During the sit-to-stand test patients were asked to sit in a standard arm chair and then to stand up and sit down 5 times as quickly as possible. The patients were asked to complete this task 2 times and the average sit-to-stand time was recorded. For the timed get up and go test, patients were asked to start in a seated position in a standard arm chair. The patient was then asked to stand up and walk 3 meters around a piece of tape and then return back to the chair and sit down. The patient was asked to complete this as quickly as possible safely. The time was recorded from the time the patient stood up until they sat back down in the chair. Again, this task was completed 2 times and the average time was used for data analysis. The next functional test that was completed was the 4-square step test, which was performed using standard techniques that have been previously described.[28] The 4-square step test was completed 2 times and the average of the 2 times was used for analysis. Finally, all subjects were asked to complete a series of 5 walking trials along a 10 meter walkway. Walking speed was recorded during the middle 5 meters of the walk using a series of timing gates. The average walking speed was determined from the 5 walking trials and was used for analysis.

Radiographic Analysis

As previously noted, there is concern that placement of a arthroplasty component on a talus previously instrumented in a hindfoot arthrodesis may further compromise the vascularity of the talus and lead to early component subsidence and malposition.[16] A subset of 35 of the 70 ankles in the hindfoot arthrodesis group were paired with an exact age-, sex-, and implant-matched cohort of 35 ankles in the control group. To objectively and reproducibly determine the position of the talar component in a qualitative manner, we used the inferior (plantar) calcaneal border as a fixed reference point, as other common anatomic features sometimes used to assess talar component position such as the calcaneal tuberosity[2] are obliterated in many hindfoot fusions. Using the PACS (General Electric; Fairfield, CT, USA) virtual imaging software utilized at our institution, a line was drawn along the longitudinal axis of the talar component (Figure 1). A perpendicular line was drawn from the exact midpoint of this line and extended through the inferior calcaneal border. The point at which this crossed the inferior calcaneal border was marked, and the distance from this point to the midpoint of the longitudinal axis of the talar component was measured. This measurement was repeated on the weight-bearing radiographs at most recent follow-up. Any interval decrease in this height was defined as the talar component subsidence.

To control for talar component loosening and subsequent flexion or extension on the talus, which would thus change the position of the reference point on the inferior calcaneal border, a modified gamma angle[2,3] was also calculated for each radiograph. This was calculated by the intersection of the long axis of the talar component with a line drawn from the posterior talar component through the middle of the talar neck (Figure 1). The gamma angle from the immediate postoperative radiograph was compared to that on the most recent follow-up radiograph to detect any change in sagittal plane alignment.

