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REVIEW

Patient selection for total ankle arthroplasty

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Laurens W van der Plaat[1]
Daniël Haverkamp[2]

[1]Department of Orthopaedic Surgery, Noordwest Ziekenhuisgroep, Alkmaar, the Netherlands; [2]Slotervaart Center of Research and Education (SCORE), MC Slotervaart Hospital, Amsterdam, the Netherlands

Abstract: Total ankle arthroplasty is a treatment option for end-stage osteoarthritis of the ankle, as is ankle arthrodesis. Many variables, including patient characteristics, are thought to influence clinical outcome and survival. As with any surgery, but especially with total ankle replacement (TAR), patient selection is considered critical for good (long-term) outcome. In this review, we summarize the available scientific evidence regarding patient characteristics and its influence on the results of TAR.

Keywords: total ankle arthroplasty, ankle prosthesis, ankle arthrodesis, patient characteristics, contraindications

Introduction

The number of total ankle replacements (TARs) performed is ever increasing,[1–8] and indications are expanding[2] due to improvements in design and outcome. Historically, osteonecrosis/loss of bone stock,[9–14] neuroarthropathy,[9–11,13,14] (diabetic) neuropathy,[12] diabetes,[15] peripheral vascular disease,[9–13] smoking,[15] poor skin integrity/envelope,[9,11] osteoporosis,[9,11,13] (gross) deformity,[9,10,12,13,16] noncompliancy,[12] high physical demand/body mass index (BMI),[9,12,13,15,16] marked ankle instability[9,10,16] and (a history of) joint infection[9–14] are considered (relative) contraindications to modern total ankle arthroplasty, but the scientific basis for these recommendations is scarce.

It remains difficult to choose between TAR and ankle arthrodesis (AA) as they are both viable options for the surgical treatment of end-stage ankle osteoarthritis (OA). Despite many attempts to compare outcomes, clear-cut guidelines to choose between the two are lacking. A critical review of the available evidence with regard to patient characteristics might help guide the choice between TAR and AA.

The optimal patient for TAR is said to be physically low-demanding,[13,14] non-obese,[13,15] older,[14,15,17] with end-stage non-traumatic primary ankle arthrosis[17] or multiple joint arthritis[15] with minimal deformity,[13–15] good bone stock,[14] no neurovascular leg impairment[14,15] and excellent/more than two-thirds of normal range of motion.[13,17] Unfortunately, the majority of our patients do not meet these requirements,[13] and scientific evidence for these recommendations is unavailable.[10]

The goal of this review is therefore to summarize the current evidence on patient characteristics with regard to selection for TAR.

Correspondence: Laurens W van der Plaat
Department of Orthopaedic Surgery, Noordwest Ziekenhuisgroep, Alkmaar, Wilhelminalaan 12, 1815 JD, Alkmaar, the Netherlands
Email lplaat@hotmail.com

Daniël Haverkamp
Slotervaart Center of Research and Education (SCORE), MC Slotervaart Hospital, Louwesweg 6, 1066EC Amsterdam, the Netherlands
Email Daniel@drhaverkamp.com

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General patient characteristics

Gender

To our knowledge, the possible influence of gender on patient satisfaction and/or revisions has not been studied explicitly. In register studies, no influence of gender on TAR survival was found.[1,5,18–20] This is in accordance with results from other studies.[21,22] Female gender was found to be a significant risk factor for wound-healing problems, but after correcting for confounding variables, it was no longer a predictor for disturbed wound healing.[23] In a national database study, male gender was found to be a statistically significant risk factor for the occurrence of one or more complications within 30 days after surgery.[8]

Considering all evidence, we think gender should play no role when considering a patient for TAR.

Age

Younger age at implantation might influence longevity of the implant in two ways. The TAR will need to function longer due to a higher life expectancy of the patient. Additionally, younger patients tend to be more active, which has been proven to be associated with polyethylene wear of hip prostheses.[24] Special consideration should be given to patients with inflammatory joint disease (IJD), as they are younger at implantation in general[25] but less active due to the fact that multiple joints are often affected.

Influence of age on results of TAR has been explicitly investigated by a few authors. In 1999, Kofoed and Lundberg-Jensen published their results of 100 (un)cemented Star prostheses. Thirty were implanted in patients aged <50 years, with a survival of 75% at 6.8 years. Seventy in patients aged ≥50 years, with a survival of 81% at 6.0 years, with no statistically significant difference between the groups.[26] Others have also found lower age at implantation not to be a significant risk factor for revision.[22,25,27]

A review of 103 Salto prostheses (n=31 <50 years; n=72 ≥50 years) at an average 41 months' follow-up revealed no statistically significant differences with regard to major complications and survival between groups.[28]

In a cohort of 395 primary Inbone, Salto Talaris and Star prostheses wound complications, reoperations and revisions were similar in three age groups (<55, 55–70 and >70 years) at an average 3.5 years of follow-up.[29]

Barg et al[30] found age under 70 years to be an independent predictor of failure of the Hintegra ankle prosthesis at an average follow-up of 6.3 years. Others have also found lower age at implantation to be a risk factor for revision.[21,31]

Spirt et al reported that each 1-year increase in age at implantation of the Agility prosthesis resulted in a 3.5% decrease in failure hazard, with patients aged ≤54 years at implantation having a 2.65 times greater risk of failure compared to patients aged ≥55 years at implantation. The estimated survival rate at 61 months with failure as the end point was 0.74 (0.60–0.91) for the younger group, compared to a survival rate at 47 months of 0.89 (0.80–0.99) for the older group.[32]

A report from 780 TARs from the Swedish Ankle Register showed patients with primary or posttraumatic osteoarthritis (PTA) under 60 years of age to have a 1.8 higher chance of revision compared to older patients. This relationship was not found for patients with rheumatoid arthritis and only statistically significant in women.[3] No relation between age and survival was found in the Norwegian, Finnish and New Zealand Ankle Register.[1,19,20] Influence of age on wound-healing problems was not observed by Raikin et al.[23] In an epidemiological study by Seaworth et al,[6] younger age at implantation was found to be a risk factor for failure.

Possibly, activity level, with its influence on polyethylene wear, is a confounding factor,[24] explaining the conflicting evidence on the influence of age on survival of TAR. Younger age at implantation leads to more load cycles, which in itself is expected to lead to revision down the line. With an average follow-up of 4–7 years in the studies explicitly comparing age groups, evidence on the long-term survival of TARs is still lacking, and we therefore feel younger age should remain a contraindication for TAR (especially in non-IJD patients), not through an absolute age limit, but by taking into consideration the aspired activity level of the patient. When considering a younger patient for TAR, the distinct possibility of future revisions (either through revision arthroplasty and/or salvage fusion) should be discussed.

