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Conversion of painful tibiotalocalcaneal arthrodesis to total ankle replacement using a 3-component mobile bearing prosthesis

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ABSTRACT

Background: The aim of this study was to assess the short-term clinical and radiographic outcomes in patients who underwent conversion of a painful tibiotalocalcaneal arthrodesis to a total ankle replacement.
Methods: Six patients with painful ankle arthrodesis after tibiotalocalcaneal arthrodesis were included in this study. In all patients, conversion to total ankle replacement was performed using a 3rd-generation, non-constrained, cementless three-component prosthesis. The outcomes were analyzed at a mean follow-up of 3.4 ± 1.9 years (range 1.0–6.5).
Results: One patient with painful arthrofibrosis underwent two open arthrolysis procedures at 1.2 and 5.6 years post index surgery, respectively. No revision of tibial or talar prosthesis components was necessary in this study. All patients reported significant pain relief and significant improvement in functional status.
Conclusion: In the present study, the conversion of a painful ankle arthrodesis following tibiotalocalcaneal arthrodesis to a total ankle replacement was a reliable surgical treatment.

1. Introduction

Tibiotalocalcaneal (TTC) arthrodesis is a well-described salvage procedure in patients with significant degenerative changes of the ankle and/or hindfoot joint with or without concomitant hindfoot deformities [9,10,20,32,39–41,44,45]. The main aim of TTC arthrodesis is to eliminate or reduce hindfoot pain and instability. However, TTC arthrodesis often results in a rigid hindfoot with some range of motion from the Chopart joint [43,46]. Patients often complain about possible functional limitations [39]. Furthermore, this procedure may have complications including delayed union or non-union of the tibiotalar and/or subtalar joint(s), malunion, infection, and wound complications among others [8]. In the current literature, a union rate between 75% and 93% [7,30–32,36,39,44] has been reported while an incidence of hindfoot malunion of up to 10% has been noted [8,32].

The surgical treatment of hindfoot malunion or non-union in patients with prior TTC arthrodesis is not simple. Revision TTC arthrodesis is a technically challenging procedure with higher complication rates and worse clinical outcomes than primary TTC arthrodesis [11]. In patients with malunited or non-united tibiotalar joints, a conversion of ankle arthrodesis to total ankle replacement (TAR) is a valuable surgical treatment option which has been highlighted in clinical studies over the last two decades (Table 1). The majority of these studies have addressed the clinical and radiographic outcomes in patients with tibiotalar malunion or non-union after tibiotalar arthrodesis. To date, few studies have focused on the results of TTC arthrodesis (Table 1).

The objective of our study was to describe the clinical and radiographic outcomes of patients who underwent conversion of primary TTC arthrodesis to TAR. Specifically, we analyzed (1) intraoperative and perioperative complications; (2) prosthesis component stability; (3) radiographic outcomes including prosthesis component alignment in the coronal and sagittal plane; (4) clinical outcomes including postoperative pain relief, range of motion (ROM), and quality of life; and (5) postoperative outcomes of patients who initially underwent TTC versus tibiotalar arthrodesis.

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Table 1
Literature review highlighting outcomes in patients with conversion of ankle arthrodesis to total ankle replacement

