Can a Three-Component Prosthesis be Used for Conversion of Painful Ankle Arthrodesis to Total Ankle Replacement?

Markus Preis MD, Travis Bailey MD, Lucas S. Marchand MD,
Alexej Barg MD

Received: 19 November 2016 / Accepted: 3 April 2017 / Published online: 19 April 2017
© The Association of Bone and Joint Surgeons® 2017

Abstract

Background In patients with painful ankle arthrodesis, the surgical treatment is challenging, and may include takedown of ankle arthrodesis and conversion to a total ankle replacement (TAR). This procedure is technically demanding given the altered anatomy after arthrodesis. Few studies have evaluated TAR in the setting of prior arthrodesis.

Questions/Purposes (1) What intraoperative and perioperative complications were observed in patients who underwent conversion of an ankle arthrodesis to a TAR? (2) Was durable fixation achieved at short term, and what was the alignment of the components? (3) What subsequent

surgical procedures were performed, including revisions? (4) What improvements were observed in pain, tibiotalar range of motion (ROM), and quality of life?

Methods Between January 2007 and December 2014, 18 patients with a painful ankle arthrodesis underwent conversion to TAR at our tertiary referral center. During this period, the indications for conversion of ankle arthrodesis to TAR were tibiotalar nonunion or malunion after attempted arthrodesis in patients who declined revision ankle arthrodesis. The goal of revision surgery was to help patients regain hindfoot mobility and to decrease pain. During the study period, all patients who met indications were treated with a conversion procedure. Of the 18 patients included, 14 were men and four were women. The mean age of the patients was 51 ± 7 years. The mean followup was 54 ± 27 months, with no loss to follow up observed. The initial ankle arthrodesis was performed 6 ± 3.5 years before conversion to TAR. In all patients, the conversion to TAR was performed using a nonconstrained cementless three-component prosthesis. Intraoperative and postoperative complications, revision procedures, and prosthesis component loosening were evaluated. Weightbearing radiographs were used to determine the angular alignment of the tibial and talar components using $\alpha/\beta/\gamma$ angles and to analyze the bone-implant interface. Osseointegration was defined as visible trabecular structures at the bone-implant interface without radiolucent lines. The criteria for radiographic loosening was defined as subsidence or migration of prosthesis components and/or a cystic lesion with a diameter at least 2 mm. Clinical assessment included pain evaluation, measurement of ankle ROM, and quality of life.

Results Two of the 18 patients sustained an intraoperative medial malleolar fracture. In three patients, delayed wound healing was observed. At latest followup, four patients had

Each author certifies that neither he, nor any member of his immediate family, have funding or commercial associations (consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research*® editors and board members are on file with the publication and can be viewed on request.

Clinical Orthopaedics and Related Research® neither advocates nor endorses the use of any treatment, drug, or device. Readers are encouraged to always seek additional information, including FDA-approval status, of any drug or device prior to clinical use.

Each author certifies that his institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

This work was performed at Aukammklinik, Wiesbaden, Germany.

M. Preis

Department of Orthopaedics, Aukammklinik, Wiesbaden, Germany

T. Bailey, L. S. Marchand, A. Barg (✉)

Department of Orthopaedics, University of Utah, 590 Wakara Way, Salt Lake City, UT 84108, USA

e-mail: alexej.barg@hsc.utah.edu; alexejbarg@mail.ru

incomplete osseointegration (posterior quarter of the bone-prosthesis interface on the tibial side). None of the 18 patients had prosthesis loosening. In all patients, both components were neutrally aligned. Two patients had painful arthrofibrosis with reduced ROM, which we treated with an open arthrolysis and exchange of mobile-bearing inlay; one other patient is considering a revision for substantial tibial component medial tilt with collapse of the medial arch. At the latest followup, the mean dorsiflexion and plantar flexion were $8.5^\circ \pm 3^\circ$ and $15^\circ \pm 5^\circ$, respectively. The mean visual analog scale (VAS) score decreased from 9 ± 0.8 to 1.7 ± 1.6 ($p < 0.001$). The Short Form Health Survey questionnaire (SF-36) physical and mental outcome scores improved from 34 ± 5 to 74 ± 11 ($p < 0.001$) and from 49 ± 4 to 75.5 ± 7 ($p < 0.001$).

Conclusions Conversion of an ankle arthrodesis to a TAR is a technically challenging procedure. In this small series, it was associated with frequent complications including arthrofibrosis, and functional outcomes including postoperative ROM were lower than reported for primary TAR. However, pain and function did improve. Further studies are necessary to address long-term clinical and radiographic outcomes in this patient cohort.

Level of Evidence Level IV, therapeutic study.

Introduction

During the last two decades, total ankle replacement (TAR) has gained increased acceptance as a treatment option for patients with end-stage ankle osteoarthritis [10, 11, 23, 29, 49, 59]. However, ankle arthrodesis is the preferred treatment for the majority of patients with end-stage ankle osteoarthritis [1, 12, 18, 47, 64]. Different surgical techniques have been described that often result in short- and mid-term postoperative pain relief [47]. However, the complications after ankle arthrodesis include tibiotalar malunion or nonunion [15, 22, 26], functional gait impairment [17, 20, 46, 57], and premature deterioration of adjacent joints [18, 21, 45].

In patients with a painful nonunited or malunited ankle arthrodesis, the surgical treatment is challenging and may include takedown of the ankle arthrodesis and conversion to TAR (Table 1). This procedure is technically demanding [28, 52] and only a few studies have evaluated this surgical option in this patient population (Table 1). We therefore wished to evaluate our experience with conversion of painful ankle arthrodesis to TAR.