Activity level

As stated earlier, activity level might be an important factor influencing TAR survival. Nevertheless, research into this relationship is seldomly performed. Valderrabano et al[33] found no harmful influence of increased activity level on the revision rate at an average 2.8 years of follow-up of 152 Hintegra TARs. In accordance with these results at 3.7 years of follow-up, no relationship between physical activity level and the incidence of periprosthetic lucencies in 101 TARs (Buechel-Pappas and Mobility) was found.[34] Bonnin et al[35] also found no relationship between activity level and adverse effects with the Salto prosthesis.

Unfortunately, due to short follow-up, the relationship between activity level and revision rate remains unclear. Despite the absence of a scientific basis, guidelines for sports activities after TAR have been proposed.[33] These correlate closely with the results of a recent survey among foot and ankle surgeons regarding sports activities after TAR.[36] When counseling a patient for TAR, the patients' aspired activity level and types of physical activity should be taken into account, and the patient should be counseled with regard to future sports.

BMI

Historically, obesity (defined as BMI ≥30) was considered a (relative) contraindication for TAR,[11] and since then, a few studies have evaluated this relationship. BMI of obese patients does not decrease after successful TAR,[37] but does obesity decrease survival of TAR?

Barg et al[38] reported a survival rate of 93% at 6 years follow-up of 123 Hintegra prostheses in a group of obese patients, comparable to the results of regular cohorts. These findings were confirmed in their total cohort of 722 Hintegra prostheses, where obesity was not associated with failure of TAR.[30]

When comparing the results of TARs (Mobility, Hintegra and Star) in obese and non-obese patients, Bouchard et al found that, at an average of 3.8 years of follow-up, both groups showed significantly improved scores on the Ankle Osteoarthritis Scale and the Short Form-36 (SF-36). Furthermore, there were no significant differences with regard to complications and revisions.[39] These findings were in accordance with those of others.[40,41]

High BMI was not found to be a risk factor for infection in a combined primary and revision TAR cohort[42] and also not for wound-healing problems.[23,43]

With longer follow-up (8 years) of the Agility prosthesis, however, Schipper et al[44] found obese patients to have a 2.8 times higher chance of revision compared to non-obese patients. Especially, obese patients with idiopathic OA were at risk.

In a Medicare database study, obese patients had a significantly higher chance of complications including revision within 90 days compared to the non-obese group.[45] However, the cohorts differed significantly with regard to age, tobacco use and comorbidities (including diabetes and peripheral vascular disease), all in favor of the non-obese group, and therefore, these results should be interpreted with care. However, obese patients with comorbidities clearly are not ideal candidates for TAR.

The majority of studies into the subject have not found a relation between BMI and results of TAR. Perhaps, the relationship between BMI and survival is also influenced by activity level or the cumulative load exerted on the prosthesis, with sedentary overweight patients showing similar survival to active non-overweight patients. We therefore think high BMI in itself (within reasonable limits) should not be considered a contraindication for TAR.

Smoking

Even though smoking has been deemed a contraindication for TAR,[15] to our knowledge, there is only one study investigating the relationship between smoking and TAR. In a retrospective review of 642 Inbone, Salto-Talaris and Star TARs, smoking was shown to significantly increase wound breakdown. Infections and (non)-revision surgery were not significantly different between groups.[46]

In other studies, <12 pack years of smoking was not found to be a significant risk factor for wound-healing problems[23,43] or infection in a combined cohort of primary and revision TARs.[42] This is in accordance with results from others.[25] With the current knowledge of the delirious effects of smoking on bone and soft tissue healing and the benefits of (temporary) perioperative cessation,[46,47] requiring patients to abstain from smoking before high-risk surgery as TAR seems reasonable.

Comorbidities

Diabetes

At an average 5 years of follow-up of 173 Hintegra TARs, clinical failure defined as an American Orthopaedic Foot & Ankle Society (AOFAS) hindfoot score of 79 or less was significantly higher in the diabetic group (21%), compared to the nondiabetic group (15%). However, the number of revisions did not differ between groups. The rate of delayed wound healing was not significantly different between groups, except when comparing uncontrolled diabetics to nondiabetics.[48] Raikin et al[23] also found diabetes to be a risk factor for minor wound-healing problems (solvable with local wound care and/or oral antibiotics) although in well-controlled diabetics. A relationship with major wound-healing problems (requiring surgery) was not observed. Whalen et al[43] did not find a relation between diabetes and wound breakdown. Delayed wound healing and diabetes were found to be risk factors for infection in a retrospective review of a cohort of primary and revision TARs by Patton et al.[42]

Gross et al compared the results of Star, Salto-Talaris and Inbone TARs in 50 diabetic patients to those of 55 controls from a total cohort of 813 primary TARs. The number of

secondary surgeries, infections and revisions was not statistically different between groups at 2–3 years of follow-up, even though the American Society of Anesthesiologists (ASA) score, BMI, age and smoking history were significantly higher in the diabetic group.[49] This is in accordance with the findings from others.[25] However, in a national database study, after correcting for confounding variables, diabetes was found to be independently associated with in-hospital (general) complications (relative risk 4.1) but not with surgical debridement. No subgroup analysis for controlled and uncontrolled diabetes was performed.[50]

Current literature does not unequivocally support the notion of diabetes being a contraindication for primary TAR, possibly with the exception of uncontrolled diabetes.[48,51] We advise to have every diabetic counseled preoperatively to optimize their diabetic control before performing surgery.

Neuro(arthro)pathy and vascular insufficiency

We were unable to find literature regarding the influence of neuro(arthro)pathy and vascular insufficiency on results of TAR, probably because these conditions are still considered absolute contraindications for TAR. Whalen et al reported on a consecutive series of 57 TARs; 16 had wound breakdown, with 4 progressing to deep infection. Three of these were later shown to have an occluded or absent anterior tibial artery, leading the authors to recommend preoperative vascular studies in patients with known (risk factors for) cardiovascular disease.[43] A simple and useful algorithm for preoperative vascular workup, which we recommend following, was described by Sorg et al:[52]

1. Check pulses of dorsal foot artery and posterior tibial artery
2. If absent, perform an ankle-brachial index
3. If the results are <0.9 or >1.2, then perform angiography
4. If a stenosis or complete obstruction is found, then perform vascular surgery before TAR

Other

Bilateral OA

Bilateral ankle fusion (AA) is said to greatly impair gait and function,[53] and therefore, patients with bilateral ankle OA should be especially considered for TAR.[14] However, Vaughan et al[54] reported good results of eight patients with bilateral AA at 6 years of follow-up, with seven of eight (88%) patients being satisfied and an AOFAS score of 79.5. This is in accordance with results from others.[55] In a series of 16 patients with a TAR and a contralateral TAR, patients were equally satisfied with each ankle.[56] The sparse literature covering this topic does not support the notion that end-stage bilateral OA should be treated with at least unilateral TAR.