Study	Type of study	LoE	Number of patients (feet)	Initial procedure (n)	Prosthesis type (n)	Follow-up (years)	Complications			Clinical outcomes
							Intraoperative (n)	Perioperative (n)	Postoperative (n)	
Atkinson et al. [14]	RS, SC	V	1 (1)	TTC AD (1)	HINTEGRA (1)	1	None	None	None	• AOFAS score 51 → 84 • SF-36 mental components 49 → 50.5 • SF-36 physical components 37 → 45
Greisberg et al. [13]	RS, SC	IV	22 (23)	TT AD (23)	Agility (23)	3.3 (0.6–5.8)	Malleolar Fx (6)	None	• Talar component subsidence (1) • Valgus instability (1) • Painful arthrofibrosis (3)	• AOFAS score 42 → 68 • Ankle ROM 26° (5°–35°)
Hintermann et al. [14]	PS, SC	IV	29 (30)	TT AD (24), TTC AD (6)	HINTEGRA (30)	4.7 (3.0–7.5)	• Malleolar Fx (5) • Transection of FHL tendon (1)	Delayed wound healing (1)	• Aseptic talar component loosening requiring revision arthroplasty (1) • Painful arthrofibrosis requiring tibiocalcaneal AD (2)	• VAS 7.5 → 1.8 • AOFAS score 34 → 71 • Ankle ROM 25.5° (8°–40°)
Pellegrini et al. [33]	RS, SC	IV	23 (23)	TT AD (12), TTC AD (11)	INBONE (14), STAR (7), Salto Talaris (2)	2.8 (1.0–8.4)	Malleolar Fx (2)	• Superficial wound problems (5) • Transient irritation of deep peroneal nerve (1) and tibial nerve (2)	• Aseptic talar component loosening (3) requiring revision arthroplasty (2) or TTC AD (1) • Subtalar OA requiring subtalar AD (1) • Varus hindfoot deformity requiring calcaneal osteotomy (1) • Ankle impingement requiring open debridement (1) • Posterior ankle impingement requiring arthroscopic debridement (1)	• VAS 66 → 18 • SF-36 score 38 → 56 • DF 2° ± 2.9°; PF 19.9° ± 9.3°
Preis et al. [38]	RS, SC	IV	18 (18)	TT AD (18)	HINTEGRA (18)	4.6 (2.1–9.2)	Malleolar Fx (2)	• Delayed wound healing (3) • CRPS type II (1)	• Painful arthrofibrosis requiring open arthrolysis (2) • Medial ankle instability with collapsing of the medial arch (1)	• VAS 8.6 → 1.7 • AOFAS score 23 → 68 • SF-36 mental components 49 → 75.5 • SF-36 physical components 34 → 74
Williamson et al. [50]	RS, SC	V	1 (1)	TT autofusion (1)	Salto XT revision (1)	1	None	None	None	• FAOS hindfoot score 37 → 83.5 • SF-12 62.5 → 97 • DF 5°, PF 20°

Table 1 (*Continued*)

Study	Type of study	LoE	Number of patients (feet)	Initial procedure (n)	Prosthesis type (n)	Follow-up (years)	Complications			Clinical outcomes
							Intraoperative (n)	Perioperative (n)	Postoperative (n)	
Present study	RS, SC	IV	6 (6)	TTC AD (6)	HINTEGRA (6)	3.4 (1.0–6.5)	None	• Superficial infection requiring i.v. antibiotics (1) • CRPS type II (1)	Painful arthrofibrosis requiring open arthrolysis (1)	• VAS 8.7 → 1.5 • AOFAS hindfoot score 16 → 69 • SF-36 mental components 43 → 78 • SF-36 physical components 27 → 74 • Ankle ROM −5.8°→35.7°

AD, arthrodesis; AOFAS, American Orthopaedic Foot and Ankle Society; CRPS, complex regional pain syndrome; DF, dorsiflexion; FAOS, Foot and Ankle Outcome Score; FHL, flexor hallucis longus; Fx, fracture; v., intravenous; LoE, level of evidence; OA, osteoarthritis; PF, plantar flexion; PS, prospective; ROM, range of motion; RS, retrospective; SC, single-center; SF-12, 12-Item Study Short Form Health Survey; SF-36, 36-Item Study Short Form Health Survey; STAR, Scandinavian Total Ankle Replacement; TT, tibiotalar; TTC, tibiotalocalcaneal; VAS, visual analog scale.

2. Patients and methods

2.1. Patient demographics

This retrospective study was approved by the institutional review board (Landesärztekammer Hessen) with a waiver of informed consent. The patient cohort was identified by searching the German Foot and Ankle Society's TAR register [25,26] for conversion procedures of TTC arthrodesis to TAR performed at the first author's institution between January 1, 2007 and December 31, 2016.

In total, six consecutive patients (four male, two female) with a mean age of 53.5 ± 8.8 years (range 44.7–66.3) were included for final analysis (Table 2). There were no excluded patients during this period of time. The mean body mass index was 25.2 ± 1.2 kg/m^2 (range 23.9–26.9). The initial TTC arthrodesis was performed 9.1 ± 5.5 years (range 2.9–17.7) prior to conversion procedure. The indication for the initial TTC arthrodesis was end-stage posttraumatic osteoarthritis (n = 5) or rheumatoid arthritis (n = 1) with concomitant subtalar arthritis. All patients who underwent conversion of TTC arthrodesis to TAR suffered from painful ankle arthrodesis. One patient was a moderate smoker. No other important comorbidities including diabetes mellitus were observed in our patient cohort.

