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Tibiotalocalcaneal arthrodesis with a triple-bend intramedullary nail (A3)—2-year follow-up in 60 patients

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ABSTRACT

Background: The aim of the study was to analyze the clinical aspects including 2-year follow-up of tibiotalocalcaneal arthrodesis (TTCA) with a triple-bend retrograde intramedullary nail (A3, Stryker, Airview Boulevard, MN, USA).
Methods: All patients with TTCA with A3 between October 18, 2011 and April 29, 2013 were included. Visual Analogue Scale Foot and Anklenkle (VAS FA), indications for surgery, details of surgery, radiographic measurements, and complications were analyzed.
Results: A total of 66 patients were included. The mean VAS FA was 29.6. Most common indications were arthrosis (n = 43; 65%) and deformity (n = 36; 55%). The accuracy of correction and implant position was 9.4 (maximum 10) on average. Infection rate was 3% (n = 2). Sixty (91%) patients completed follow-up: VAS FA 59.9, fusion rate 100%, high accuracy of correction and implant position.
Conclusions: TTCA with the A3 implant system showed accurate correction and implant position. Two-year follow-up in 60 patients (91%) showed good clinical outcome scores and 100% fusion rate.

1. Introduction

Tibiotalocalcaneal arthrodesis (TTCA) is a salvage procedure for restoration of a stable and plantigrade foot in deformities at the ankle and/or hindfoot and concomitant degenerative changes at the ankle and subtalar joints [1–8]. Typical indications are also failed (corrective) arthrodesis of the ankle and subtalar joints, fused ankle and degeneration of the subtalar joint, failed total ankle replacement with insufficient substance of talar body and/or degeneration of subtalar joint, massive hindfoot instability, and severe pilon fractures [1–7,9–11]. TTCA may be performed with different techniques. Screws, plates, external fixators, intramedullary nails, and combinations of different implants have been described [2–5,11–13]. TTCA with intramedullary implants can be performed with retrograde femoral nails or retrograde ankle arthrodesis nails [2–8]. The first biomechanical studies in the literature investigated first-generation retrograde (femoral) nails without foot and ankle specific locking options [14–17]. Second-generation nails with foot and ankle specific locking options such as anteroposterior locking within the calcaneus and/or optional compression were designed to increase stability [18–20]. In 2010, another system with a triple-bend retrograde intramedullary nail (A3, Stryker, Airview Boulevard, MN, USA) was introduced [1]. In an earlier biomechanical study this implant was compared with another system (HAN, Synthes, West Chester, PA, USA) [12]. Both constructs showed sufficient stability compared with earlier data from the same model [12]. The data suggest that both implants allow for sufficient primary stability for TTCA in osteoporotic and consequently also in nonosteoporotic bone [1]. The A3 nail is in continuous use in the authorś institution. The aim of this study was to analyze the clinical aspects of the A3-system including 2-year follow-up.

2. Methods

2.1. Study design

All patients that sustained an unilateral TTCA with A3 between October 18, 2011 and April 29, 2013 were included in the study. No exclusion criteria were defined except bilateral surgery at once or at different times. Demographic data, Visual Analogue Scale Foot and Anklenkle (VAS FA), use of aids for ambulation (crutches, wheelchair), use of special shoe wear were recorded at time of inclusion and follow-up [21]. Indications for surgery, details of surgery, and complications with resulting measures were recorded. The indications were defined by the two senior surgeons based on

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clinical and radiographic evaluation including radiographic measurements as described. The details of surgery included different surgical times (entire surgery or skin-to-skin-time, tourniquet time, time for A3 insertion (first guidewire to compression or fixation of endcap)), implants used (nail size, optional endcap use), implantation mode (use of compression mode or angular locking mode), problems during surgery, and assessment of accuracy of correction and implant position by the surgeon (Visual-Analogue-Scale (VAS) 0–0, 0 = most inaccurate imaginable, 10 = most accurate imaginable) [1]. Intra- and postoperative complications were registered. Delayed union up to 1 year were not specified as complication. The following radiographs were obtained and analyzed for this study. Preoperatively: bilateral dorsoplantar and lateral views of the entire foot, bilateral ankle a.p., bilateral Saltzman views, and entire leg affected side with full weight bearing (if possible due to the general condition of the patient) [22,23]. A total of 6, 9, and 12 weeks postoperatively: radiographs a.p. and lateral of the lower leg/ankle/hindfoot of the affected side without weight bearing. One and 2-year follow-up: bilateral dorsoplantar and lateral views of the entire foot, bilateral ankle a.p, bilateral Saltzman views with weight bearing [22,23]. Intraoperatively, 2D- and 3D-fluoroscopic imaging (ARCADIS-3D, Siemens, Erlangen, Germany) was obtained and analyzed for the study [24]. Additional radiographs, or CT, or PedCAT preoperatively and at one- and 2-year followup were obtained but not analyzed for this study [25]. Two-year follow-up was defined as follow-up 24 to 27 months after surgery.