Factors related to the ankle joint

Etiology of arthritis

Of all factors potentially influencing TAR survival, etiology of arthritis has received the most attention. But surprisingly little studies have explicitly addressed the subject (Table 1). Most cohort studies on TAR divide etiology in PTA, idiopathic OA, OA due to IJD and "other". More recently, bleeding disorders,[57–64] gout[65] and instability[66] have been studied as separate entities.

None of the studies in Table 1 found etiology to significantly influence survival. Not surprisingly, patients with IJD had significantly worse scores on the physical component scale of the Short Form Health Survey, the Kofoed score and the disability scale of the Ankle Osteoarthritis Scale compared to patients with non-IJD.

Survival of Star and Norwegian TPR TARs was not influenced by the etiology of arthritis in the Norwegian Arthroplasty Register.[1] This is in accordance with the results from the New Zealand Ankle Registry,[20] the Finnish Arthroplasty Register[19] and others.[21,27,32,67,68] Contrary to these findings, the Swedish register estimated that survival at 10 years of follow-up was 0.72 for patients with RA, 0.68 in primary OA and 0.66 in PTA.[3] Barg et al[30] also found lower survival in patients with primary OA (0.71) and PTA (0.84), compared to other etiologies (0.94) at >10 years of follow-up.

Perhaps, the relationship between etiology and survival of TAR is confounded by activity level, with, for instance, patients suffering from IJD being less active due to the nature of their disease with multiple joints affected. This might explain the absence of differences in survival between varying etiologies at shorter follow-up, whereas with longer follow-up survival in IJD patients might be better. This would be in accordance with the findings of Hurowitz et al,[25] who found patients with IJD being younger at implantation, but with better survival.

Deformity

The majority (55%) of osteoarthritic ankles have a varus deformity (when defined as the angle between the tibial shaft and the talar dome <90°), while only 8% will present with a valgus deformity (when defined as the angle between the tibial shaft and the talar dome >99°).[69] The importance of deformity correction before or during TAR has been recog-

Table 1 Studies comparing results of TAR for different etiologies

Prosthesis	Group 1											Group 2								
	Etiol	n	F-up (mth)	Surv	Add. proc	Reop.	AOFAS	SF-36 pcs/mcs	AOS p/d	K.	Com.	Etiol	n	Surv	Add. proc	Reop.	AOFAS	SF-36 pcs/mcs	AOS p/d	K.	Com.
Hintegra[127]	PTA	37	38	97%	54%	16%	85				38%	Idiop	30	100%	27%*	0%	88				27%*
Star[128,**]	PTA/Idiop	25	168	73%						94‡		IJD	27	76%						83‡	
Agility, Star, Mobility and Hintegra[129]	Non-IJD	50§	66	90%	22%	18%		42/?	20/24		18%	IJD	50	88%‖	62%	6%		34*/NS	19/34*		16%

Notes: *P<0.05; **cemented prostheses; †at 120 months follow-up; §matched group (for age, type of prosthesis and duration of follow-up) from database; ‖at 64 months follow-up.

Abbreviations: TAR, total ankle replacement; Etiol, etiology; F-up, follow-up; mth, months; Surv, survival; Add. proc, additional procedures (pre- and/or during TAR); Reop., reoperations; AOFAS, American Orthopaedic Foot & Ankle Society hindfoot score; SF-36, Short Form Health Survey; pcs, physical component scale; mcs, mental component scale; AOS, Ankle Osteoarthritis Scale; p/d, pain/disability; K., Kofoed score; Com., complications; PTA, posttraumatic osteoarthritis; Idiop, idiopathic osteoarthritis; IJD, osteoarthritis due to inflammatory joint disease; NS, no statistically significant difference.

nized for a long time,[17,70–73] and coronal plane deformities of >10° have been recommended as absolute contraindications for TAR.[22] To overcome these problems, surgical techniques for correction of these deformities have been described.[71,74–84]

Differentiating between symmetrical and asymmetrical deformities appears to be of paramount importance.[75,85] From the senior authors' (DH) experience, generally speaking, varus ankles can be reliably corrected through a medial malleolar osteotomy as described by Doets et al.[74] However, valgus ankles pose a more difficult problem, especially when the deep deltoid ligament (the prime stabilizer of the ankle joint)[86,87] has become insufficient. These ankles have a tendency to relapse into valgus with maltracking and loosening as a consequence.

Results of studies comparing results of TAR with preoperative coronal plane deformities to non-deformed ankles are summarized in Table 2. With the exception of the study by Doets et al, no differences in survival were found. No concomitant procedures to correct these deformities during TAR placement were described by Doets et al.[22] Their paper should be viewed as descriptive in this regard, highlighting the fact that preoperative deformities could negatively influence TAR results.

Only Hobson et al[88] found a significant difference in postoperative AOFAS scores between groups. A higher score was obtained by the patients with deformity. The authors hypothesized that the deformed group had more to gain. Their results could not be replicated by later studies.

Considering the scientific evidence, it seems safe to assume that deformity is no longer a contraindication for TAR, as long as stepwise realignment procedures are meticulously followed.

Prior procedures

From a cohort of 619 primary and 347 revision TARs, 29 (15 primary, 14 revision) were diagnosed with deep infection. The number of prior surgeries in the infected group was 2.3, compared to 1.1 in the matched control group.[42] These results are in accordance with the findings from other authors.[89] Hurowitz et al[25] and Whalen et al,[43] on the other hand, found no significant influence of previous surgery on survival and wound breakdown, respectively.

Other

Bone defects

The development of bone cysts, with possible talar collapse after TAR, has been recognized as threat to long-term survival.[90] The etiology of these cysts has not fully been

Table 2 Studies comparing results of TAR in deformed and non-deformed ankles

Prosthesis	Preoperative coronal plane deformity									No preoperative coronal plane deformity (controls)							
	n	Deformity	F-up (mth)	Survival	AOFAS	VAS pain	SF-36 pcs/mcs	AOS p/d	Complic	n	Deformity	Survival	AOFAS	VAS pain	SF-36 pcs/mcs	AOS p/d	Complic
LCS/BP[22]	17	>10°	96	48%						76	<10°	90%*					
Star[88]	32	>10°	48	75%	77					91	<10°	81%	86*				NS
Hintegra[130]	23	>10°**	27	96%	83	2.8				22	<10°	95%	79	3.4			NS
Inbone and Salto Talaris[131]	17	>15°	24	100%						38	<5°°	100%	NS		NS		NS
Star[132]	43	>10°	41	96%						90	<10°	95%					
Hintegra and Mobility[133]	24	>20°	25	96%	83	3.0			6‡	79	<20°	89%§	79	4.0			11‖
Hintegra, Mobility and Star[134]	36	>10°**	35		81		42/57	18/29		36	<10°		82		42/52	21/24	

Notes: *$P<0.05$; **only varus ankles included; ‡1 revision; §at 37 months follow-up; ‖4 revisions.