2.2. Surgical technique and postoperative management

Conversion to TAR was performed using the cementless HINTEGRA total ankle prosthesis (Allegra Orthopaedics, New South Wales, Australia), a non-constrained, three-component prosthesis (Fig. 1) [4,16]. All procedures were performed by the first author, an experienced foot and ankle surgeon. For postoperative pain control, all patients had a preoperative popliteal block placed by the anesthesia team [1]. Perioperative antibiotic prophylaxis was performed using intravenous (i.v.) cefazolin. After general anesthesia was induced, the patient was placed in the supine position and an ipsilateral thigh tourniquet with 250 mmHg was used. In patients with retained hardware (n = 5), the hardware was removed through the original incision. The surgical technique for TAR has been described in detail previously [14,15,38]. In summary, the fused ankle joint was exposed through a 10–12 cm straight, midline anterior incision. An intraoperative C-arm was used to mark the original tibiotalar joint using Kirschner wires. The tibial and talar cuts were performed using cutting blocks [15,38]. In patients with previously osteotomized fibula (n = 4), fibula reconstruction (lengthening) was performed using a separate lateral incision. In all patients, an extensive capsulotomy and arthrolysis was performed through a separate posterolateral approach. In 4 of 6 patients, additional a z-shaped lengthening of the posterior tibial tendon was performed through a separate medial approach.

Postoperative rehabilitation included 15 kg partial weight-bearing using a stable walking boot for 6 weeks. Patients were seen for their first clinical and radiographic follow-up at 6 weeks. Weight bearing was then slowly increased utilizing a stabilizing walker over the following 2 weeks.

2.3. Clinical evaluation

Patient reported pain levels were assessed using the visual analog scale (VAS) from 0 points (no pain) to 10 points (maximal pain) [18]. The American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score was used for functional assessment [21]. Patients were seen preoperatively and postoperatively in the outpatient clinic by two independent medical assistants who were not involved in the surgery. Ankle ROM was measured clinically

Table 2
Demographic data of six patients with conversion of tibiotalocalcaneal arthrodesis to total ankle replacement.

Case	Gender	Age (years)	BMI (kg/m^2)	Smoking	Time since index surgery (years)	Follow-up (years)
1	Female	44.7	23.9	Yes	17.7	4.3
2	Female	66.3	25.1	No	11.1	6.5
3	Male	61.7	26.9	No	2.9	3.0
4	Male	45.8	26.4	No	12.0	3.6
5	Male	48.8	23.9	No	5.5	1.8
6	Male	53.6	25.0	No	5.2	1.0
Mean ± SD (range)		53.5 ± 8.8 (44.7–66.3)	25.2 ± 1.2 (23.9–26.9)		9.1 ± 5.5 (2.9–17.7)	3.4 ± 1.9 (1.0–6.5)

BMI, body mass index; SD, standard deviation.