2.2. Implant (A3, Stryker, Airview Boulevard, MN, USA, Fig. 1) [12]

Fig. 1 The A3–Anatomic Arthrodesis System is designed for simultaneous arthrodesis of the ankle and subtalar joints (Fig. 1) [12]. The implant consists of a retrograde intramedullary non-cannulated nail, locking screws, a compression bolt, and endcap. The specific shape of the A3 nail includes a distal double bend; one posterior (15°) and one lateral (10°), and a proximal bend, which is a slight recurvatum. The direction of the distal locking screws is adapted to the axes of the talus (15° plantarflexion in relation to tibial axis/middle nail portion, and 15° internal rotation) and calcaneus (15° dorsiflexion in relation to tibial axis/middle nail portion). A compression bolt provides mechanical compression between the calcaneus and talus, and between the talus and tibia, and angular locking of the calcaneal locking screw with the nail. The compression bolt is inside the nail under the calcaneal locking screw. The compression is performed after calcaneal, talar, and tibial locking. When forwarded, the compression bolt pushes the calcaneal locking screw with the calcaneus towards the talus and the talus towards the tiba. Static locking without compression is optional. An endcap with 5, 10, and 15 mm length is optional. An endcap is considered when the distal end of the nail is not flush with the lower surface of the calcaneus at the nail entry point but further inside the bone. The endcap length is chosen to allow for flush distal endcap end with the lower surface of the calcaneus at the nail entry point. An aiming device for the preparation of the canal for the nail includes a guide for two wires, which allows for exact placement of the drill while respecting the distal double bend of the nail. The aiming arm is attached to the nail during and after nail insertion and allows precise locking screw placement with different options for static, dynamic of compressive locking.

2.3. Surgical procedure including planning and postoperative management [1]

Software-based planning was performed based on preoperative radiographs (software Hectec® classic, version 2.0, Landshut, Germany)(Fig. 2). This planning included the correction of the deformity if necessary, and definition of implant size and position. An unsterile tourniquet was placed at the thigh. Patients were positioned in prone position with the feet placed over the edge of the table. Preparation and sterile draping followed. The foot and leg

Fig. 1. A3 (Anatomic Arthrodesis System, Stryker, Airview Boulevard, MN, USA).