Abbreviations: n, number of ankle prostheses; F-up, follow-up; mth, months; AOFAS, American Orthopaedic Foot & Ankle Society hindfoot score; VAS, Visual Analog Scale; SF-36, Short Form Health Survey; pcs, physical component scale; mcs, mental component scale; AOS, Ankle Osteoarthritis Scale; p/d, pain/disability; Complic, complications; LCS, low-contact stress; BP, Buechel–Pappas; NS, no statistically significant difference.

elucidated.[91–95] Sometimes, these cases are revised with total talar prostheses,[96] but this falls outside the scope of this review.

Results of primary TAR with total talar replacement have been reported in a few case series/reports. The first year after implantation, these patients seem to function well.[97] Isolated talar body replacement (without replacing the distal tibia) with a metal component has been very successful at 10–36 years follow-up. Twenty-eight of 33 were still in place at latest follow-up, with an average AOFAS score of 75.[98] At 53 months follow-up of 55 ceramic total talar replacements, 0 needed revision, and scores on foot and ankle questionnaires significantly improved.[99]

Currently, scientific evidence for TAR for end-stage ankle arthritis with substantial bone loss is lacking, but isolated total talar replacement seems promising.

Tumors

Shekkeris et al reported results of six patients treated by a custom-made distal tibia and ankle prosthesis. Due to persistent infection, two were converted to below-knee amputation, with the remaining four being able to comfortably perform most activities of daily living (ADL) at 9.6 years of follow-up. One patient required talar revision for aseptic loosening.[100] In six patients treated with a customized hinged ankle prosthesis after 5.3 years of follow-up, pain was minimal during ADL. One required revision because of talar collapse.[101] At 40 months follow-up of six comparable patients, three were converted to amputation (two local recurrence, one deep infection), with the remaining three able to function pain free with a stable prosthesis.[102]

OA of neighboring joints

AA is said to increase OA in neighboring joints, and therefore, TAR should be considered in patients with concomitant ankle and sub/midtalar OA.[103] A causal relationship, however, has not been definitively established.[104,105] Treatment options for combined ankle and subtalar OA are TAR with subtalar arthrodesis (either as staged procedures or simultaneously) or tibiotalocalcaneal (TTC) fusion.[106]

TTC fusion can be performed in multiple ways,[107] which is beyond the scope of this review. In a cohort of 41 patients with TTC fusion, 80% had successfully fused at 45 months' follow-up, with a complication rate of 41%. Patient-reported outcomes were not described.[108] Rammelt et al reported on 38 patients with TTC fusions with an average follow-up of 2 years. Fusion rate was 84% with a complication rate of 24% and SF-36 physical health score of 41 and SF-36 mental

health score of 53 with 61% reporting minimal or no pain (average numeric rating scale 2).[109]

In a consecutive series of 1001 TARs, 26 patients subsequently required a hind- or midfoot fusion. The fusion rate was 93%, and the complication rate was 12%. SF-36 score was 56 at an average 71 months of follow-up.[110] This fusion rate is similar to the 92% reported by Usuelli et al in 25 patients undergoing simultaneous TAR with subtalar fusion. No further major complications were reported. At 12 months of follow-up, the average SF-12 physical health score was 44, the mental health component 51 and the visual analog pain scale 2.[111]

Kim et al[112] compared the results of 60 patients with TAR and pre-, per- or postoperative hindfoot fusions to those of a control group with isolated TAR consisting of the remainder of the same cohort. Patient satisfaction, complication and survival rate were not different between groups.

The cohorts with TTC fusion do not solely consist of patients with combined ankle and subtalar OA, and therefore, comparison to results of TAR with subtalar fusion is difficult. Based on the current evidence, TAR combined with subtalar fusion does not seem to be strictly superior to TTC fusion with regard to functional results but might result in slightly higher fusion rates and lower complication rates.

Post-infectious OA

Implantation of 22 TARs in patients who were symptom free for an average 9 years after prior septic arthritis or osteomyelitis of the ankle was not complicated by deep infection. However, 14% required reoperation (two subtalar AA, one cyst grafting). AOFAS, SF-36 and VAS scores all improved significantly.[113] The sparse literature regarding this topic does not support the notion of post-infectious OA being a contraindication for TAR.

Avascular talar necrosis

Evidence-based treatment of avascular necrosis (AVN) of the talus is lacking.[114] It appears to be a contraindication for TAR when reading the summary of previous literature (nine cases) by Lee et al.[115] Of these nine cases reported, five had collapsed at 2–5 years of follow-up and three more had complications. Lee et al reported two cases of their own. A Hintegra TAR was implanted in two patients for AVN after establishing talar revascularization with magnetic resonance imaging and radionuclide bone scanning. These two patients had AOFAS scores of 91 and 85 at 30 and 24 months' follow-up, respectively.[115]

Devalia et al reported results of seven patients treated with a two-stage procedure, consisting of subtalar arthrodesis for revascularization of the talus, followed by TAR on average 10 months later. At 3 years of follow-up, the AOFAS score was 78. However, radiological signs of talar subsidence were noted at 1 year follow-up without progression or deterioration of clinical scores at 3 years in two patients.[116]

At this time, we consider treatment of AVN of the talus with TAR experimental due to lacking sufficient scientific evidence.

Discussion

Over time, the results of more and more TAR cohorts have been published. Most authors provided information on the cohort (gender, etiology of arthritis, etc.). Unfortunately, the characteristics of patients with failed TARs are rarely specified (except incidentally etiology of arthritis), which makes it difficult to determine the risk factors for failure. We propose that future studies on this subject include all characteristics of the patients with failed TARs discussed in this review.

In addition to patient characteristics, other factors, such as the type or version of prosthesis used,[1,3,30] duration of surgery,[20,89] surgeon volume[117,118] and surgeon experience,[119–124] might influence the number of complications and TAR survival although conflicting evidence exists. These factors are not within the scope of this review.

One of the strengths of our study is the extent of literature review as we are certain that the vast majority of relevant data have been included in this review due to our comprehensive knowledge of literature pertaining to TAR. Another strength is the scope of patient characteristics discussed, with all current and historical factors considered to be of influence on TAR analyzed. A third strength is our clear recommendation for future TAR cohort studies, specifically regarding characteristics of patients with failed TARs.

Our study is not without limitations. As it was written as an editorial, the PRISMA guidelines[125,126] for a systematic review, with subsequent high level of evidence, were not followed. The available scientific evidence was therefore not graded, and no meta-analysis was performed. Furthermore, our conclusions are partially based on the results of TARs no longer available on the market for various reasons. Due to paucity of available evidence, this is inescapable. However, as we have focused on patient characteristics, we do not think this invalidates our results; we expect similar results with currently available implants.