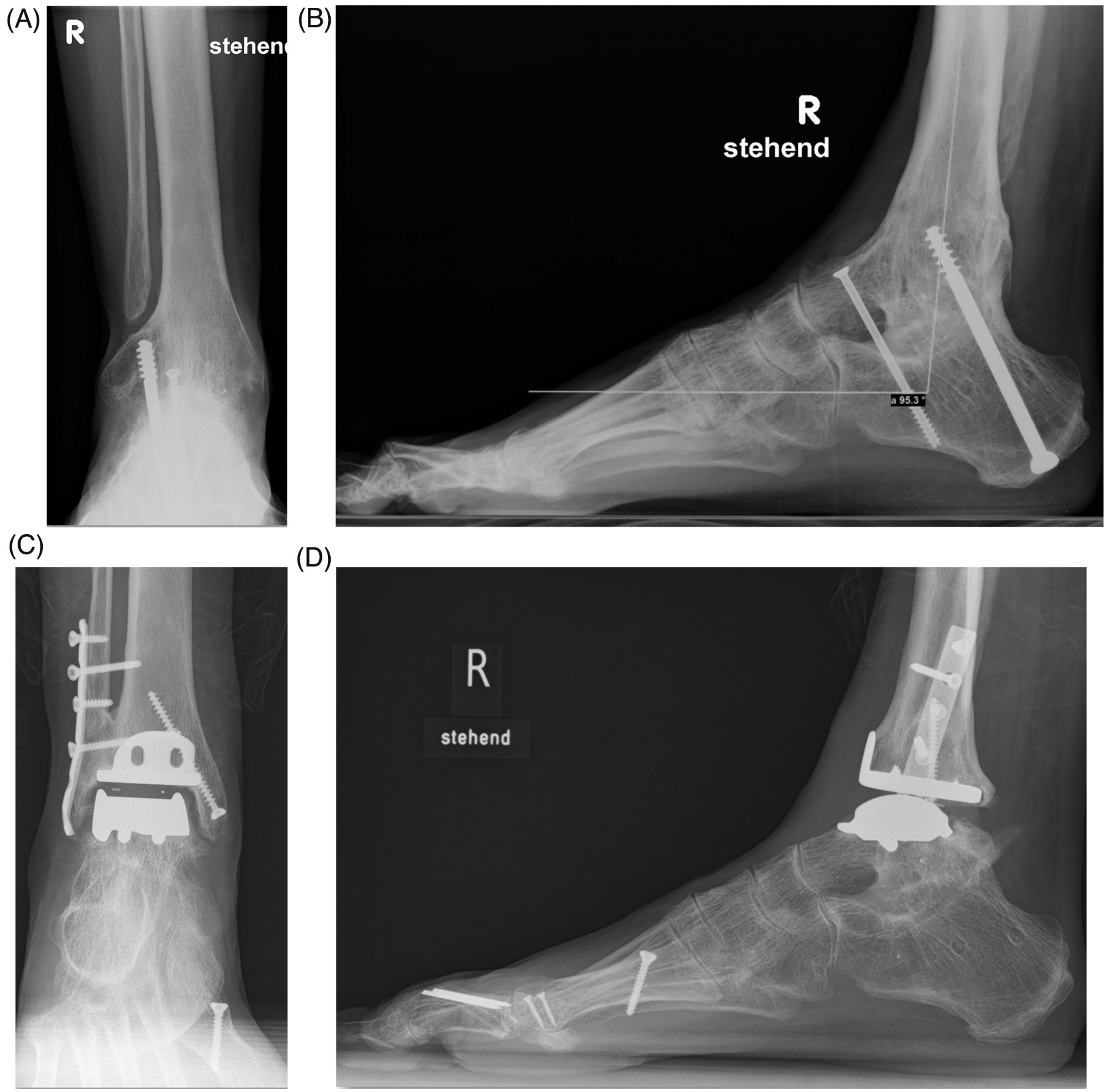

Fig. 1. A 45-year-old female with a painful malunited tibiotalocalcaneal arthrodesis performed 17.7 years ago. (A) Anteroposterior and (B) lateral views demonstrate complete osseous fusion of the tibiotalar joint with initially osteotomized fibula and 5° of equinus deformity. (C) Anteroposterior and (D) lateral views of the ankle demonstrate appropriate alignment and osseous integration of both prosthesis components and appropriate length of the fibula at 5 years follow-up. The overall pain was 3 on the visual analog scale with a maximum walking distance 1–2 km.

with a goniometer in a weight-bearing position [29]. The preoperative and postoperative quality of life was assessed using the 36-Items Medical Outcomes Study Short Form Health Survey (SF-36) [48].

2.4. Radiographic evaluation

Preoperative and postoperative radiographic evaluation was performed on weight-bearing ankle radiographs in two planes including anteroposterior (AP) and lateral views. The talonavicular joint was assessed preoperatively and postoperatively using the Kellgren–Lawrence scoring system for arthritis [19]. The angular positions of the tibial and talar components were assessed by measuring α-, β-, and γ-angles. The α- and β-angles were measured between the longitudinal axis of the tibia and the articular surface of the tibial component in the AP and lateral views, respectively [3,16,28]. The 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 [3,16,28]. The coronal intercomponent alignment was assessed by measuring valgus-varus tilt on AP ankle radiographs. The sagittal intercomponent alignment was measured using AP offset as described before [2]. The stability of the prosthesis component was assessed by analyzing the bone-implant interface on the tibial side using weight-bearing lateral radiographs [6,23,24]. Four zones were defined on the tibial side from anterior to posterior. Each zone was classified as normal, lucent (radiolucent line <2 mm), or cystic loosening (cystic lesion with a diameter at least 2 mm) [47]. Due to the prosthesis design, the bone-implant interface on the talar side was not visible on conventional radiographs. Loosening of the talar component was defined as subsidence into the talus by >5 mm or change in position of >5° relative to a line drawn from the top of the talonavicular joint to the tuberosity of the calcaneus [16,22].