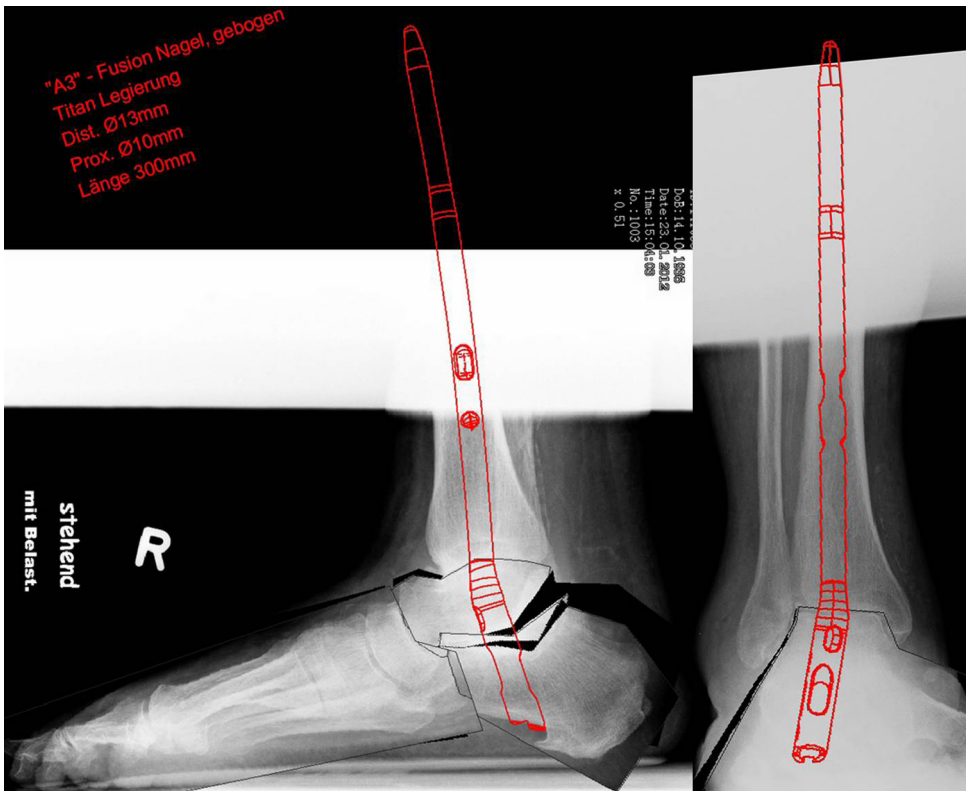

Fig. 2. Software-based planning based on preoperative radiographs (software Hectec® classic, version 2.0, Landshut, Germany). Different corrections were included in the planning (Plantiflexion of talus and dorsiflexion of calcaneus with increase of lateral talocalcaneal angle on lateral view and planning; hindfoot varisation on a.p. view and planning).

was unwrapped with an Esmarch bandage and the tourniquet was insufflated with 350 mm Hg pressure. A posterolateral or posterior approach between Achilles and peroneal tendons was performed. Ankle and subtalar joints were exposed. Joint preparation with cartilage and/or osteophyte removal and optional corrective osteotomies followed. In all patients without existing total knee replacement, cancellous bone was harvested from the ipsilateral proximal tibia. When this was not performed due to an existing total knee replacement, demineralized human bone matrix (DBM, DIZG, Berlin, Germany) was used as transplant. Corticocancellous bone blocks from the ipsilateral posterior pelvic rim were optionally harvested. The cancellous bone or DBM were inserted in ankle and subtalar joints, and the optional corticocancellous bone block(s) into the subtalar joint. During correction, placement of autografts/DBM, and placement of the A3 (guidewires, nail, locking screws, compression bolt, and optional endcap), fluoroscopic control with lateral and anteroposterior views was performed. The distal bend of the nail was positioned at the level of the ankle under fluoroscopic control. The calcaneal locking screw was implanted first, followed by the talar locking screw and the tibial locking screws. Finally, the compression bolt was tightened to perform the compression. Fluoroscopic-2D-imaging and 3D-imaging (ARCADIS-3D, Siemens, Erlangen, Germany) for assessment of bone and implant position [24]. A 10 French drainage was inserted, and closure in 2 layers (subcutaneous and skin) was performed. A sterile dressing was applied. The tourniquet was opened with the dressing in place. An orthosis (Vacuped, Oped, Germany) was applied.

Bed rest and leg elevation for 3 days was performed postoperatively. Local standards for thrombosis prophylaxis were followed. The drainage was removed 2 days postoperatively. A total of 3 days postoperatively, mobilization with 15 kg in the orthosis was performed. If the patient was not able to perform partial weight bearing, mobilization in a wheel chair was performed. The first radiological assessment (radiographs entire foot dorsoplantar, lateral, and oblique views) regarding fusion was performed after 6 weeks postoperatively. Full weight bearing without orthosis was allowed when ankle and subtalar joints were considered to have fused. If fusion was not considered to be sufficient, further partial weight bearing with 30 kg in the orthosis was performed. Further assessments were carried out at 9 and 12 weeks postoperatively. Full weight bearing without orthosis was allowed when ankle and subtalar joints were considered to have fused at 9 weeks or at 12 weeks. When fusion was not considered to be sufficient at 12 weeks full weight bearing without orthosis was allowed and dynamization was indicated and performed.

2.4. Radiographic measurements and fusion assessment

All measurements and assessments of fusion were made three times by two different investigators. Bland and Altman plots and repeatability coefficients were used as measures of inter- and intraobserver repeatability [26]. The 95% limits of agreement represent a judgement of how well the measurements of the two investigators agreed. By definition, the measurement error was smaller than the repeatability coefficient for 95% of the observations.

The hindfoot angle was measured preoperatively, intraoperatively and at 2-year follow-up. The hindfoot angle was measured on Saltzman views acquired in standing position with full weight bearing (Fig. 3) preoperatively, and at 2-year follow-up (Fig. 5), and on paracoronar reformations of ARCADIS-3D images (Fig. 4) intraoperatively [24,25]. The hindfoot angle was defined as the