Conclusion

Many factors historically considered to be contraindications for TAR should no longer be considered contraindications based on scientific evidence. Some of these factors are probably interconnected (for instance, BMI, activity level, diabetes and vascular disease). Instead of considering each of these factors in isolation, the surgeon should try to judge the patient as a whole when choosing between TAR and AA.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Fevang BT, Lie SA, Havelin LI, Brun JG, Skredderstuen A, Furnes O. 257 ankle arthroplasties performed in Norway between 1994 and 2005. *Acta Orthop*. 2007;78(5):575–583.
2. Hsu AR, Haddad SL. Will total ankle arthroplasty become the new standard for end-stage ankle arthritis? *Orthopedics*. 2014;37(4):221–223.
3. Henricson A, Nilsson JA, Carlsson A. 10-year survival of total ankle arthroplasties: a report on 780 cases from the Swedish Ankle Register. *Acta Orthop*. 2011;82(6):655–659.
4. 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(10):1361–1368.
5. Tomlinson M, Harrison M. The New Zealand Joint Registry: report of 11-year data for ankle arthroplasty. *Foot Ankle Clin*. 2012;17(4):719–723.
6. Seaworth CM, Do HT, Vulcano E, Mani SB, Lyman SL, Ellis SJ. Epidemiology of total ankle arthroplasty: trends in New York State. *Orthopedics*. 2016;39(3):170–176.
7. Singh JA, Ramachandran R. Time trends in total ankle arthroplasty in the USA: a study of the National Inpatient Sample. *Clin Rheumatol*. 2016;35(1):239–245.
8. Zhou H, Yakavonis M, Shaw JJ, Patel A, Li X. In-patient trends and complications after total ankle arthroplasty in the United States. *Orthopedics*. 2016;39(1):e74–e79.
9. Easley ME, Vertullo CJ, Urban WC, Nunley JA. Total ankle arthroplasty. *J Am Acad Orthop Surg*. 2002;10(3):157–167.
10. Guyer AJ, Richardson G. Current concepts review: total ankle arthroplasty. *Foot Ankle Int*. 2008;29(2):256–264.
11. Alvine FG. The agility ankle replacement: the good and the bad. *Foot Ankle Clin*. 2002;7(4):737–53, vi.
12. Doets HC, van der Plaat LW, Nelissen R. The current and future role of total ankle arthroplasty in the treatment of the arthritic ankle. A review. *Minerva Ortop Traumatol*. 2007;58(5):401–421.
13. Krause FG, Schmid T. Ankle arthrodesis versus total ankle replacement: how do I decide? *Foot Ankle Clin*. 2012;17(4):529–543.
14. Saltzman CL. Perspective on total ankle replacement. *Foot Ankle Clin*. 2000;5(4):761–775.
15. Gougoulias NE, Khanna A, Maffulli N. History and evolution in total ankle arthroplasty. *Br Med Bull*. 2009;89:111–151.
16. Ziegler J, Amlang M, Bottesi M, Kirschner S, Witzleb WC, Günther KP. Ergebnisse endoprothetischer Versorgung bei Patienten vor dem 50 Lebensjahr [Results for endoprosthetic care in patients younger than 50 years]. *Orthopade*. 2007;36(4):325–336. German.
17. Conti SF, Wong YS. Complications of total ankle replacement. *Clin Orthop Relat Res*. 2001;391:105–114.
18. Henricson A, Skoog A, Carlsson A. The Swedish Ankle Arthroplasty Register: an analysis of 531 arthroplasties between 1993 and 2005. *Acta Orthop*. 2007;78(5):569–574.
19. Skyttä ET, Koivu H, Eskelinen A, Ikävalko M, Paavolainen P, Remes V. Total ankle replacement: a population-based study of 515 cases from the Finnish Arthroplasty Register. *Acta Orthop*. 2010;81(1):114–118.
20. Hosman AH, Mason RB, Hobbs T, Rothwell AG. A New Zealand national joint registry review of 202 total ankle replacements followed for up to 6 years. *Acta Orthop*. 2007;78(5):584–591.
21. Brunner S, Barg A, Knupp M, et al. 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(8):711–718.
22. Doets HC, Brand R, Nelissen RG. Total ankle arthroplasty in inflammatory joint disease with use of two mobile-bearing designs. *J Bone Joint Surg Am*. 2006;88(6):1272–1284.
23. Raikin SM, Kane J, Ciminiello ME. Risk factors for incision-healing complications following total ankle arthroplasty. *J Bone Joint Surg Am*. 2010;92(12):2150–2155.
24. Schmalzried TP, Shepherd EF, Dorey FJ, et al. The John Charnley Award. Wear is a function of use, not time. *Clin Orthop Relat Res*. 2000;381:36–46.
25. Hurowitz EJ, Gould JS, Fleisig GS, Fowler R. Outcome analysis of agility total ankle replacement with prior adjunctive procedures: two to six year followup. *Foot Ankle Int*. 2007;28(3):308–312.
26. Kofoed H, Lundberg-Jensen A. Ankle arthroplasty in patients younger and older than 50 years: a prospective series with long-term follow-up. *Foot Ankle Int*. 1999;20(8):501–506.
27. Claridge RJ, Sagherian BH. Intermediate term outcome of the agility total ankle arthroplasty. *Foot Ankle Int*. 2009;30(9):824–835.
28. Rodrigues-Pinto R, Muras J, Martín Oliva X, Amado P. Total ankle replacement in patients under the age of 50. Should the indications be revised? *Foot Ankle Surg*. 2013;19(4):229–233.
29. Demetracopoulos CA, Adams SB Jr, Queen RM, DeOrio JK, Nunley JA 2nd, Easley ME. Effect of age on outcomes in total ankle arthroplasty. *Foot Ankle Int*. 2015;36(8):871–880.
30. 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(13):1175–1183.
31. Dhawan R, Turner J, Sharma V, Nayak RK. Tri-component, mobile bearing, total ankle replacement: mid-term functional outcome and survival. *J Foot Ankle Surg*. 2012;51(5):566–569.
32. Spirt AA, Assal M, Hansen ST Jr. Complications and failure after total ankle arthroplasty. *J Bone Joint Surg Am*. 2004;86-A(6):1172–1178.
33. Valderrabano V, Pagenstert G, Horisberger M, Knupp M, Hintermann B. Sports and recreation activity of ankle arthritis patients before and after total ankle replacement. *Am J Sports Med*. 2006;34(6):993–999.
34. Naal FD, Impellizzeri FM, Loibl M, Huber M, Rippstein PF. Habitual physical activity and sports participation after total ankle arthroplasty. *Am J Sports Med*. 2009;37(1):95–102.
35. Bonnin MP, Laurent JR, Casillas M. Ankle function and sports activity after total ankle arthroplasty. *Foot Ankle Int*. 2009;30(10):933–944.
36. Macaulay AA, VanValkenburg SM, DiGiovanni CW. Sport and activity restrictions following total ankle replacement: a survey of orthopaedic foot and ankle specialists. *Foot Ankle Surg*. 2015;21(4):260–265.
37. Penner MJ, Pakzad H, Younger A, Wing KJ. Mean BMI of overweight and obese patients does not decrease after successful ankle reconstruction. *J Bone Joint Surg Am*. 2012;94(9):e57.
38. Barg A, Knupp M, Anderson AE, Hintermann B. Total ankle replacement in obese patients: component stability, weight change, and functional outcome in 118 consecutive patients. *Foot Ankle Int*. 2011;32(10):925–932.
39. Bouchard M, Amin A, Pinsker E, Khan R, Deda E, Daniels TR. The impact of obesity on the outcome of total ankle replacement. *J Bone Joint Surg Am*. 2015;97(11):904–910.
40. Baker JF, Perera A, Lui DF, Stephens MM. The effect of body mass index on outcomes after total ankle replacement. *Ir Med J*. 2009;102(6):188–190.
41. Gross CE, Lampley A, Green CL, et al. The effect of obesity on functional outcomes and complications in total ankle arthroplasty. *Foot Ankle Int*. 2016;37(2):137–141.
42. Patton D, Kiewiet N, Brage M. Infected total ankle arthroplasty: risk factors and treatment options. *Foot Ankle Int*. 2015;36(6):626–634.
43. Whalen JL, Spelsberg SC, Murray P. Wound breakdown after total ankle arthroplasty. *Foot Ankle Int*. 2010;31(4):301–305.