2.5. 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 non-normally distributed data, respectively. An unpaired *t*-test and Mann–Whitney rank sum test were used for comparison of unpaired normally and non-normally distributed data, respectively. Fisher's exact test was used for comparison of unpaired binomial data. A *p* value of ≤0.05 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).

3. Results

3.1. Operative characteristics

The mean surgery duration was 180 ± 16 min (range 158–195). The mean duration of tourniquet was 110 ± 11 min (range 96–120). The following concomitant one-stage procedures were performed: removal of hardware (n = 5), reconstruction of distal fibula (n = 4), anatomic reconstruction of lateral ligaments (n = 4), and dorsiflexion osteotomy of the 1st metatarsal (n = 1).

3.2. Intraoperative, perioperative, and postoperative complications

No intraoperative complications were observed in our patient cohort. In five patients, wound healing occurred uneventfully within 2 weeks. One patient had delayed wound healing with superficial infection treated with i.v. antibiotics and local wound care, resulting in complete wound healing 4 months after the initial surgery. One patient developed CRPS Type 2 which resolved completely within 6 months after surgery.

The same patient who experienced CRPS developed painful arthrofibrosis with ankle ROM including dorsiflexion and plantar flexion of 10° and 10°, respectively. An open arthrolysis, inlay exchange, partial hardware removal of the fibula, and Hook lengthening of Achilles tendon was performed 1.2 years after the index procedure. The initial postoperative course was uneventful with improved ankle ROM including dorsiflexion and plantar flexion of 15° and 25°, respectively. Over time, the patient developed a recurrent, painful arthrofibrosis with ankle ROM restriction including dorsiflexion and plantar flexion of 10° and 10°, respectively. A second revision surgery was performed 4.2 years later (5.6 years after the index surgery) including open arthrolysis and inlay exchange resulting in pain reduction and ROM improvement.

3.3. Clinical outcome

The mean follow-up in this study was 3.4 ± 1.9 years (range 1–6.5). All patients experience significant pain relief and functional improvement at the latest follow-up (Table 3).

3.4. Radiographic outcome

In one patient, radiolucencies were observed in the posterior quarter of the bone-prosthesis interface on the tibial side at the latest follow-up (3.6 years). The radiolucency was seen at an early postoperative time frame and was not progressive. No talar subsidence was observed in any patient. Tibial and talar components were neutrally aligned in the coronal and sagittal planes (Table 4). No varus- or valgus-tilt was observed in any of the ankles with TAR. The mean anteroposterior offset ratio was neutral (range 0.0 to 0.1).

3.5. Clinical and radiographic outcome comparison in patients with initial tibiotalar vs. tibiotalocalcaneal arthrodesis

Recently, we published clinical and radiographic outcomes in patients who initially underwent tibiotalar arthrodesis [38]. We compared demographic data, complication rate, and clinical and radiographic outcomes between patients from that previous study and patients in this study. Demographic data were comparable in both groups with regard to gender, age, body mass index, and comorbidities (Table 5). Rates of intraoperative, perioperative, and postoperative complications were also similar in both patient cohorts (Table 5). The conversion procedure took on average 21 min longer in patients with previous TTC arthrodesis, as reconstruction of the distal fibula was performed in four of six versus two of 18 procedures (Table 5). Preoperative AOFAS hindfoot score and preoperative summary of mental and physical SF-36 items for quality of life were significantly lower in patients who initially underwent TTC arthrodesis. However, postoperative clinical outcomes including pain relief, ankle ROM, AOFAS hindfoot

Table 3
Clinical outcome in six patients with conversion of tibiotalocalcaneal arthrodesis to total ankle replacement.