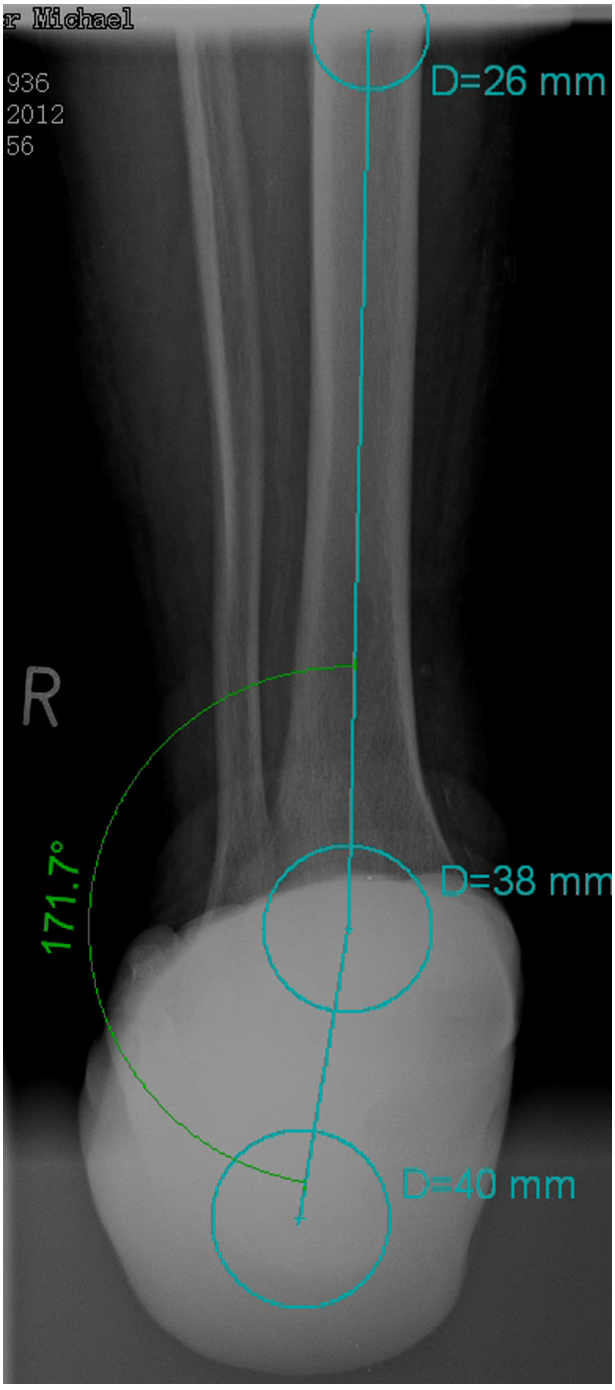

Fig. 3. Software-based measurement of hindfoot angle on preoperative radiographs (software Hectec® classic, version 3.0, Landshut, Germany). Same patient as Fig. 2. The centre of the tibial shaft, ankle, and posterior calcaneal process were defined by circles.

angle created between the axis of the distal tibia and the line between the centre of the talar dome and the posterior calcaneal process (Fig. 3) [25]. This angle was defined to be positive for hindfoot valgus and negative for hindfoot varus. For ARCADIS-3D the plane for the measurement was virtually rotated within the 3D-dataset to achieve an exact congruency to the bone axis of the tibia and the axis of the hindfoot. [25]. This was typically the case when this plane was congruent with the axis of the ankle, i.e., a line between medial and lateral malleolus comparable to a Mortise orientation but within a 3D-space.

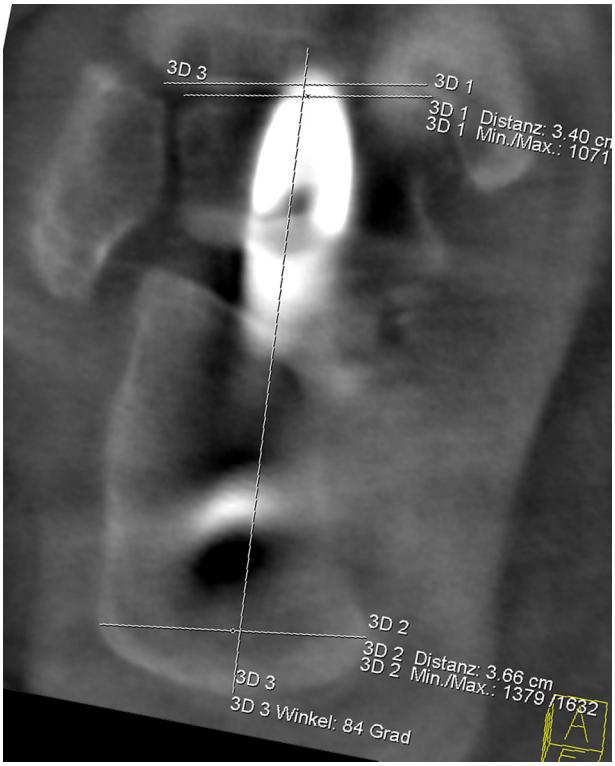

Fig. 4. Software-based measurement of hindfoot angle on intraoperative coronal 3D-reformation (device ACRADS-3D with software Syngo XS, version VE31GSL19P21VC10ASL129P167SP1, Siemens, Germany). Same patient as Figure 2 and 3.