44. Schipper ON, Denduluri SK, Zhou Y, Haddad SL. Effect of obesity on total ankle arthroplasty outcomes. *Foot Ankle Int*. 2016;37(1):1–7.
45. Werner BC, Burrus MT, Looney AM, Park JS, Perumal V, Cooper MT. Obesity is associated with increased complications after operative management of end-stage ankle arthritis. *Foot Ankle Int*. 2015;36(8):863–870.
46. Lampley A, Gross CE, Green CL, et al. Association of cigarette use and complication rates and outcomes following total ankle arthroplasty. *Foot Ankle Int*. 2016;37(10):1052–1059.
47. Lee JJ, Patel R, Biermann JS, Dougherty PJ. The musculoskeletal effects of cigarette smoking. *J Bone Joint Surg Am*. 2013;95(9):850–859.
48. Choi WJ, Lee JS, Lee M, Park JH, Lee JW. The impact of diabetes on the short- to mid-term outcome of total ankle replacement. *Bone Joint J*. 2014;96-B(12):1674–1680.
49. Gross CE, Green CL, DeOrio JK, et al. Impact of diabetes on outcome of total ankle replacement. *Foot Ankle Int*. 2015;36(10):1144–1149.
50. Schipper ON, Jiang JJ, Chen L, Koh J, Toolan BC. Effect of diabetes mellitus on perioperative complications and hospital outcomes after ankle arthrodesis and total ankle arthroplasty. *Foot Ankle Int*. 2015;36(3):258–267.
51. Marchant MH Jr, Viens NA, Cook C, Vail TP, Bolognesi MP. The impact of glycemic control and diabetes mellitus on perioperative outcomes after total joint arthroplasty. *J Bone Joint Surg Am*. 2009;91(7):1621–1629.
52. Sorg H, Waizy H, Stukenborg-Colsman C, Vogt PM, Knobloch K. Präoperative Perfusionsuntersuchung vor Sprunggelenksersatzoperationen [Preoperative perfusion analysis before total ankle arthroplasty]. *Handchir Mikrochir Plast Chir*. 2012;44(6):360–365. German.
53. Gianni S, Leardini A, O'Connor JJ. Total ankle replacement: review of the designs and of the current status. *Foot Ankle Surg*. 2000;6:77–88.
54. Vaughan P, Gordon D, Goldberg A, Cullen N, Singh D. Patient satisfaction and function after bilateral ankle arthrodeses. *Foot Ankle Surg*. 2015;21(3):160–163.
55. Henricson A, Kamrad I, Rosengren B, Carlsson A. Bilateral arthrodesis of the ankle joint: self-reported outcomes in 35 patients from the Swedish Ankle Registry. *J Foot Ankle Surg*. 2016;55(6):1195–1198.
56. Henricson A, Fredriksson M, Carlsson A. Total ankle replacement and contralateral ankle arthrodesis in 16 patients from the Swedish Ankle Registry: self-reported function and satisfaction. *Foot Ankle Surg*. 2016;22(1):32–34.
57. Asencio JG, Leonardi C, Biron-Andreani C, Schved JF. Short-term and mid-term outcome of total ankle replacement in haemophilic patients. *Foot Ankle Surg*. 2014;20(4):285–292.
58. Barg A, Elsner A, Hefti D, Hintermann B. Total ankle arthroplasty in patients with hereditary hemochromatosis. *Clin Orthop Relat Res*. 2011;469(5):1427–1435.
59. Barg A, Barg K, Wiewiorski M, et al. Endoprothetischer Ersatz des oberen Sprunggelenks bei Patienten mit Gerinnungsstörungen [Total ankle replacement in patients with bleeding disorders]. *Orthopade*. 2015;44(8):623–638. German.
60. van der Heide HJ, Novakova I, de Waal Malefijt MC. The feasibility of total ankle prosthesis for severe arthropathy in haemophilia and prothrombin deficiency. *Haemophilia*. 2006;12(6):679–682.
61. Scholz R, Scholz U. Die endoprothetische Versorgung des oberen Sprunggelenks bei h.mophiler Arthropathie [The total ankle replacement for severe arthropathy in haemophilia]. *Hamostaseologie*. 2008;28(suppl 1):S40–S44. German.
62. Strauss AC, Goldmann G, Wessling M, et al. Total ankle replacement in patients with haemophilia and virus infections – a safe alternative to ankle arthrodesis? *Haemophilia*. 2014;20(5):702–708.
63. Kotela A, Lorkowski J, Żbikowski P, Ambroziak P, Kucharzewski M, Kotela I. Total ankle arthroplasty in patients with inherited bleeding disorders. *Haemophilia*. 2015;21(3):e257–e259.
64. Preis M, Bailey T, Jacxsens M, Barg A. Total ankle replacement in patients with haemophilic arthropathy: primary arthroplasty and conversion of painful ankle arthrodesis to arthroplasty. *Haemophilia*. Epub 2017 Mar 17.