Case	VAS		AOFAS hindfoot score		Total ROM		SF-36 physical		SF-36 mental	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	10	3	8	68	−20	35	25	70	41	72
2	9	0	25	78	0	37	28	80	45	81
3	8	2	22	65	0	20	28	74	41	76
4	8	2	10	68	−5	25	26	71	43	80
5	8	1	12	63	−10	40	28	74	43	81
6	9	1	18	70	0	37	25	74	43	81
mean ± SD (range)	8.7 ± 0.8 (8–10)	1.5 ± 1.0 (0–3)	15.8 ± 6.9 (8–25)	68.7 ± 5.2 (63–78)	−5.8 ± 8.0 (−20 to 0))	35.7 ± 12.3 (20–55)	26.6 ± 1.9 (25–28)	73.8 ± 3.4 (70–80)	42.7 ± 1.7 (41–45)	78.3 ± 3.7 (72–81)
P value[a]	<0.001[b]		<0.001[b]		<0.001[b]		<0.001[b]		<0.001[b]	

AOFAS, American Orthopaedic Foot and Ankle Society; pre, preoperative; post, postoperative; ROM, range of motion; SD, standard deviation; SF-36, 36-Items Medical Outcomes Study Short Form Health Survey; VAS, visual analog scale.
[a] Preoperative vs. postoperative.
[b] Using paired *t*-test.

Table 4
Radiographic outcome in six patients with conversion of tibiotalocalcaneal arthrodesis to total ankle replacement.

Case	Tibiotalar joint	TT-TN angle	Subtalar joint	Talonavicular joint[a]		Prosthesis alignment		
				Pre	Post	α-angle	β-angle	γ-angle
1	Fused	125°	Fused	2	2	87°	89.5°	12.5°
2	Fused	115°	Fused	2	2	88°	86.5°	18°
3	Fused	112.5°	Fused	1	2	87.5°	85.5°	15°
4	Fused	121.5°	Fused	2	2	88.5°	87°	15.5°
5	Fused	125°	Fused	2	2	87°	88°	17°
6	Fused	114.5°	Fused	2	2	88°	88°	12.5°
Mean ± SD (range)		118.9 ± 5.5 (112.5–125)				87.7 ± 0.6 (87–88.5)	87.4 ± 1.4 (85.5–89.5)	15.1 ± 2.3 (12.5–18)

pre, preoperative; post, postoperative; SD, standard deviation; TT-TN, tibiotalo-talonavicular.
[a] Using Kellgren–Lawrence scoring system for arthritis.

Table 5
Conversion to total ankle replacement: comparison between patients with initial tibiotalar [38] vs. tibiotalocalcaneal arthrodesis.

	Patients with initial tibiotalar arthrodesis [38]	Patients with initial tibiotalocalcaneal arthrodesis	*p* Value
Demographic data			
Number of patients (ankles)	18 (18)	6 (6)	–
Gender male:female	14:4	4:2	0.618[a]
Mean age in years (range)	51.5 ± 7.5 (42.0–67.5)	53.5 ± 8.8 (44.7–66.3)	0.583[b]
Mean BMI in kg/m^2 (range)	26.4 ± 3.1 (22.5–34.3)	25.2 ± 1.2 (23.9–26.9)	0.376[b]
Etiology of ankle OA posttraumatic/rheumatoid/haemophilic	13/4/1	5/1/0	0.509[c]
Diabetes mellitus yes:no	2:16	0:6	1.000[a]
Smoking yes:no	1:17	1:5	0.446[a]
Surgical data			
Mean time since initial arthrodesis in years (range)	6.2 ± 3.5 (1.8–14.0)	9.1 ± 5.5 (2.9–17.7)	0.152[b]
Mean surgery duration in minutes (range)	159 ± 22 (122–197)	180 ± 16 (158–195)	0.037[b]
Distal fibula reconstruction yes:no	2:16	4:2	0.018[a]
Complications			
Intraoperative complications yes:no	2:16	0:6	1.000[a]
Perioperative complications yes:no	3:15	2:4	0.568[a]
Postoperative complications yes:no	3:15	1:5	1.000[a]
Clinical outcome			
Mean follow-up in years (range)	4.5 ± 2.2 (2.1–9.2)	3.4 ± 1.9 (1.0–6.5)	0.405[c]
Mean preoperative VAS (range)	8.6 ± 0.8 (7–10)	8.7 ± 0.8 (8–10)	0.943[c]
Mean postoperative VAS (range)	1.7 ± 1.6 (0–7)	1.5 ± 1.0 (0–3)	0.972[c]
Mean preoperative ROM in degrees (range)	−1.4 ± 2.3 (−5 to 0)	−5.8 ± 8.0 (−20 to 0)	0.185[c]
Preoperative fixed equinus deformity yes:no	6:12	3:3	0.635[a]
Mean postoperative ROM in degrees (range)	23.3 ± 7.1 (15–38)	29.8 ± 8.0 (20–37)	0.073[b]
Mean preoperative AOFAS hindfoot score (range)	23.2 ± 6.0 (12–32)	15.8 ± 6.9 (8–25)	0.019[b]
Mean postoperative AOFAS hindfoot score (range)	67.6 ± 13.6 (22–92)	68.7 ± 5.2 (63–78)	0.687[c]
Mean preoperative SF-36 physical health summary (range)	33.6 ± 5.1 (27.0–44.9)	26.6 ± 1.9 (24.5–28.3)	0.003[b]
Mean postoperative SF-36 physical health summary (range)	73.6 ± 10.8 (33.6–86.0)	73.8 ± 3.4 (70.0–80.0)	0.299[c]
Mean preoperative SF-36 mental health summary (range)	48.9 ± 4.1 (40.8–55.0)	42.7 ± 1.7 (40.8–45.3)	0.003[c]
Mean postoperative SF-36 mental health summary (range)	75.5 ± 6.8 (53.8–83.4)	78.3 ± 3.7 (71.5–80.8)	0.483[c]
Radiological outcome			
Mean α-angle in degrees (range)	88.1 ± 1.2 (85.6–90.0)	87.7 ± 0.6 (87.0–88.5)	0.439[b]
Mean β-angle in degrees (range)	85.5 ± 1.8 (82.3–88.0)	87.4 ± 1.4 (85.5–89.5)	0.023[b]
Mean γ-angle in degrees (range)	14.9 ± 1.7 (12.0–18.0)	15.1 ± 2.3 (12.5–18.2)	0.800[b]