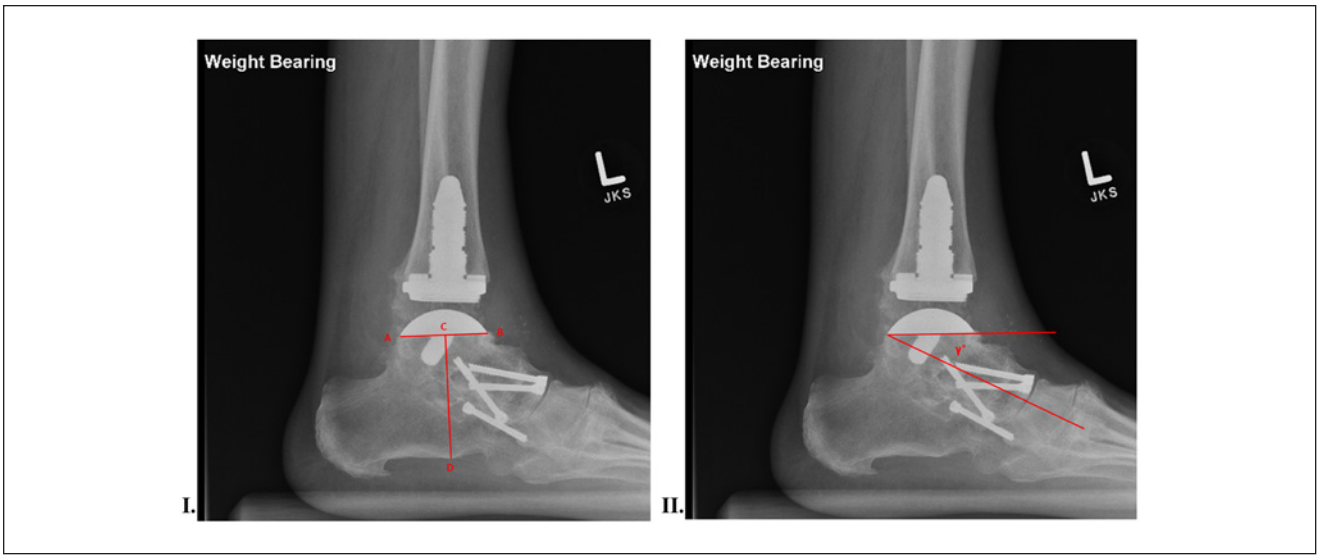

Figure 1. Radiographic analysis of talar component position. (I) To determine component subsidence, a line was drawn along the longitudinal axis of the talar component (line AB). The midpoint of this line was calculated (point C). A line perpendicular to line AB was drawn from point C to the inferior calcaneal border (line CD). The distance of line CD was compared between the first weight-bearing postoperative radiographs and the radiographs at most recent follow-up. (II) To determine talar component loosening, the angle formed by the longitudinal axis of the talar component and a line drawn from the most posterior aspect of the component through the center of the talar neck was calculated (angle γ).

Statistical Methods

The demographic data were analyzed using an independent samples *t* test to determine if any differences existed in age, BMI, or follow-up time between the control group and the hindfoot fusion group. To determine if differences existed between the operative groups with regard to the operative side, gender, and primary diagnosis a chi-square analysis was completed. In addition, a series of 2 × 3 repeated measures ANOVA were completed to determine if any significant differences existed between time points (preoperative, 1-year postoperative, and the most recent follow-up) and between the operative groups (control versus hindfoot fusion). The level of significance for all tests was set at $P < .05$. Significant differences were then assessed using Tukey's post hoc testing to determine which time points were significantly different. All statistical analyses were performed using SPSS version 20.0 (Chicago, IL, USA).

Results

Radiographic and clinical evaluation suggested all hindfoot arthrodeses progressed to fusion. The SF-36 total and subscales, AOFAS Hindfoot-Ankle Pain subscale, FADI, and SMFA Function and Bother index scores were significantly improved at the most recent follow-up after TAR compared to preoperative assessment (all *P* values < .001), with no significant differences between the hindfoot arthrodesis and control groups (Table 3). The SF-36 total score improved from 48.6 to 67.4 ($P < .001$) in the hindfoot fusion group compared an increase from 49.7 to 73.1 ($P < .001$) in the control group. The AOFAS Hindfoot-Ankle Pain score improved from 11.8 to 29.7 ($P < .001$) in the hindfoot fusion group compared to an improvement of 11.4 to 31.0 ($P < .001$) in the control group. The FADI scores improved from 0.53 to 0.19 ($P < 0.001$) in the hindfoot fusion group and 0.54 to 0.16 ($P < .001$) in the control group. The SMFA Function and Bother index scores improved from 38.2 to 19.3 and 39.6 to 19.7 in the hindfoot fusion group (both *P* values < .001); they improved from 35.1 to 14.3 and 40.2 to 16.4 in the control group (both *P* values < .001).

The AOFAS Hindfoot-Ankle total, function, and alignment scores were significantly improved at the most recent follow-up for both groups (all *P* values < .001; Table 3); the control group, however, demonstrated significantly higher scores than the hindfoot fusion group in all 3 scales. The AOFAS total scores improved from 38.1 to 71.0 points in the hindfoot fusion group, which was significantly lower than the control group improvement of 42.5 to 81.6 ($P < .001$). Similarly, the AOFAS function scores improved from 24.5 to 42.3 in the hindfoot fusion group compared to 30.9 to 48.9 in the control group ($P < .001$). The AOFAS alignment score improved from 6.0 to 8.3 in the hindfoot fusion group compared to 6.4 to 9.5 in the control group ($P = .04$).

The control group also demonstrated a significantly greater improvement in VAS pain score when compared with the hindfoot arthrodesis group at 1 year ($P = .009$; Table 3), and this improvement was maintained through the

Table 3. Clinical Outcome Measures After Total Ankle Replacement (TAR).