The calcaneal pitch angle was measured preoperatively, and at 2-year follow-up. The calcaneal pitch angle was measured on a lateral radiographs acquired in standing position with full weight bearing (therefore not measured intraoperatively). It was defined as the angle created between two lines, one line between the lowest part of the posterior calcaneal process and the lowest part of the anterior calcaneal process, and one horizontal line [25].

A deviation of the hindfoot angle and calcaneal pitch angle was calculated. The deviation was defined as absolute difference between measured and desired angle, i.e., all values were defined to be positive. The desired angles were defined as 5° for hindfoot angle, and 20° for calcaneal pitch angle.

Fusion was assessed on the radiographs taken 6, 9, 12 weeks, one year, and two years postoperatively. Fusion was defined as 50% or more bony consolidation [1].

2.5. Statistical analysis

The data was analyzed with Microsoft Excel™ (Version 14.0.7145.5000, Microsoft, Redmont, WA, USA). A paired *t*-test was used for statistical comparison of VAS FA, and comparison of deviation of hindfoot angle and calcaneal pitch angle before surgery and at follow-up. A Chi2-test was used for all other parameters.

3. Results

3.1. Patients

A total of 66 patients were included. Thirty-seven were male (56%) and 29 female (44%). Mean age at time of surgery was 58.5 years (range, 22–80; standard deviation (std), 13.4); mean weight 89.1 kg (range, 46–160; std, 23.5); mean height 171.8 cm