Specifically, we asked (1) What intraoperative and perioperative complications were observed in patients who underwent conversion of an ankle arthrodesis to a TAR? (2) Was durable fixation achieved at short term, and what was the alignment of the components? (3) What subsequent surgical procedures were performed, including revisions?

(4) What improvements were observed in pain, tibiotalar ROM, and quality of life?

Patients and Methods

The institutional review board (Landesärztekammer Hessen) approved this retrospective study, and informed consent was waived. Patients were identified by searching the German Foot and Ankle Society's TAR register [40, 41] for the period from January 1, 2007, to December 31, 2014. Only procedures performed at the first author's institution were searched.

During the period in question, indications for conversion of ankle arthrodesis to TAR were patients with tibiotalar nonunion or malunion with goals of regaining hindfoot mobility and decreasing pain after the revision surgery; these patients all had declined revision ankle arthrodesis. For this study a nonunion ($n = 2$) was defined as incomplete osseous healing at more than 6 months after arthrodesis based on conventional weightbearing radiographs. Malunion ($n = 18$) was defined as alignment deviation of more than 7° in the sagittal and/or coronal plane. The contraindications for conversion were: acute or chronic infection, neuromuscular disorders, neuroarthropathy (Charcot arthropathy), diabetic syndrome with polyneuropathy, severe osteoporosis, and immunosuppressive therapy. During that period, all patients who met inclusion criteria (18 of 42 with painful tibiotalar nonunion or malunion) underwent conversion of their ankle arthrodesis to TAR. The database search yielded 18 patients who underwent conversion of their ankle arthrodesis to TAR. The minimum followup for inclusion was 24 months (mean, 54 months). All 18 patients were accounted for (Table 2). Fourteen of the 18 patients were men and four were women with a mean age of 51 ± 7 years (Table 2). Major comorbidities included diabetes mellitus in two of 18, hemophilia A in four of 18, and tobacco use in one of 18. The initial ankle arthrodesis was performed 6 ± 3 years before conversion to TAR (Table 2). The most-common etiology for ankle osteoarthritis was posttraumatic in 13 of 18 patients (Table 2).

TAR was performed using the cementless HINTEGRA® total ankle system (Newdeal, Lyon, France; Integra LifeSciences, Plainsboro, NJ, USA), a nonconstrained three-component prosthesis (Fig. 1) [8, 29]. All procedures were performed by the first author (MP), an experienced and fellowship-trained orthopaedic foot and ankle surgeon. Two of the authors (TB, AB), who did not operate on any of the patients, independently reviewed register records and patient radiographs. All patients had a popliteal block placed by the anesthesia team preoperatively [2]. An intraoperative "single-shot" antibiotic prophylaxis was administered using intravenous cefazolin unless the patient

Table 1. Complications and clinical outcomes in other series of patients undergoing conversion of ankle arthrodesis to total ankle replacement

Study	Type of study	Level of evidence	Number of patients (number of feet)	Prosthesis design (number)	Followup (months)	Intraoperative complications (number)	Postoperative complications (number)	Clinical outcome
Greisberg et al., 2004 [24]	Retrospective, single center	IV	22 (23)	Agility TM (23) (Depuy, Warsaw, IN, USA)	39 (7–69)	Malleolar fracture (6)	Talar component subsidence (1) Valgus instability (1) Painful arthrofibrosis (3)	AOFAS score 42 to 68 Ankle ROM 26° (5°–35°)
Hintermann et al., 2009 [27]	Prospective, single center	IV	29 (30)	HINTEGRA [®] (30) (Newdeal, Lyon, France; Integra Life Sciences, Plainsboro, NJ, USA)	56 (36–90)	Malleolar fracture (5) Transection of flexor hallucis longus tendon (1)	Delayed wound healing (1) Aseptic talar component loosening resulting in revision arthroplasty (1) Painful arthrofibrosis (2) resulting in tibiocalcaneal arthrodesis (1)	VAS pain score 7.5 to 2 AOFAS score 34 to 71 Ankle ROM 25.5° (8°–40°)
Pellegrini et al., 2015 [51]	Retrospective, single center	IV	23 (23)	INBONE [®] (14) (Wright Medical, Arlington, TN, USA); S.T.A.R. [®] (7) (Small Bone Innovations, Morrisville, PA, USA); Salto Talaris [®] (2) (Tornier, Amsterdam, Netherlands)	33 (12–101)	Malleolar fracture (2)	Superficial wound problems (5) Transient irritation of deep peroneal nerve (1) and tibial nerve (2) Secondary subtalar osteoarthritis requiring subtalar arthrodesis (1) Varus deformity requiring calcaneal osteotomy (1) Ankle impingement requiring open débridement (1) Posterior ankle impingement requiring arthroscopic débridement (1)	VAS pain score 66 ± 22 to 18 ± 18 SF-36 score 38 ± 19 to 56 ± 23 Dorsiflexion 2° ± 3°, plantar flexion 20° ± 9°
Current study	Retrospective, single center	IV	18 (18)	HINTEGRA [®] (18) (Newdeal, Lyon, France; Integra Lifesciences, Plainsboro, NJ, USA)	54 (25–110)	Malleolar fracture (2)	Delayed wound healing (3) complex regional pain syndrome type II (1) Painful arthrofibrosis requiring open arthrolysis (2) Medial ankle instability with collapsing of the medial arch (1)	VAS pain score 9 to 2 AOFAS score 23 to 68 SF-36 mental components 49 to 75.5 SF-36 physical components 34 to 74

AOFAS = American Orthopaedic Foot and Ankle Society, ROM = range of motion, SF-36 = Short Form Health Survey questionnaire, VAS = visual analog scale