	Hindfoot Fusion Group (Mean, SD)	Control Group (Mean, SD)	Time × Group (*P* Value)[a]	Group Differences (*P* Value)	Improvement After TAR (*P* Value)
FADI scores[b]					
Preoperative	0.5 (0.1)	0.5 (0.12)	.190	.354	<.001
Most recent follow-up	0.2 (0.2)	0.2 (0.2)			
Short Form–36 Total[b]					
Preoperative	48.6 (19.2)	49.7 (16.2)	.409	.258	<.001
Most recent follow-up	67.4 (21.9)	73.1 (19.0)			
Short Form–36 Pain[b]					
Preoperative	37.6 (15.9)	38.0 (15.2)	.413	.220	<.001
Most recent follow-up	66.3 (19.7)	71.6 (21.6)			
Short Form–36 Mental Health[b]					
Preoperative	75.9 (18.0)	74.3 (18.6)	.305	.708	<.001
Most recent follow-up	79.5 (14.4)	81.2 (15.7)			
Short Form–36 Physical Function[b]					
Preoperative	24.7 (16.3)	26.4 (15.4)	.234	.110	<.001
Most recent follow-up	54.4 (25.2)	63.4 (24.6)			
AOFAS Total score[b,c]					
Preoperative	38.1 (15.5)	42.5 (16.3)	.146	<.001	<.001
Most recent follow-up	70.5 (18.9)	81.6 (12.7)			
AOFAS Pain score[b]					
Preoperative	11.8 (11.3)	11.4 (10.6)	.505	.400	<.001
Most recent follow-up	29.7 (10.5)	31.0 (9.0)			
AOFAS Function score[b,c]					
Preoperative	24.5 (8.6)	30.9 (10.7)	.458	<.001	<.001
Most recent follow-up	42.3 (10.0)	49.8 (6.7)			
AOFAS Alignment score[b,c]					
Preoperative	6.0 (4.2)	6.4 (3.7)	.412	.040	<.001
Most recent follow-up	8.3 (3.2)	9.5 (1.7)			
SMFA Function[b]					
Preoperative	38.2 (14.0)	35.1 (11.3)	.61	.056	<.001
Most recent follow-up	19.3 (16.5)	14.3 (12.1)			
SMFA Bother[b]					
Preoperative	39.6 (17.4)	40.2 (16.9)	.356	.452	<.001
Most recent follow-up	19.7 (19.7)	16.4 (15.9)			

AOFAS, American Orthopaedic Foot and Ankle Society; FADI, Foot and Ankle Disability Index; SMFA, Short Musculoskeletal Function Assessment.
[a]Interaction between time and group (evaluating if the groups are responding differently over time).
[b]Indicates a significant difference between time points independent of operative group.
[c]Indicates a significant difference between operative groups independent of time.

most recent follow-up assessment (71.2 points preoperatively improved to 10.4 for the control group compared to 65.8 to 18.2 for the fusion group).

With regard to the functional outcomes, walking speed, sit-to-stand time, and 4-square step test time, all were significantly improved at each postoperative time point for each group ($P < .05$). The hindfoot fusion group, however, completed both the sit-to-stand and 4-square step test significantly slower than did the control group, independent of the time when the testing was completed ($P < .001$). Finally, the hindfoot fusion group demonstrated a significantly greater improvement in the timed get up and go test compared to the control group at the 1 year follow-up ($P = .027$), but by the most recent follow-up the times between the 2 groups were not significantly different.

In the radiographic analysis, there was no significant difference in mean subsidence of the talar component between the control (2.0 mm) and fusion (2.6 mm) groups ($P = .334$). When this was controlled for any change in gamma angle of greater or equal to 3.0 degrees, indicating significant loosening of the component that would compromise the reproducibility of the fixed reference point on the inferior calcaneal border, there remained no significant difference between the 2 groups in terms of component subsidence ($P = .397$).

Implant survivorship was significantly different between the 2 groups. There were 8 (2.4%) failures in the control

group (3 deep infections, 5 aseptic failures) compared to 7 (10.0%, $P < .05$) in the fusion group (one deep infection and 6 aseptic failures), requiring removal of the metal components and either revision TAR or conversion to ankle arthrodesis. Six (85.7%) of the 7 patients in the hindfoot fusion group who went on to have a failed TAR were treated with tibiotalocaneal arthrodesis as a salvage procedure; 5 with an intramedullary nail, and 1 with an anterior plate and screw construct with a long axial screw placed across the tibiotalar and talocalcaneal joints. The remaining patient had a tibiotalar arthrodesis with anterior plate and screw construct.