65. Barg A, Knupp M, Kapron AL, Hintermann B. Total ankle replacement in patients with gouty arthritis. *J Bone Joint Surg Am*. 2011;93(4):357–366.
66. Nieuwe Weme RA, van Solinge G, N Doornberg J, Sierevelt I, Haverkamp D, Doets HC. Total ankle replacement for posttraumatic arthritis. Similar outcome in postfracture and instability arthritis: a comparison of 90 ankles. *Acta Orthop*. 2015;86(4):401–406.
67. Mann JA, Mann RA, Horton E. STAR ankle: long-term results. *Foot Ankle Int*. 2011;32(5):S473–S484.
68. Schutte BG, Louwerens JW. Short-term results of our first 49 Scandanavian total ankle replacements (STAR). *Foot Ankle Int*. 2008;29(2):124–127.
69. Valderrabano V, Horisberger M, Russell I, Dougall H, Hintermann B. Etiology of ankle osteoarthritis. *Clin Orthop Relat Res*. 2009;467(7):1800–1806.
70. Greisberg J, Hansen ST Jr. Ankle replacement: management of associated deformities. *Foot Ankle Clin*. 2002;7(4):721–36, vi.
71. Stamatis ED, Myerson MS. How to avoid specific complications of total ankle replacement. *Foot Ankle Clin*. 2002;7(4):765–789.
72. Wood PL, Sutton C, Mishra V, Suneja R. A randomised, controlled trial of two mobile-bearing total ankle replacements. *J Bone Joint Surg Br*. 2009;91(1):69–74.
73. de Asla RJ, Ellis S, Overley B, Parekh S, Brigido S. Total ankle arthroplasty in the setting of valgus deformity. *Foot Ankle Spec*. 2014;7(5):398–402.
74. Doets HC, van der Plaat LW, Klein JP. Medial malleolar osteotomy for the correction of varus deformity during total ankle arthroplasty: results in 15 ankles. *Foot Ankle Int*. 2008;29(2):171–177.
75. Choi WJ, Kim BS, Lee JW. Preoperative planning and surgical technique: how do I balance my ankle? *Foot Ankle Int*. 2012;33(3):244–249.
76. Barg A, Pagenstert GI, Leumann AG, Müller AM, Henninger HB, Valderrabano V. Treatment of the arthritic valgus ankle. *Foot Ankle Clin*. 2012;17(4):647–663.
77. Knupp M, Bolliger L, Barg A, Hintermann B. Sprunggelenkprothese bei Varusarthrose [Total ankle replacement for varus deformity]. *Orthopade*. 2011;40(11):964–970. German.
78. Orthner E. Total ankle arthroplasty in varus instability – a new method of correction. *Fuß Sprungg*. 2011;9:96–101.
79. Roukis TS. Modified Evans peroneus brevis lateral ankle stabilization for balancing varus ankle contracture during total ankle replacement. *J Foot Ankle Surg*. 2013;52(6):789–792.
80. Shock RP, Christensen JC, Schuberth JM. Total ankle replacement in the varus ankle. *J Foot Ankle Surg*. 2011;50(1):5–10.
81. Valderrabano V, Frigg A, Leumann A, Horisberger M. Sprunggelenkprothese bei Valgusarthrose [Total ankle arthroplasty in valgus ankle osteoarthritis]. *Orthopade*. 2011;40(11):971–974. German.
82. Ryssman D, Myerson MS. Surgical strategies: the management of varus ankle deformity with joint replacement. *Foot Ankle Int*. 2011;32(2):217–224.
83. Ryssman DB, Myerson MS. Total ankle arthroplasty: management of varus deformity at the ankle. *Foot Ankle Int*. 2012;33(4):347–354.
84. Schuberth JM, Christensen JC, Seidenstricker CL. Total ankle replacement with severe valgus deformity: technique and surgical strategy. *J Foot Ankle Surg*. 2017;56(3):618–627.
85. Haskell A, Mann RA. Ankle arthroplasty with preoperative coronal plane deformity: short-term results. *Clin Orthop Relat Res*. 2004;424:98–103.
86. Clare MP. A rationale approach to ankle fractures. *Foot Ankle Clin*. 2008;13:593–610.
87. Michelson JD. Ankle fractures resulting from rotational injuries. *J Am Acad Orthop Surg*. 2003;11(6):403–412.
88. Hobson SA, Karantana A, Dhar S. Total ankle replacement in patients with significant pre-operative deformity of the hindfoot. *J Bone Joint Surg Br*. 2009;91(4):481–486.
89. Kessler B, Sendi P, Graber P, et al. Risk factors for periprosthetic ankle joint infection: a case-control study. *J Bone Joint Surg Am*. 2012;94(20):1871–1876.
90. Besse JL, Lienhart C, Fessy MH. Outcomes following cyst curettage and bone grafting for the management of periprosthetic cystic evolution after AES total ankle replacement. *Clin Podiatr Med Surg*. 2013;30(2):157–170.