Table 2. Demographic data of 20 patients who underwent conversion of painful ankle arthrodesis to total ankle replacement

Patient number	Age (years)	Gender	BMI (kg/m ²)	Diabetes mellitus	Smoking	Initial ankle arthrodesis	Etiology of ankle osteoarthritis	Time since initial ankle arthrodesis (months)	Fibula
1	64	Male	25	No	No	Tibiotalar arthrodesis, 3 cannulated screws, 1 staple	Hemophilic	26	Intact
2	53	Male	29	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	87	Intact
3	49	Male	25	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	32	Intact
4	44	Male	30	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	41	Intact
5	43	Male	27	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	115	Intact
6	55	Female	22	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	74	Intact
7	50	Male	27	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Hemophilic	101	Intact
8	52	Male	31	Yes	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	103	Intact
9	67	Female	24	No	No	Tibiototalcalcaneal arthrodesis, 3 cannulated screws	Rheumatoid	73	Intact
10	46	Male	24	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	21	Osteotomized
11	52	Male	24	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	121	Osteotomized
12	46	Female	22	Yes	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	33	Intact
13	57	Male	26	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Hemophilic	44	Intact
14	43	Male	34	No	Yes	Tibiotalar arthrodesis, 4 screws	Posttraumatic	39	Intact
15	62	Male	24	No	No	Tibiotalar arthrodesis, 3 screws	Posttraumatic	133	Intact
16	54	Female	26	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	69	Intact
17	42	Male	28	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Posttraumatic	168	Intact
18	46	Male	26	No	No	Tibiotalar arthrodesis, 3 cannulated screws	Hemophilic	68	Intact
Mean ± SD (range)	51 ± 7 (42–67)		26 ± 3 (22–34)					75 ± 42 (21–168)	Intact

BMI = body mass index, SD = standard deviation

Fig. 1A–F A 53-year-old man underwent tibiotalar arthrodesis. (A) AP and (B) lateral views of his ankle show complete osseous fusion of the tibiotalar joint. (C) The hindfoot alignment view shows varus malalignment of the hindfoot. (D) The overall alignment of the lower extremity is neutral. His overall pain was 8 on the VAS with a

maximal walking distance less than 100 m. (E) Lateral and (F) AP views of the patient's ankle show appropriate alignment and osseous integration of both prosthesis components at 5 years followup. The overall pain was 2 on VAS with a maximal walking distance of 3–5 km.

had an allergy. After general anesthesia was induced, the patient was placed in the supine position. All procedures were performed with application of a thigh tourniquet. In patients with retained hardware, the hardware was removed from the most-appropriate previous incision. A 10- to 12-cm straight, midline, anterior incision was made over the distal tibia to expose the extensor retinaculum. The fused

ankle was then exposed between the extensor hallucis longus and the anterior tibial tendon. Attention was paid to the anterior neurovascular bundle behind the extensor hallucis longus. The original tibiotalar joint was marked with four K-wires under fluoroscopic guidance, as planned on preoperative radiographs. Care was taken to mark the joint line at the proper level. The tibial and talar cuts were

performed using cutting blocks [28]. In patients with a previously osteotomized fibula, fibular reconstruction was performed through a separate lateral longitudinal incision. Other concomitant procedures performed at the time of the conversion procedure included: fibular reconstruction ($n = 2$), medial malleolus reconstruction ($n = 1$), talonavicular fusion and medializing calcaneal osteotomy ($n = 1$), Achilles lengthening ($n = 13$), and lateral ligament reconstruction ($n = 2$) (Table 3) [28].

After the wound was closed in a layered fashion, a well-padded short leg splint was used to support the hindfoot in a neutral position. The first dressing was removed and changed at the second postoperative day. Postoperatively, the patients were mobilized with the foot placed in a stabilizing walker for 6 weeks. Partial weightbearing with 15 kg was allowed. At 6 weeks, patients were transitioned to full weightbearing using a stabilizing walker for 2 additional weeks. After the walker was removed, physiotherapy was begun, which included active and passive ankle motion, stretching and strengthening of the triceps surae, and proprioceptive exercises [8].

Affected ankles were evaluated based on weightbearing radiographs in two planes (AP and lateral ankle views). Radiographs were evaluated at 6 weeks (nonweightbearing radiographs), 3 months, 6 months, 1 year, and then annually thereafter. Degenerative changes of the subtalar and talonavicular joints were assessed preoperatively and postoperatively using the Kellgren-Lawrence scale [19, 35]: Grade 0, no radiographic findings of osteoarthritis; Grade 1, minute osteophytes of doubtful clinical importance; Grade 2, definite osteophytes with an unimpaired joint space; Grade 3, definite osteophytes with moderate joint space narrowing; and Grade 4, definitive osteophytes with narrowing of several joint spaces and subchondral sclerosis. The angular positions of the tibial and talar components were assessed from $\alpha/\beta/\gamma$ angles: α angle and β angle were measured between the longitudinal axis of the tibia and the articular surface of the tibial component on the AP and lateral views, respectively; γ angle was measured between a line drawn through the anterior shield and the posterior edge of the talar component and a line drawn along the center of the talar neck on the lateral view [7, 29, 43]. The intercomponent alignment was assessed by measuring valgus-varus tilt in the coronal plane. The AP offset in the sagittal plane also was measured [4]. To assess the radiographic bone-implant interface on the tibial side, weightbearing lateral radiographs were analyzed [13, 38, 39]. Four zones were defined on the tibial side. Each zone was classified as osseointegrated (visible trabeculae at the prosthesis-bone interface), or cystic loosening (cystic lesion with a diameter at least 2 mm) [60]. Loosening of the talar component, as seen on the lateral radiograph, was defined as subsidence in the