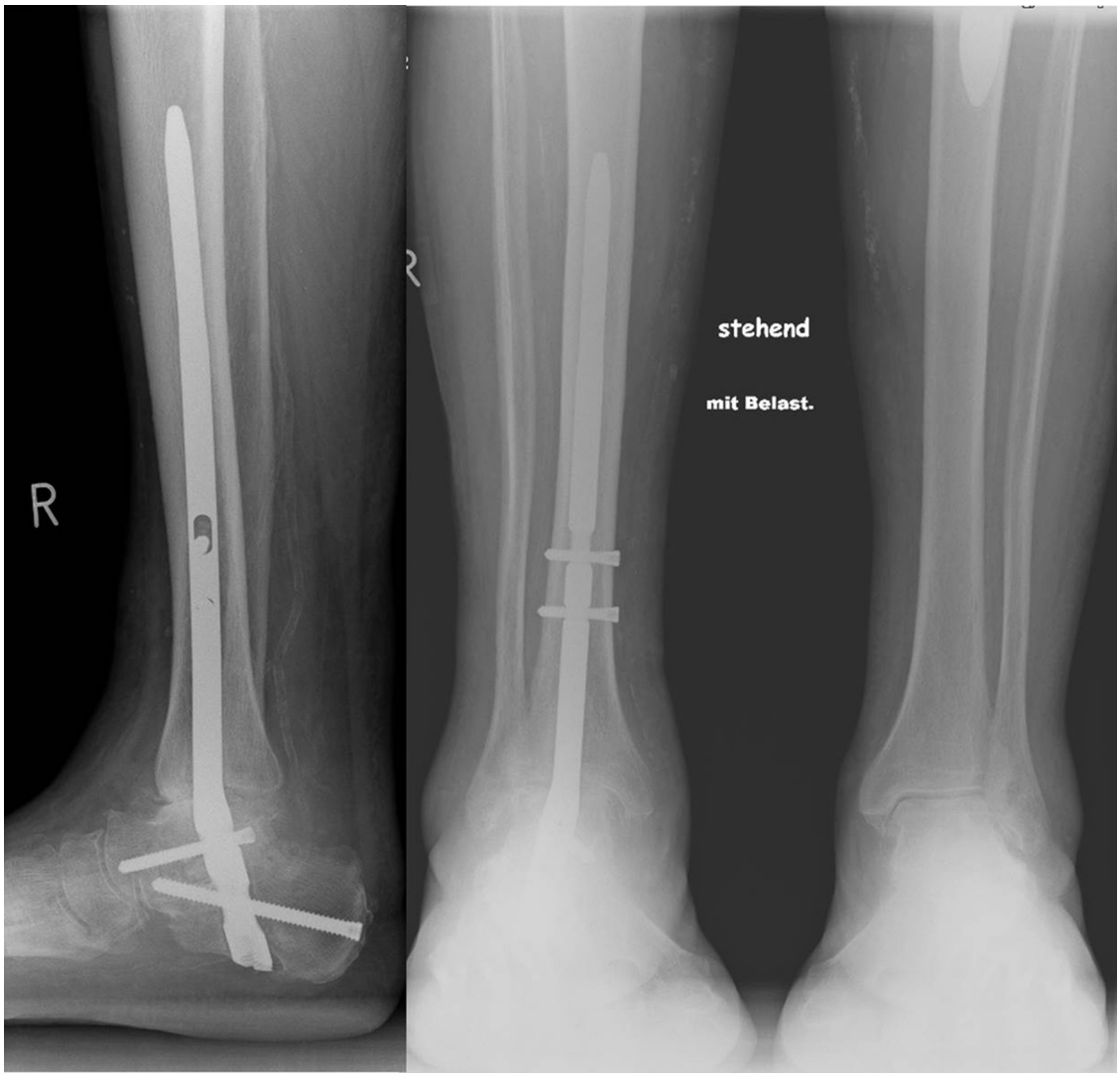

Fig. 5. Radiographs at 2-year follow-up. Same patient as Figure 2 – 4.

(range, 150–193; std, 9.2); mean body mass index (BMI) 30.0 kg/m^2 (range, 18.0–58.8; std, 7.5). The right side was operated in 41 patients (62%) and the left side in 25 (38%). Table 1 shows the use of special shoe wear and walking aids. The mean VAS FA was 29.6 (range, 0–69; std, 17.6).

3.2. Indications

Table 2 shows the indications for surgery. Most common indications were arthrosis ($n = 43$; 65%) and deformity ($n = 36$; 55%). Among the deformities, varus (27%), equinus (27%), and combined (29%) deformities were most common.

3.3. Details of surgery

The mean time for the entire surgery (skin-to-skin-time) was 92.2 (range, 55–145; std, 35.1) minutes, the mean tourniquet time was 95.2 (range, 58–150; std, 37.2) minutes, and the mean time for A3 insertion (first guidewire to compression or fixation of endcap) was 17.5 (range, 5–31; std, 4.9) min. The nail size was 300 × 10 mm in all patients. Autologous cancellous bone transplantation from the ipsilateral proximal tibia was used in 64 (97%), and DBM in 2 (4%) patients. Additional autologous corticocancellous bone block(s) were inserted into the subtalar joint in 6 (9%) patients. No endcap was used in 63 (95%) patients, and a 5 mm endcap in 3 (5%). In all patients, the compression mode with calcaneotalar and talotibial compression was used. The accuracy of correction and implant position was 9.4 on average (range, 7.5–10; std, 0.5)

3.4. Complications

A total of 5 complications were registered in 5 patients (8%), of which 2 (3%) occurred intraoperatively and 3 (5%) postoperatively. Intraoperative complications were one minor split of the tibial shaft without further measures executed (Patient no. 6), and one stuck 1st guidewire in the first guidewire template (Patient no. 13) that could be removed after 7 minutes (A3 implantation time in total 26 minutes). Postoperative complications were one talar locking screw penetrating the talonavicular joint between 3 and 6 months postoperatively without further measure executed (Patient no. 5), and two infections (3%, patients 26 and 27) that were addressed with multiple debridements, vacuum-assisted-system, implant removal, and reinsertion of implants after postoperative microbiological specimens were negative. Both patients healed and fused timely without further measures.

Table 1
Distribution of type of shoe wear and walking aids at time of inclusion in the study (pre-operatively) and at two-year-follow-up.

Type shoe-wear	Preoperatively		Two-year follow-up		Chi2 test
	n	%	*n*	%	
Standard shoe	42	63.6	56	93.3	<0.001
Orthopaedic shoe	18	27.3	4	6.7	–
Orthosis	6	9.1	0	0.0	–
Total	66	100	60	100	–
Type walking aids	Preoperatively		Two-year follow-up		Chi2 test
	n	%	*n*	%	
None	45	68.2	51	85.0	0.05
One stick or crutch	12	18.2	6	10.0	–
Two crutches	6	9.1	2	3.3	–
Wheelchair	3	4.5	1	1.7	–
Total	66	100	60	100	–

Standard shoe defined as all non-orthopaedic shoes. i.e., also shoes with insoles and/or rocker bottom modification. Orthopaedic shoe defined as completely specially custom made shoe.