AOFAS, American Orthopaedic Foot and Ankle Society; BMI, body mass index; OA, osteoarthritis; ROM, range of motion; SF-36, 36-Item Study Short Form Health Survey; VAS, visual analog scale.
[a] Using Fisher's exact test.
[b] Using unpaired *t*-test.
[c] Using Mann–Whitney rank sum test.

score, and quality of life, were comparable in both groups (Table 5). The alignment of tibial and talar components were similar at the latest follow-up in all patients as measured using α-, β-, and γ-angle (Table 5).

4. Discussion

Malunion and/or non-union are major complications which may occur in patients who undergo TTC arthrodesis [8,32]. If conservative treatment fails in patients with TTC arthrodesis related complications, revision surgery options are challenging and may include revision arthrodesis [11] or conversion to TAR [33]. The conversion of a painful ankle arthrodesis to TAR was first described by Greisberg et al. in 2004 (Table 1) [13]. Recently, we published our experience with this procedure in patients who initially had isolated tibiotalar arthrodesis [38]. The majority of clinical studies addressing outcomes in patients who have undergone conversion of ankle arthrodesis to TAR include patients with initial tibiotalar arthrodesis. Few studies have addressed the results of TTC arthrodesis (Table 1).

In the last two decades, TAR has gained increased acceptance among foot and ankle surgeons as a treatment option in patients with end-stage ankle OA [5]. As satisfactory results were observed using current prosthesis designs [5,12,49], the indications for TAR have been broadened including revision TAR [17] and conversion of ankle arthrodesis to TAR (Table 1). However, the conversion of painful ankle arthrodesis to TAR is a technically demanding procedure requiring many freehand steps (e.g. marking of tibiotalar joint line) [15,34]. Intraoperative complications are not uncommon and may include intraoperative malleolus fractures in up to 26% of all cases [33]. In our previous study that included 18 patients with previous tibiotalar arthrodesis we observed two intraoperative medial malleolus fractures [38]. In the current study, no intraoperative complications were observed. This can be attributed to the extensive experience of the first author with TAR (more than 500 primary TARs) who performed all conversion procedures in this study.