talus by more than 5 mm or change in position greater than 5° relative to a line drawn from the top of the talonavicular joint to the tuberosity of the calcaneus [29, 37]. Patients were seen preoperatively and postoperatively in the outpatient clinic by two medical assistants (SB, SF) who had not assisted in the operations. All patients were seen postoperatively in our institution. The clinical examination involved careful assessment of ankle alignment, stability, and ROM. Ankle ROM was determined clinically with a goniometer placed along the lateral border of the leg and foot with patients in a weightbearing position as described by Lindsjö et al. [44]. Subtalar ROM also was determined clinically using a goniometer [25]. The patients rated their pain on a VAS from 0 points (no pain) to 10 points (maximal pain) [34]. For functional assessment, the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score was calculated [36]. All patients completed the entire Medical Outcomes Study Short Form Health Survey questionnaires (SF-36) on quality of life preoperatively and postoperatively [61].

Statistical Analysis

A Kolmogorov-Smirnov normality test was performed to determine if the data were normally distributed. A paired t -test and Wilcoxon signed-rank test were used for comparison of paired normally and nonnormally distributed data, respectively. A p value of 0.05 or less was considered statistically significant. Data were analyzed using IBM SPSS® Statistics, Version 22 (IBM Corporation, Armonk, NY, USA) and SigmaPlot Version 12.5 (Systat Software Inc, San Jose, CA, USA).

Results

Two patients sustained an intraoperative medial malleolar fracture, which were treated by open reduction and internal screw fixation. Both fractures healed within 6 weeks after the initial surgery. In three patients, delayed wound healing was observed. These patients underwent daily wound care by a certified wound care specialist (SB). Two of three patients had complete wound healing within 4 weeks, whereas the third patient had final healing within 6 months of the initial surgery. No patient developed a chronic or periprosthetic joint infection. One patient had complex regional pain syndrome Type II develop postoperatively, which resolved within 6 months.

At latest followup, four patients had incomplete osseointegration (posterior quarter of the bone-prosthesis interface on the tibial side). The incomplete osseointegration was identified early after surgery (at 6 weeks

Table 3. Surgical details of 20 patients who underwent conversion of painful ankle arthrodesis to total ankle replacement

Patient number	Removal of hardware	Distal fibula reconstruction	Medial malleolus reconstruction	Other osseous procedures	Soft tissue procedures	Duration of surgery (minutes)	Duration of tourniquet (minutes)
1	Yes	No	Yes	None	Lengthening of achilles tendon	155	120
2	Yes	No	No	None	Lengthening of achilles tendon	168	120
3	Yes	No	No	None	Lengthening of achilles tendon	155	120
4	Yes	No	No	None	None	124	85
5	Yes	No	No	None	Lengthening of achilles tendon	133	120
6	Yes	No	No	None	Lengthening of achilles tendon	160	120
7	Yes	No	No	None	Lengthening of achilles tendon	157	120
8	Yes	No	No	None	Lengthening of achilles tendon	165	120
9	No	No	No	Talonavicular arthrodesis, medial displacement osteotomy of calcaneus	Lengthening of achilles tendon	197	120
10	Yes	Yes	No	None	None	188	105
11	No	Yes	No	None	Lateral ligament reconstruction	185	120
12	Yes	No	No	None	Lengthening of achilles tendon	165	110
13	Yes	No	No	None	None	155	120
14	Yes	No	No	None	Lengthening of achilles tendon	125	110
15	Yes	No	No	None	None	122	107
16	Yes	No	No	None	Lengthening of achilles tendon	165	120
17	Yes	No	No	None	Lengthening of achilles tendon	175	120
18	Yes	No	No	None	Lengthening of achilles tendon	165	120
Mean $\pm$ SD (range)						159 $\pm$ 22 (122–197)	116 $\pm$ 7 (95–120)

SD = standard deviation

Table 4. Degenerative changes of the subtalar and talonavicular joints assessed using the Kellgren-Lawrence scale: a comparison preoperative and postoperative scores

Kellgren-Lawrence scale	Subtalar joint			Talonavicular joint		
	Preoperative	Postoperative	p value	Preoperative	Postoperative	p value
0	2	2	1.000*	6	6	1.000*
1	4	5		8	8	
2	10	9		2	2	
3	1	1		1	1	
4	1	0		1	0	
Fused	0	1		0	1	

*Using Wilcoxon signed-rank test.

followup) and was not progressive. No talar component subsidence was observed in any patient. None of the 20 patients had prosthesis loosening. Both components were neutrally aligned as measured by α angle (mean, $88^\circ \pm 1^\circ$), β angle (mean, $86^\circ \pm 2^\circ$), and γ angle (mean, $15^\circ \pm 2^\circ$). The tibiotalar intercomponent alignment was neutral in the coronal plane with mean intercomponent tilt of $-0.1^\circ \pm 0.6^\circ$ and in the sagittal plane with mean AP offset ratio of 0.0 ± 0.0 . The osteoarthritis grade in the subtalar and talonavicular joints was comparable before the surgery and at the latest followup (Table 4).

Two patients had painful arthrofibrosis with reduced ROM. In both patients, an open arthrolysis and exchange of the mobile-bearing inlay were performed 1.4 and 1.5 years postoperatively. One patient had substantial tibial component medial tilt with collapse of the medial arch, this was potentially related to incomplete restoration of coronal alignment at the time of the conversion procedure. At the time of this writing, revision was pending (removal of prosthesis components and conversion to tibiotalar arthrodesis) (Fig. 2).