Discussion

At follow-up of 3.2 years, TAR performed with ipsilateral hindfoot arthrodesis resulted in significant improvements in pain and functional outcome, including SF-36, SMFA, AOFAS Hindfoot-Ankle, and VAS scores as well as measures of gait analysis and walking speed. In contrast to the prior study by Kim et al,[16] however, overall outcome, pain relief, and implant survivorship was inferior to that of isolated TAR.

It should be noted that some of the metrics implemented may not have been ideally suited to compare those with a hindfoot fusion compared to those without a fusion. For example, the AOFAS hindfoot and ankle scoring system assigns each patient a score from 0 to 6 based on hindfoot motion. For patients with a successful hindfoot fusion, they are immediately relegated to a maximal score of 94 points rather than 100 points as in the case of those with primary TAR. Thus, although the hindfoot fusion group showed significant improvements in the AOFAS total and function scores (total scores improved from 38.1 to 71.0 points and function scores improved from 24.5 to 42.3), it may not have been fair to compare them to the primary TAR group that could conceivably receive 6 more points for hindfoot motion (total scores improved from 42.5 to 81.6 and function scores from 30.9 to 48.9).

There was a significantly higher incidence of rheumatoid arthritis in the hindfoot fusion group (14.0%) compared to the control group (3.6%), similar to the study by Kim et al.[16] This can likely be explained at least in part by the finding that rheumatoid arthritis tends to affect multiple joints, such as the neighboring hindfoot joints. As discussed by Kim et al,[16] the results of TAR in rheumatoid arthritis have been shown to be good[27] and not inferior[18] to those undergoing TAR for primary osteoarthritis, so we assume that a slightly different distribution of etiology would not seriously compromise our findings.

The rate of mobile-bearing prosthesis implantation was similar between the fusion group (27.1%) and the control group (30.8%). Although the overall percentage of fixed-bearing implants used in the 2 groups was similar (72.9% in the fusion group versus 69.3% in the control group), there was a higher rate of INBONE prosthesis implantation versus the Salto-Talaris prosthesis in the fusion group compared to the control group (Table 1). Queen et al[21] specifically looked at the outcomes of patients who received a Salto-Talaris versus INBONE fixed-bearing prosthesis, however, and found no significant difference in terms of functional outcome or ankle range of motion at 2 years between patients who received the 2 prostheses.

Of note, all 7 (100%) failures in the hindfoot fusion group did have an INBONE prosthesis. The INBONE system utilizes an intramedullary referencing system for the tibial component positioning which involves drilling through the calcaneus, talus, and tibia with a 6-mm drill. The intramedullary referencing system can be useful in cases of significant deformity associated with degenerative disease in the hindfoot. It is conceivable that increased instrumentation of the talus with this system may predispose patients to aseptic loosening and early failure in patients with an ipsilateral hindfoot fusion. Alternatively, it may be that the INBONE system was selected preferentially in cases of significant hindfoot deformity and thus these patients may have been at an inherently higher risk for early failure in this study.

Some authors[16] have suggested a 2-stage approach for patients requiring a subtalar and/or hindfoot fusion in conjunction with TAR. Specifically, there is concern that a 1-stage procedure will lead to higher rates of avascular necrosis of the talus due to aggressive denuding and devascularization of the sinus tarsi and lead to early talar component subsidence, malposition, and subsequent implant failure. We did not have sufficient patient numbers to perform a statistical analysis of whether timing of hindfoot arthrodesis in relation to total ankle implantation affected outcome and thus cannot make a recommendation as to whether the procedures should be staged or simultaneously performed. In this series, of the 7 patients in the fusion group who were considered failures, 2 (28.6%) had hindfoot fusions prior to TAR, 3 (42.8%) had hindfoot fusions at the time of TAR, and 2 (28.6%) had a hindfoot fusion after TAR implantation. Kim et al[16] demonstrated a tendency toward higher soft tissue scarring and bony impingement with staged procedures but a higher rate of instability or dislocation of the polyethylene component with simultaneous procedures. At midterm follow-up in this study, however, there was no significant difference in terms of radiographic talar component subsidence in the hindfoot fusion group compared to the control group at 2 years. More longitudinal follow-up studies may be necessary to support this finding.