91. van Wijngaarden R, van der Plaat L, Nieuwe Weme RA, Doets HC, Westerga J, Haverkamp D. Etiopathogenesis of osteolytic cysts associated with total ankle arthroplasty, a histological study. *Foot Ankle Surg*. 2015;21(2):132–136.
92. Besse JL. Osteolytic cysts with total ankle replacement: frequency and causes? *Foot Ankle Surg*. 2015;21(2):75–76.
93. Schipper ON, Haddad SL, Pytel P, Zhou Y. Histological analysis of early osteolysis in total ankle arthroplasty. *Foot Ankle Int*. 2017;38(4):351–359.
94. 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(7):907–914.
95. Dalat F, Barnoud R, Fessy MH, Besse JL; French Association of Foot Surgery AFCP. Histologic study of periprosthetic osteolytic lesions after AES total ankle replacement. A 22 case series. *Orthop Traumatol Surg Res*. 2013;99(6 suppl):S285–S295.
96. Wagener J, Gross CE, Schweizer C, Lang TH, Hintermann B. Custom-made total ankle arthroplasty for the salvage of major talar bone loss. *Bone Joint J*. 2017;99-B(2):231–236.
97. Lampert C. [Ankle joint prosthesis for bone defects]. *Orthopade*. 2011;40(11):978–983. German.
98. Harnroongroj T, Harnroongroj T. The talar body prosthesis: results at ten to thirty-six years of follow-up. *J Bone Joint Surg Am*. 2014;96(14):1211–1218.
99. Taniguchi A, Takakura Y, Tanaka Y, et al. An alumina ceramic total talar prosthesis for osteonecrosis of the talus. *J Bone Joint Surg Am*. 2015;97(16):1348–1353.
100. Shekkeris AS, Hanna SA, Sewell MD, et al. Endoprosthetic reconstruction of the distal tibia and ankle joint after resection of primary bone tumours. *J Bone Joint Surg Br*. 2009;91(10):1378–1382.
101. Lee SH, Kim HS, Park YB, Rhie TY, Lee HK. Prosthetic reconstruction for tumours of the distal tibia and fibula. *J Bone Joint Surg Br*. 1999;81(5):803–807.
102. Natarajan MV, Annamalai K, Williams S, Selvaraj R, Rajagopal TS. Limb salvage in distal tibial osteosarcoma using a custom mega prosthesis. *Int Orthop*. 2000;24(5):282–284.
103. Bonasia DE, Dettoni F, Femino JE, Phisitkul P, Germano M, Amendola A. Total ankle replacement: why, when and how? *Iowa Orthop J*. 2010;30:119–130.
104. Sheridan BD, Robinson DE, Hubble MJ, Winson IG. Ankle arthrodesis and its relationship to ipsilateral arthritis of the hind- and mid-foot. *J Bone Joint Surg Br*. 2006;88(2):206–207.
105. van der Plaat LW, van Engelen SJ, Wajer QE, et al. Hind- and midfoot motion after ankle arthrodesis. *Foot Ankle Int*. 2015;36(12):1430–1437.
106. Marx RC, McGarvey WC. The role of arthroplasty in combined hind foot and ankle arthritis. *Sem Arthrop*. 2010;21:303–309.
107. Asomugha EU, Den Hartog BD, Junko JT, Alexander IJ. Tibiotalocalcaneal fusion for severe deformity and bone loss. *J Am Acad Orthop Surg*. 2016;24(3):125–134.
108. Pellegrini MJ, Schiff AP, Adams SB Jr, DeOrio JK, Easley ME, Nunley JA 2nd. Outcomes of tibiotalocalcaneal arthrodesis through a posterior achilles tendon-splitting approach. *Foot Ankle Int*. 2016;37(3):312–319.
109. Rammelt S, Pyrc J, Agren PH, et al. Tibiotalocalcaneal fusion using the hindfoot arthrodesis nail: a multicenter study. *Foot Ankle Int*. 2013;34(9):1245–1255.
110. Gross CE, Lewis JS, Adams SB, Easley M, DeOrio JK, Nunley JA 2nd. Secondary arthrodesis after total ankle arthroplasty. *Foot Ankle Int*. 2016;37(7):709–714.
111. Usuelli FG, Maccario C, Manzi L, Gross CE. Clinical outcome and fusion rate following simultaneous subtalar fusion and total ankle arthroplasty. *Foot Ankle Int*. 2016;37(7):696–702.
112. Kim BS, Knupp M, Zwicky L, Lee JW, Hintermann B. Total ankle replacement in association with hindfoot fusion: outcome and complications. *J Bone Joint Surg Br*. 2010;92(11):1540–1547.
113. Shi GG, Huh J, Gross CE, et al. Total ankle arthroplasty following prior infection about the ankle. *Foot Ankle Int*. 2015;36(12):1425–1429.
114. Gross CE, Haughom B, Chahal J, Holmes GB Jr. Treatments for avascular necrosis of the talus: a systematic review. *Foot Ankle Spec*. 2014;7(5):387–397.
115. Lee KB, Cho SG, Jung ST, Kim MS. Total ankle arthroplasty following revascularization of avascular necrosis of the talar body: two case reports and literature review. *Foot Ankle Int*. 2008;29(8):852–858.
116. Devalia KL, Ramaskandhan J, Muthumayandi K, Siddique M. Early results of a novel technique: hindfoot fusion in talus osteonecrosis prior to ankle arthroplasty: a case series. *Foot*. 2015;25(4):200–205.
117. Basques BA, Bitterman A, Campbell KJ, Haughom BD, Lin J, Lee S. Influence of surgeon volume on inpatient complications, cost, and length of stay following total ankle arthroplasty. *Foot Ankle Int*. 2016;37(10):1046–1051.
118. Pinar N, Vernet E, Bizot P, Brilhault J. Total ankle arthroplasty – total ankle arthroplasty in Western France: influence of volume on complications and clinical outcome. *Orthop Traumatol Surg Res*. 2012;98(4 suppl):S26–S30.
119. Anderson T, Montgomery F, Carlsson A. Uncemented STAR total ankle prostheses. Three to eight-year follow-up of fifty-one consecutive ankles. *J Bone Joint Surg Am*. 2003;85-A(7):1321–1329.
120. Clement RC, Krynetskiy E, Parekh SG. The total ankle arthroplasty learning curve with third-generation implants: a single surgeon's experience. *Foot Ankle Spec*. 2013;6(4):263–270.
121. Schuberth JM, Patel S, Zarutsky E. Perioperative complications of the agility total ankle replacement in 50 initial, consecutive cases. *J Foot Ankle Surg*. 2006;45(3):139–146.
122. Haskell A, Mann RA. Perioperative complication rate of total ankle replacement is reduced by surgeon experience. *Foot Ankle Int*. 2004;25(5):283–289.
123. Myerson MS, Mroczek K. Perioperative complications of total ankle arthroplasty. *Foot Ankle Int*. 2003;24(1):17–21.
124. Schimmel JJ, Walschot LH, Louwerens JW. Comparison of the short-term results of the first and last 50 Scandinavian total ankle replacements: assessment of the learning curve in a consecutive series. *Foot Ankle Int*. 2014;35(4):326–333.
125. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *J Clin Epidemiol*. 2009;62(10):1006–1012.
126. Moher D, Shamseer L, Clarke M, et al; PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev*. 2015;4:1.
127. Bai LB, Lee KB, Song EK, Yoon TR, Seon JK. Total ankle arthroplasty outcome comparison for post-traumatic and primary osteoarthritis. *Foot Ankle Int*. 2010;31(12):1048–1056.
128. Kofoed H, Sorensen TS. Ankle arthroplasty for rheumatoid arthritis and osteoarthritis: prospective long-term study of cemented replacements. *J Bone Joint Surg Br*. 1998;80(2):328–332.
129. Pedersen E, Pinsker E, Younger AS, et al. Outcome of total ankle arthroplasty in patients with rheumatoid arthritis and noninflammatory arthritis. A multicenter cohort study comparing clinical outcome and safety. *J Bone Joint Surg Am*. 2014;96(21):1768–1775.
130. Kim BS, Choi WJ, Kim YS, Lee JW. Total ankle replacement in moderate to severe varus deformity of the ankle. *J Bone Joint Surg Br*. 2009;91(9):1183–1190.
131. Queen RM, Adams SB Jr, Viens NA, et al. Differences in outcomes following total ankle replacement in patients with neutral alignment compared with tibiotalar joint malalignment. *J Bone Joint Surg Am*. 2013;95(21):1927–1934.
132. Reddy SC, Mann JA, Mann RA, Mangold DR. Correction of moderate to severe coronal plane deformity with the STAR ankle prosthesis. *Foot Ankle Int*. 2011;32(7):659–664.
133. Sung KS, Ahn J, Lee KH, Chun TH. Short-term results of total ankle arthroplasty for end-stage ankle arthritis with severe varus deformity. *Foot Ankle Int*. 2014;35(3):225–231.
134. Trajkovski T, Pinsker E, Cadden A, Daniels T. Outcomes of ankle arthroplasty with preoperative coronal-plane varus deformity of 10 degrees or greater. *J Bone Joint Surg Am*. 2013;95(15):1382–1388.