At the latest followup, mean dorsiflexion and plantar flexion were $8.5^\circ \pm 3^\circ$ and $15^\circ \pm 5^\circ$, respectively. There was no correlation with the numbers available, between postoperative ROM and the time between initial ankle arthrodesis and TAR (Pearson correlation $r = 0.425$; $p = 0.077$). Mean subtalar ROM increased from $14^\circ \pm 10^\circ$ to $16^\circ \pm 10^\circ$ ($p = 0.005$), although this difference is unlikely to be clinically important. Mean VAS decreased from 9 ± 1 to 2 ± 2 ($p < 0.001$). Three patients reported being pain-free and 16 of 18 had a VAS of 2 or less. The mean AOFAS hindfoot score increased from 23 ± 6 to 68 ± 14 ($p < 0.001$). The summarized components of the SF-36 physical and mental outcome scores improved from 34 ± 5 to 74 ± 11 (range, 34–86) and from 49 ± 4 to 75.5 ± 7 ($p < 0.001$).

Discussion

A painful malunion or nonunion is a major complication after ankle arthrodesis [15, 47]. The surgical options for a revision arthrodesis often are limited; therefore, alternative treatment options should be discussed. Conversion of painful ankle arthrodesis to TAR is a possible salvage procedure for these patients. However, few studies have addressed the complication rate and clinical outcomes in patients who have undergone conversion of a painful ankle arthrodesis to a TAR (Table 1) [24, 27, 51]. We found that the frequency of intraoperative, perioperative, and postoperative complications was fairly high, and a substantial subset (two of 18) underwent reoperation at short-term (2-year minimum) followup. We observed durable fixation of prosthesis components with a low frequency of incomplete osseointegration around the posterior aspect of the bone-prosthesis interface on the tibial side. At the latest followup, patients reported pain relief and improved ankle ROM.

Our study has numerous limitations. Although the study design was retrospective, all patient data were collected longitudinally and transferred to the German Foot and Ankle Society's TAR register. Second, the mean duration of followup in this study was 5 years, which may not be sufficient to detect problems that may arise during longer periods of surveillance, such as component loosening. Future studies are planned to evaluate the clinical and radiographic outcomes in this patient cohort at longer-term followup (10 years). Third, the total number of patients included in this study was relatively small. Thus, any statistical comparisons in this study should be interpreted with caution, particularly the no-difference findings, which may have been the result of insufficient statistical power. Fourth, the functional outcome in this study was partially assessed using the AOFAS hindfoot score, which is a

Fig. 2A–G A 67-year-old woman has a painful malunited tibiotalar arthrodesis. (A) AP and (B) lateral views of her ankle show complete osseous fusion of the hindfoot with end-stage osteoarthritis of the talonavicular joint. The patient's initial postoperative course was uneventful. (C) AP and (D) lateral views of her ankle show appropriate alignment and osseous integration of both prosthesis

components and complete osseous healing of the calcaneal osteotomy and subtalar and talonavicular arthrodesis at 2 years followup. (E) AP and (F) lateral views of the ankle and (G) the hindfoot alignment view show collapse of the medial arch and valgus tilt of the replaced ankle 6 months later. Revision surgery is pending.

nonvalidated score [53]. This deficiency was not known in 2007 when the clinical assessment first began. Fifth, the ankle ROM was only assessed clinically using a goniometer. Flexion and extension radiographs would be useful to determine motion through the prosthesis versus combined ankle and transverse tarsal motion. Additionally, this study highlights the experience of a single fellowship-trained foot and ankle surgeon and thus may not be generalizable. Finally, numerous other procedures were performed concurrently with the TAR in this series, and it can be difficult to discern the degree to which those procedures may have contributed to the observed results. That said, the TAR certainly was the largest of the interventions performed in any of these patients, and it seems reasonable to conclude that the TAR contributed substantially to the improvements we observed.

During the last decade, TAR has been shown to be a reliable surgical option in patients with a painful malunited or nonunited ankle arthrodesis (Table 1). The frequency of intraoperative, perioperative, and postoperative complications observed in this study is comparable to those reported by others, with respect to patients undergoing a conversion procedure (Table 1) and in patients undergoing primary TAR [10, 63]. The conversion of painful ankle arthrodesis to TAR is a technically demanding procedure [3, 28, 52, 62], and we believe it should be limited to trained foot and ankle surgeons with adequate experience performing primary TAR. In three of 20 patients, fibular reconstruction was performed owing to the previous osteotomy performed at the initial ankle arthrodesis. This condition is a possible relative contraindication for this procedure [28, 52], because the anatomic reconstruction of the mortise is important to provide the stability of the replaced ankle.

Aseptic loosening of one or both prosthesis components is the most-common reason for revision of TAR [10, 11, 33, 42, 54]. In our patient cohort, no revision resulting from aseptic loosening was performed. However, in four of 18 patients, we observed incomplete osseointegration at the posterior quarter of the bone-prosthesis interface on the tibial side. No progression of radiolucent lines was observed during the time at intermediate followup. We recommend annual followup with conventional imaging to evaluate for progressive change. In ankles in which the progression of radiolucency may be seen or suspected, we recommend performing CT for exact assessment of radiolucent lines [60]. Instability and/or subluxation is another possible reason for revision surgery in up to 9% of all TARs [54, 55]. In our patient cohort, one patient had TAR dislocation owing to collapse of the medial midfoot with consecutive valgus subluxation of the ankle.