We did demonstrate a significantly lower survivorship rate in the fusion group (90.0%) compared to the control group (97.6%) at 3.2-year follow-up. On the basis of

current literature, survivorship of total ankle arthroplasty implants, when measured as the retention of metal components, ranges from 70% to 98% at 3 to 6 years, and 80% to 95% at 8 to 12 years.[8] High survivorship of the STAR and Salto-Talaris implants have been recently reported at 93.9% at 5 years[20] and 96.0% at 2.8 years,[24] respectively, with marked improvement of pain, function, and quality-of-life measures;[20,24] there are no published studies evaluating the survivorship of INBONE prostheses at similar length follow-up to date. The survivorship of both groups in this study is consistent with results reported in the recent literature. Although the rate was significantly higher in the control group, it should be noted that the patients in this group likely represent a more ideal patient cohort to undergo TAR, as they do not have significant deformity and/or neighboring joint disease requiring a hindfoot arthrodesis, and it is not surprising their overall survivorship is superior to the fusion group.

This investigation has highlighted several important directions for future research. There is a concern that placing a total ankle prosthesis in the setting of a fused hindfoot will create abnormal stresses on the ankle joint and will thus lead to increased early wear or degeneration of the implant. One of the prostheses used in this study, the STAR total ankle, is a mobile-bearing design, compared to the fixed-bearing components of the INBONE and Salto-Talaris. The STAR was only recently approved by the FDA in 2009, and it remains the only mobile-bearing implant currently available in the United States. It is possible that the nonconstrained design of the STAR prosthesis will provide improved motion, outcome, and ultimately survivorship in the setting of a fused hindfoot. In a replaced ankle, the flat bearing surfaces between the tibial component and polyethylene insert allow some rotation in a mobile-bearing design, and authors have speculated that this may play an important role in the transfer of rotational movement from the tibia into calcaneal inversion/eversion in patients with a fused hindfoot,[4,16] although there are currently no data to support this theory. As more patients receive the STAR implant, it will be important to perform a subgroup analysis of this study comparing the outcome of those with mobile-bearing implants versus those with traditional fixed-bearing implants.

Important strengths of this investigation include a large consecutive sample size, relatively long follow-up at 3.2 years compared to other studies, and comprehensive longitudinal clinical and functional outcome assessments. There are, however, several key limitations to this study. We lacked a sufficient number of patients with at least 2-year follow-up who had received the STAR necessary for a subgroup analysis comparing mobile- to fixed-bearing TARs in patients with ipsilateral hindfoot fusion. This comparison may provide key information for clinical decisions in the future, particularly since our data suggests overall clinical outcome is slightly inferior compared to that of isolated primary TAR. The use of both fixed- and mobile-bearing implants in this study conceivably could explain the disparity between our findings and those published by Kim et al[16] demonstrating equivalent outcome between patients with a hindfoot fusion and primary TAR; in that study all patients received the mobile-bearing Hintegra prosthesis available in Europe (Newdeal SA, Lyon, France). Finally, it should be noted that in this study all patients with a hindfoot arthrodesis were deemed to have achieved bony union on the basis of clinical examination and radiographic analysis. Coughlin et al[5] demonstrated in a series of hindfoot arthrodeses that standard radiographs substantially overestimate the rate of hindfoot fusion when compared to computed tomography (CT) and showed CT scans are significantly more reliable in determining bony union. Given that radiographs were used as the sole imaging modality to assess union in our patients, it is possible that some patients in the fusion group had unappreciated nonunions that may have served as a confounding factor.

In summary, at a follow-up of 3.2 years, TAR performed with ipsilateral hindfoot arthrodesis results in significant, predictable improvements in pain, function, and quality of life with acceptable failure rates consistent with those published in the literature.[8] When indicated, therefore, hindfoot arthrodesis may safely be performed in conjunction with TAR. Importantly, however, in contrast to prior studies, we have shown that overall clinical outcome and implant survivorship is slightly inferior to that of isolated primary TAR.[8,20,24] Given the relatively short follow-up of this investigation, a more comprehensive longitudinal assessment is needed to assess long-term outcomes in this patient cohort.

Declaration of Conflicting Interests

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