3.5. Clinical course

A total of 48 patients (73%) reached full weight bearing without orthosis after 6 weeks, 52 (79%) after 9 weeks, and 66 (100%) after 12 weeks. Dynamization was performed in 6 patients (9%) after 12 weeks. In 5 of these six patients, fusion was noted at later follow-up (see below), and one was did not complete follow-up.

3.6. Two-year-follow-up

A total of 60 (91%) patients completed follow-up. The 6 (9%) patients that did not complete follow-up (No. 3, 4, 6, 19, 27, 58) were not the patients with complications except one (No. 6, minor tibial split, see above). The mean VAS FA at follow-up was 59.9 (range, 14.7–97.7; std, 22.3; compared with preoperative VAS FA, 29.6, paired *t*-test, $p < 0.001$).

Table 1 shows the use of special shoe wear and walking aids. The distribution of both was significantly different in comparison with the preoperative distribution (CHi2 $\leq$ 0.05). Use of orthopaedic shoes, orthosis, sticks, crutches or wheelchairs decreased, and use of standard shoes increased.

3.7. Radiographic measurements and fusion assessment

Table 3 shows the results of the radiographic assessments. The deviation of the measured angles from the desired angles (hindfoot angle, 5° valgus; calcaneal pitch angle, 20°) were lower at follow-up (each $p < 0.001$). Table 4 shows the fusion rates. At 2-year follow-up all ankle and subtalar joints of the 60 patients that completed follow-up were considered as fused.

4. Discussion

Intramedullary devices for TTCA have increased the surgeon's possibilities for hindfoot stabilization [6–8,27]. Many of the patients considered for TTCA have multiple comorbidities affecting bony stability [6–8,27]. Intracalcaneal fixation has been shown to be an important factor affecting stability [18,20,27]. Mann et al. concluded that the posterior-to-anterior routing of a calcaneal locking screw significantly enhances stability [18]. Muckley et al. demonstrated the superiority of angle-stable over non-angle-stable intracalcaneal locking [20]. Klos et al. found increased stability of cement augmented locking screws [28]. However, only the locking screws themselves and not the nail position, was considered for all investigations [12]. Most nails have a distal lateral bend but only the A3 has an additional posterior distal bend [12]. This feature was designed to increase the distance of the nail within the calcaneus with the intention to increase stability [12].

We achieved a fusion rate of 91% of included patients and 100% of patients that completed 2-year -follow-up. The infection rate was 3% (detailed discussion of the infections below). Compared with actually published clinical date, these results are very favourable [6–8]. Rammelt et al. reported a TTCA rate of 84% and infection rate of 2.4% in 38 patients, Lucas at al 86% fusion rate and 4% infection rate in 63, and Brodsky et al., 97% fusion rate and 10% infection rate in 30 patients [6–8]. Our clinical outcome was characterized by massively increased score results (VAS FA improved from 29.6 to 59.9). A comparison with other studies is problematic because most studies did not include validated scores as used in our study [6–8,21]. The correction of the deformities intraoperatively was very accurate. Comparison with data from the literature is difficult because no other study utilized intraoperative

Table 2
Indications for TTCA with A3 (multiple choices possible).

Type of indication	*n*	%
Arthrosis	43	65.2
Deformity	36	54.5
Varus	18	27.3
Valgus	13	19.7
Equinus	18	27.3
Cavus	9	13.6
Abductus	1	1.5
Planus	7	10.6
Combined	19	28.8
Instability	12	18.2
Failed fusion	9	13.6
Failed total ankle replacement	4	6.1
Pilon fracture/pseudarthrosis	4	6.1
Amputation	3	4.5
Chopart level	2	3.0
Lisfranc level	1	1.5
Bone defect	9	13.6
Rheumatoid arthritis	2	3.0
Neuropathy	10	15.2
Diabetes mellitus	5	7.6

Bone loss defined as cavity (cyst) of ≥1 cm and/or decreased bone height (for example talar body) of ≥ 1 cm in comparison with contralateral bone(s).

Table 3
Results of the radiographic measurements.

		Hindfoot angle	Calcaneal pitch angle
Preoperative	Mean	1.1	13.4
(*n* = 66)	Range	−50 to 29.3	−17 to 50
	Std	18.3	11.7
	Deviation	14.1	10.6
Intraoperative	Mean	5	–
(*n* = 66)	Range	4–6	–
	Std	0.3	–
	Deviation	0.1	–
2-year follow-up	Mean	5.4	19.3
(*n* = 60)	Range	3–8.5	10.3–37
	Std	1.0	3.7
	Deviation	0.7	2.1
t-test (paired), deviation preoperative versus 2-yearfollow-up	<0.001	<0.001	

Std, standard deviation. The deviation was defined as *absolute* difference between measured and desired angle, i.e., all values were defined to be positive. The desired angles were defined as 5° for hindfoot angle, and 20° for calcaneal pitch angle.