The most-common postoperative complication in our patients was painful arthrofibrosis. Two of 18 patients

sustained this complication which was treated by open arthrolysis and exchange of a mobile-bearing inlay. The frequency of arthrofibrosis in our small series seemed comparable to that previously recognized with primary TAR. Other studies suggest that arthrofibrosis occurs in up to 22% of patients undergoing primary TAR [5, 6, 14, 31, 32]. Hintermann et al. [27] reported clinical and radiographic outcomes in 28 patients who underwent 30 conversion procedures. In their study, four of the 30 (13%) patients had painful arthrofibrosis postoperatively [27]. This can be related to the degeneration of periarticular soft tissues likely resulting from ankle immobilization after ankle arthrodesis. Compromised periarticular soft tissues may be a risk factor to developing painful arthrofibrosis as this complication has been seen in patients with bleeding disorders (soft tissue damage resulting from repetitive joint bleeding) [5, 9] and in patients with revision ankle arthroplasty (soft tissue damage resulting from the previous surgeries) [30, 31].

At the latest followup, the mean ankle ROM was $23^{\circ} \pm 7^{\circ}$. This is substantially lower than reported in a recent systematic review including 7942 primary ankle arthroplasties in which a ROM improvement from 23° (95% CI, 19° – 26°) to 34° (95% CI, 26° – 41°) was observed [63]. Longstanding ankle fusion with consecutive degeneration of periarticular structures may be critical to achieve physiologic ankle ROM after TAR. Surprisingly, we did not observe a major correlation between the duration of ankle arthrodesis and the ROM at the latest followup. All seven patients who had an equinus-fixed deformity preoperatively had at least 5° dorsiflexion at the latest followup. The regained ROM is one possible reason for substantial postoperative improved quality of life in our patient cohort. Numerous studies including patients with TAR using modern prosthesis designs have shown a substantial postoperative improvement in quality of life [16, 48–50, 56, 58]. Another reason for the improvement of quality of life after TAR is the pain relief we observed in our study cohort. In the systematic review by Zaidi et al. [63] with 7942 primary ankle arthroplasties, the mean pooled summary VAS scores decreased from 7.4 (95% CI, 6.8–7.9) to 1.6 (95% CI, 1.4–1.8) at 4- to 5-years followup. In our patient cohort, only three of 18 patients reported being pain-free, whereas 13 of 18 patients had mild pain (VAS, 1–2). Residual pain in the hindfoot is not uncommon in patients who underwent TAR, with one study reporting 60% of patients who underwent the procedure having residual pain [23].

In our small series, the conversion to TAR was a reliable option for surgical treatment of painful ankle arthrodesis. The observed postoperative complication rate including arthrofibrosis was high, whereas functional outcomes including postoperative ROM were lower than reported for

primary TAR. Further clinical studies are necessary to address long-term clinical and radiographic outcomes in this patient cohort.

Acknowledgments We thank Kateryna Nykytina MS (Department of Orthopaedics, University of Utah, Salt Lake City, UT, USA) for help with statistical analysis and literature review. We also thank Sina Brühl MS (Department of Orthopaedics, Aukammklinik, Wiesbaden, Germany) and Silvana Favicchio MS (Department of Orthopaedics, Aukammklinik, Wiesbaden, Germany) for their help in clinical assessment.