In patients with primary TAR, the annual failure rate has been reported to be 1.2% with a 95% confidence interval between 0.7 and 1.6, resulting in an overall survivorship of 89% at 10 years [49]. The most common reason for TAR failure is aseptic loosening of one or both prosthesis components [5,27,42]. In the current literature, the rate of aseptic prosthesis component loosening is reported between 0 and 13% in patients with conversion procedure (Table 1) [33]. In the present study, we observed one patient with radiolucent lines in the posterior 25% of the tibial prosthesis–bone-interface which did not show progression during follow-up. However, no painful loosening was observed in any of our patients. Another common postoperative complication in patients with conversion TAR is painful arthrofibrosis with substantially reduced ankle ROM, a complication with a reported incidence of up to 13% (Table 1) [13,14]. In our study, one patient developed painful ankle arthrofibrosis secondary to CRPS, requiring two open arthrolysis procedures. The relative high and constant rate of arthrofibrosis in patients with conversion procedure can be explained by degeneration of periarticular soft tissues resulting from ankle immobilization after ankle arthrodesis. Possible damage to the periarticular soft tissue envelope from previous surgeries may also play a role [14].

Postoperatively, all patients in our cohort reported significant pain relief and functional improvement, including increased ankle ROM. Although significant pain reduction was observed, only one out of six patients was completely pain free at the latest follow-up. This is well-known phenomenon where even patients with primary TAR have been reported to have residual pain in up to 60% of all procedures [12]. The mean postoperative ankle ROM was $29.8^{\circ} \pm 8^{\circ}$ with a range between 20° and 37°. This is substantially lower than the postoperative mean ankle ROM of 34° reported in patients with primary TAR [49]. The cause for decreased ankle ROM following conversion of an ankle arthrodesis to a TAR is likely secondary to degeneration and stiffness of the periarticular soft tissues following prolonged ankle immobilization after arthrodesis.

Due to the limited number of available studies with a relatively low number of patients (Table 1), it remains difficult to identify risk factors for lower postoperative outcomes or TAR failure in patients with conversion procedures. Patients with previously osteotomized fibula may have lower functional results and higher revision rates [13,14,33]. We did not observe any differences in the present or previous [38] study performed at our institution; however, this may be related to the relatively low number of included patients. Furthermore, it remains unclear whether patients with initial TTC arthrodesis have less favorable outcomes than patients who initially underwent tibiotalar arthrodesis. Pellegrini et al. [33] reported on outcomes of 23 conversion procedures, 11 of those were performed on patients who had TTC arthrodesis. However, no comparison between both subgroups was performed. We compared the results of the present study with outcomes of 18 patients who initially underwent an isolated tibiotalar arthrodesis [38]. Although the preoperative AOFAS hindfoot score and preoperative summary of mental and physical SF-36 items for quality of life were significantly lower in patients who initially underwent TTC arthrodesis, the postoperative outcome and complication rate was similar in both groups. Therefore, a prior TTC arthrodesis should not be seen as a relative contraindication for a conversion procedure.

This study has a number of limitations. First, the design of the present study was retrospective. However, all patient data was collected longitudinally and transferred to the German Foot and Ankle Society's TAR register. Second, the mean follow-up of the present study was relatively short with a 3.4 year average. Future consecutive studies are needed to address the survivorship of prosthesis components at longer-term follow-up. Third, the patient cohort was relatively small. Therefore, all findings including any statistical analyses should be carefully interpreted, as some results may be underpowered. Fourth, the ankle ROM was assessed clinically using a goniometer. It is likely that the observed ROM was a combination of "true" ankle motion and transverse tarsal motion. Fifth, one of the tools used for functional assessment was the AOFAS hindfoot score, which is a non-validated score [37]. However, we were not aware of this deficiency in 2009 when we did the first case. Furthermore, this score has been shown to have enough discriminatory capacity to assess postoperative improvement in patients with TAR [35]. Finally, all procedures were performed by a single surgeon with an extensive experience using this prosthesis design. Therefore, the observed results should be carefully generalized.

5. Conclusion

In the present small series, the conversion of a painful ankle arthrodesis following tibiotalocalcaneal arthrodesis to a total ankle replacement was a reliable surgical treatment. The observed results are comparable to those obtained in patients who had a prior isolated tibiotalar arthrodesis. Further clinical studies with more patients and longer-term follow-up are needed to confirm the short-term results of this study.

Conflicts of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Declaration and verification

The work described in this study has not been published previously and is not under consideration for publication elsewhere. Its publication is approved by all authors.

Authorship

All authors have made substantial contribution to all of the following: (1) the conception and design of the study, acquisition of data, analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

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