Table 4
Fusion rates at ankle and subtalar joint.

	Follow-up complete (n)	Ankle joint		Subtalar joint	
		Fusion (*n*)	%	Fusion (*n*)	%
6 weeks	66	48	73	55	83
9 weeks	66	52	79	60	91
12 weeks	66	54	82	64	97
1 year	60	56	93	60	100
2 years	60	60	100	60	100

3D-imaging for the assessment of the correction. We did not register loss of correction until 2-year follow-up, and the accuracy of the correction at 2 years was better than previously reported [6–8]. The surgical times with 90 min and especially A3 insertion with 17.5 min seem to be appropriate without possible data for comparison from the literature. Use of orthopaedic shoes, orthosis, sticks, crutches or wheelchairs decreased, when comparing preoperatively with 2-year follow-up, and use of standard shoes increased. This is also a positive result and again we could not find data for comparison in the literature.

4.1. Complications

The patient with the tibial split was caused by insertion of the nail without reaming before [1]. Afterwards, reaming of the tibia with 11 mm diameter was performed in all patients, and no further splits were registered. After the patient with the stuck 1st guidewire, the 1st guidewire template was exchanged. The two infections occurred in patients with diabetes mellitus, and were interpreted as not caused by the implant as such but by the preexisting comorbidities. In both patients, the executed measures (multiple debridements, vacuum-assisted system, implant removal, and reinsertion of implants after postoperative microbiological specimens were negative) led to a healed situation with favourable clinical outcome at 2-year follow-up (VAS FA, 74 and 82 points, standard shows, no sticks or crutches).

4.2. Limitations of the study

There are numerous shortcomings of the study such as the relatively low case number, a missing control group, short follow-up time, and incomplete follow-up. However, TTCA is an uncommon salvage procedure. The indications are variable, there is a high occurrence of comorbidities, and clinical studies are difficult to perform [1]. There are no studies with larger case numbers as far as we know. The missing control group is a typical shortcoming of studies dealing with uncommon pathologies. The high variability of the indications and comorbidities are typical confounders. The short and incomplete follow-up again reflects the extremely problematic patient group. However, when focusing on fusion as such, and on the extent and possible loss of correction, a follow-up time of two years and follow-up rate of more than 90% seems acceptable. Still, all patients that did not complete follow-up could be considered as bad outcome, such as nonunion, infection, and amputation of even death. This is true for all studies with a follow-up rate of less than 100% which corresponds most clinical studies. We did not consider delayed union as complication because we have experienced different patients with fusion at different joints that were not completely fused but still pain free with good mobilization. Correction was achieved during the initial surgery and loss of correction typically occurs in the early clinical course [6–8,29–33]. Fusion was noted in 100% of patients that completed follow-up, and longer follow-up would not be necessary regarding the assessment of fusion. One could argue that fusion shall be quantified with CT only. We considered assessment of fusion with conventional radiographs as appropriate as previously used in other studies [2–6,34]. We do agree that CT would be better to quantity fusion but has also higher radiation dose. We did not consider delayed union as complication as such because we have experienced different patients with fusion at different joints that were not completely fused but still pain free with good mobilization. The intra- and interobserver repeatability of radiographic measurements was sufficient (repeatability coefficients >0.75), which is important to mention because most studies do not assess this important methodological issue [35]. We measured just two radiological parameters (hindfoot angle and calcaneal pitch angle). The hindfoot angle was considered to be the most appropriate angle to assess the hindfoot axis despite potential methodological problems with the imaging technique and the measurement [25]. The calcaneal pitch angle was considered to be appropriate to estimate the deviation of the ankle/subtalar joint position in the sagittal orientation regarding dorsiflexion and plantiflexion (equinus) [25]. For both angles we defined desirable values of 5° valgus for hindfoot angle and 20° for calcaneal pitch angle. These desired values are of course also debatable but the values reflect at best a so-called orthograde hindfoot [1,25,36]. The assessment of the accuracy of correction and implant position with the VAS is a subjective scoring and seems to introduce investigator bias. We still added this scoring to register the subjective assessment of the surgeon. However, we emphasize that the angular measurements should be considered as more adequate assessment that the VAS scores.

In conclusion, TTCA with the A3 implant system allowed for timely and accurate correction, and implant insertion and position. The infection rate was low (3%). Two-year follow-up in 60 patients (91%) showed good clinical outcome scores and 100% fusion rate.

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