References

- Ahmad J, Raikin SM. Ankle arthrodesis: the simple and the complex. *Foot Ankle Clin.* 2008;13:381–400.
- Anderson JG, Bohay DR, Maskill JD, Gadkari KP, Hearty TM, Braaksma W, Padley MA, Weaver KT. Complications after popliteal block for foot and ankle surgery. *Foot Ankle Int.* 2015;36:1138–1143.
- Atkinson HD, Daniels TR, Klejman S, Pinsker E, Houck JR, Singer S. Pre- and postoperative gait analysis following conversion of tibiototalcanal fusion to total ankle arthroplasty. *Foot Ankle Int.* 2010;31:927–932.
- Barg A, Elsner A, Chuckpaiwong B, Hintermann B. Insert position in three-component total ankle replacement. *Foot Ankle Int.* 2010;31:754–759.
- Barg A, Elsner A, Hefti D, Hintermann B. Haemophilic arthropathy of the ankle treated by total ankle replacement: a case series. *Haemophilia.* 2010;16:647–655.
- Barg A, Elsner A, Hefti D, Hintermann B. Total ankle arthroplasty in patients with hereditary hemochromatosis. *Clin Orthop Relat Res.* 2011;469:1427–1435.
- Barg A, Henninger HB, Knupp M, Hintermann B. Simultaneous bilateral total ankle replacement using a 3-component prosthesis: outcome in 26 patients followed for 2–10 years. *Acta Orthop.* 2011;82:704–710.
- Barg A, Knupp M, Henninger HB, Zwicky L, Hintermann B. Total ankle replacement using HINTEGRA, an unconstrained, three-component system: surgical technique and pitfalls. *Foot Ankle Clin.* 2012;17:607–635.
- Barg A, Morris SC, Schneider SW, Phisitkul P, Saltzman CL. Surgical procedures in patients with haemophilic arthropathy of the ankle. *Haemophilia.* 2016;22:e156–176.
- Barg A, Wimmer MD, Wiewiorski M, Wirtz DC, Pagenstert GI, Valderrabano V. Total ankle replacement: indications, implant designs, and results. *Dtsch Arztebl Int.* 2015;112:177–184.
- Barg A, Zwicky L, Knupp M, Henninger HB, Hintermann B. HINTEGRA total ankle replacement: survivorship analysis in 684 patients. *J Bone Joint Surg Am.* 2013;95:1175–1183.
- Baumhauer JF. Ankle arthrodesis versus ankle replacement for ankle arthritis. *Clin Orthop Relat Res.* 2013;471:2439–2442.
- Besse JL, Brito N, Lienhart C. Clinical evaluation and radiographic assessment of bone lysis of the AES total ankle replacement. *Foot Ankle Int.* 2009;30:964–975.
- Brunner S, Barg A, Knupp M, Zwicky L, Kapron AL, Valderrabano V, Hintermann B. The Scandinavian total ankle replacement: long-term, eleven to fifteen-year, survivorship analysis of the prosthesis in seventy-two consecutive patients. *J Bone Joint Surg Am.* 2013;95:711–718.
- Chalayan O, Wang B, Blankenhorn B, Jackson JB 3rd, Beals T, Nickisch F, Saltzman CL. Factors affecting the outcomes of uncomplicated primary open ankle arthrodesis. *Foot Ankle Int.* 2015;36:1170–1179.
- Chambers S, Ramaskandhan J, Siddique M. Radiographic severity of arthritis affects functional outcome in total ankle replacement (TAR). *Foot Ankle Int.* 2016;37:351–354.
- Chopra S, Rouhani H, Assal M, Aminian K, Crevoisier X. Outcome of unilateral ankle arthrodesis and total ankle replacement in terms of bilateral gait mechanics. *J Orthop Res.* 2014;32:377–384.
- Coester LM, Saltzman CL, Leupold J, Pontarelli W. Long-term results following ankle arthrodesis for post-traumatic arthritis. *J Bone Joint Surg Am.* 2001;83:219–228.
- de Muinck Keizer RJ, Backes M, Dingemans SA, Goslings JC, Schepers T. Post-traumatic subtalar osteoarthritis: which grading system should we use? *Int Orthop.* 2016;40:1981–1985.
- Flavin R, Coleman SC, Tenenbaum S, Brodsky JW. Comparison of gait after total ankle arthroplasty and ankle arthrodesis. *Foot Ankle Int.* 2013;34:1340–1348.
- 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 Br.* 2003;85:994–998.
- Gorman TM, Beals TC, Nickisch F, Saltzman CL, Lyman M, Barg A. Hindfoot arthrodesis with the blade plate: Increased risk of complications and nonunion in a complex patient population. *Clin Orthop Relat Res.* 2016;474:2280–2299.
- Gougoulias N, Khanna A, Maffulli N. How successful are current ankle replacements?: a systematic review of the literature. *Clin Orthop Relat Res.* 2010;468:199–208.
- Greisberg J, Assal M, Flueckiger G, Hansen ST Jr. Takedown of ankle fusion and conversion to total ankle replacement. *Clin Orthop Relat Res.* 2004;424:80–88.
- Hagen M, Lemke M, Paszota L, Lahner M. Reliability of two goniometric methods for measuring active subtalar range of motion. *Technol Health Care.* 2015;23:323–331.
- Hendrickx RP, Stufkens SA, de Bruijn EE, Sierevelt IN, van Dijk CN, Kerkhoffs GM. Medium- to long-term outcome of ankle arthrodesis. *Foot Ankle Int.* 2011;32:940–947.
- Hintermann B, Barg A, Knupp M, Valderrabano V. Conversion of painful ankle arthrodesis to total ankle arthroplasty. *J Bone Joint Surg Am.* 2009;91:850–858.
- Hintermann B, Barg A, Knupp M, Valderrabano V. Conversion of painful ankle arthrodesis to total ankle arthroplasty: surgical technique. *J Bone Joint Surg Am.* 2010;92(suppl 1 pt 1):55–66.
- Hintermann B, Valderrabano V, Dereymaeker G, Dick W. The HINTEGRA ankle: rationale and short-term results of 122 consecutive ankles. *Clin Orthop Relat Res.* 2004;424:57–68.
- Hintermann B, Zwicky L, Knupp M, Henninger HB, Barg A. HINTEGRA revision arthroplasty for failed total ankle prostheses. *J Bone Joint Surg Am.* 2013;95:1166–1174.
- Horisberger M, Henninger HB, Valderrabano V, Barg A. Bone augmentation for revision total ankle arthroplasty with large bone defects. *Acta Orthop.* 2015;86:412–414.
- Hsu AR, Haddad SL. Early clinical and radiographic outcomes of intramedullary-fixation total ankle arthroplasty. *J Bone Joint Surg Am.* 2015;97:194–200.
- Hsu AR, Haddad SL, Myerson MS. Evaluation and management of the painful total ankle arthroplasty. *J Am Acad Orthop Surg.* 2015;23:272–282.
- Huskisson EC. Measurement of pain. *Lancet.* 1974;2:1127–1131.
- Kellgren JH, Lawrence JS. Radiological assessment of osteoarthritis. *Ann Rheum Dis.* 1957;16:494–502.
- Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, mid-foot, hallux, and lesser toes. *Foot Ankle Int.* 1994;15:349–353.
- Knecht SI, Estin M, Callaghan JJ, Zimmerman MB, Alliman KJ, Alvine FG, Saltzman CL. The Agility total ankle arthroplasty:

- seven to sixteen-year follow-up. *J Bone Joint Surg Am.* 2004;86:1161–1171.
38. Koivu H, Kohonen I, Sipola E, Alanen K, Vahlberg T, Tiusanen H. Severe periprosthetic osteolytic lesions after the ankle evolutive system total ankle replacement. *J Bone Joint Surg Br.* 2009;91:907–914.
 39. Kokkonen A, Ikavalko M, Tiihonen R, Kautiainen H, Belt EA. High rate of osteolytic lesions in medium-term followup after the AES total ankle replacement. *Foot Ankle Int.* 2011;32:168–175.
 40. Kostuj T, Preis M, Walther M, Aghayev E, Krummenauer F, Roder C. [German Total Ankle Replacement Register of the German Foot and Ankle Society (D. A. F.): presentation of design and reliability of the data as well as first results][in German]. *Z Orthop Unfall.* 2014;152:446–454.
 41. Kostuj T, Walther M, Roder C, Aghayev E, Preis M. [First results of the German foot and ankle society's total ankle arthroplasty register][in German]. *Fuss Sprungg.* 2012;10:161–165.
 42. Labek G, Todorov S, Iovanescu L, Stoica CI, Bohler N. Outcome after total ankle arthroplasty—results and findings from worldwide arthroplasty registers. *Int Orthop.* 2013;37:1677–1682.
 43. Lee KB, Cho SG, Hur CI, Yoon TR. Perioperative complications of HINTEGRA total ankle replacement: our initial 50 cases. *Foot Ankle Int.* 2008;29:978–984.
 44. Lindsjö U, Danckwardt-Lilliestrom G, Sahlstedt B. Measurement of the motion range in the loaded ankle. *Clin Orthop Relat Res.* 1985;199:68–71.
 45. Ling JS, Smyth NA, Fraser EJ, Hogan MV, Seaworth CM, Ross KA, Kennedy JG. Investigating the relationship between ankle arthrodesis and adjacent-joint arthritis in the hindfoot: a systematic review. *J Bone Joint Surg Am.* 2015;97:513–520.
 46. Mazur JM, Schwartz E, Simon SR. Ankle arthrodesis: long-term follow-up with gait analysis. *J Bone Joint Surg Am.* 1979;61:964–975.
 47. Nihal A, Gellman RE, Embil JM, Trepman E. Ankle arthrodesis. *Foot Ankle Surg.* 2008;14:1–10.
 48. Nunley JA, Caputo AM, Easley ME, Cook C. Intermediate to long-term outcomes of the STAR Total Ankle Replacement: the patient perspective. *J Bone Joint Surg Am.* 2012;94:43–48.
 49. Nwachukwu BU, McLawhorn AS, Simon MS, Hamid KS, Demetracopoulos CA, Deland JT, Ellis SJ. Management of end-stage ankle arthritis: cost-utility analysis using direct and indirect costs. *J Bone Joint Surg Am.* 2015;97:1159–1172.
 50. Oliver SM, Coetzee JC, Nilsson LJ, Samuelson KM, Stone RM, Fritz JE, Giveans MR. Early patient satisfaction results on a modern generation fixed-bearing total ankle arthroplasty. *Foot Ankle Int.* 2016;37:938–943.
 51. Pellegrini MJ, Schiff AP, Adams SB Jr, Queen RM, DeOrto JK, Nunley JA 2nd, Easley ME. Conversion of tibiotalar arthrodesis to total ankle arthroplasty. *J Bone Joint Surg Am.* 2015;97:2004–2013.
 52. Pellegrini MJ, Schiff AP, Adams SB Jr, Queen RM, DeOrto JK, Nunley JA 2nd, Easley ME. Tibiotalar arthrodesis conversion to total ankle arthroplasty. *JBJS Essential Surgical Techniques.* 2016;6:e27.
 53. Pinsker E, Daniels TR. AOFAS position statement regarding the future of the AOFAS Clinical Rating Systems. *Foot Ankle Int.* 2011;32:841–842.
 54. Sadoghi P, Liebensteiner M, Agreiter M, Leithner A, Bohler N, Labek G. Revision surgery after total joint arthroplasty: a complication-based analysis using worldwide arthroplasty registers. *J Arthroplasty.* 2013;28:1329–1332.
 55. Sadoghi P, Roush G, Kastner N, Leithner A, Sommitsch C, Goswami T. Failure modes for total ankle arthroplasty: a statistical analysis of the Norwegian Arthroplasty Register. *Arch Orthop Trauma Surg.* 2014;134:1361–1368.
 56. Schweitzer KM, Adams SB, Viens NA, Queen RM, Easley ME, Deorio JK, Nunley JA 2nd. Early prospective clinical results of a modern fixed-bearing total ankle arthroplasty. *J Bone Joint Surg Am.* 2013;95:1002–1011.
 57. Singer S, Klejman S, Pinsker E, Houck J, Daniels T. Ankle arthroplasty and ankle arthrodesis: gait analysis compared with normal controls. *J Bone Joint Surg Am.* 2013;95:e191.
 58. Slobogean GP, Younger A, Apostle KL, Marra CA, Wing K, Penner M, Daniels T, Glazebrook M. Preference-based quality of life of end-stage ankle arthritis treated with arthroplasty or arthrodesis. *Foot Ankle Int.* 2010;31:563–566.
 59. Valderrabano V, Hintermann B, Dick W. Scandinavian total ankle replacement: a 3.7-year average followup of 65 patients. *Clin Orthop Relat Res.* 2004;424:47–56.
 60. Viste A, Al Zahrani N, Brito N, Lienhart C, Fessy MH, Besse JL. Periprosthetic osteolysis after AES total ankle replacement: conventional radiography versus CT-scan. *Foot Ankle Surg.* 2015;21:164–170.
 61. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36): I. Conceptual framework and item selection. *Med Care.* 1992;30:473–483.
 62. Williamson ER, Demetracopoulos CA, Ellis SJ. Conversion of ankle autofusion to total ankle replacement using the Salto XT revision prosthesis. *Foot Ankle Surg.* 2016;22:e11–16.
 63. Zaidi R, Cro S, Gurusamy K, Siva N, Macgregor A, Henricson A, Goldberg A. The outcome of total ankle replacement: a systematic review and meta-analysis. *Bone Joint J.* 2013;95:1500–1507.
 64. Zwipp H, Rammelt S, Endres T, Heineck J. High union rates and function scores at midterm followup with ankle arthrodesis using a four screw technique. *Clin Orthop Relat Res.* 2010;468:958–968.