CHAPTER 30

Evolution of Total Ankle Replacement Within the US

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INTRODUCTION

Primary osteoarthritis (OA) of the ankle is less common than primary OA of the hip and knee (1). Unlike hip and knee OA, where the main cause of end-stage arthritis is primary OA and inflammatory disease, ankle OA is mainly post-traumatic in etiology. A history of trauma has been reported in up to 80% of patients with end-stage OA of the ankle (2-4). As a result, ankle OA is associated with a younger patient population than patients with hip or knee OA. Post-traumatic ankle OA typically affects patients in their 5th and 6th decade of life, compared to hip or knee OA for which patients will typically undergo replacement in the 7th or 8th decade of life (3,5,6). Total ankle replacement (TAR) in this younger patient population remains controversial, and in the past, ankle arthrodesis has been the treatment of choice.

Currently, ankle arthrodesis is still considered the gold standard for primary ankle OA, and it is still performed 6 times more frequently than TAR (7-15). However, TAR has become a viable option over the past decade with advances in implant design, instrumentation, and techniques. Recent trends have shown that the per-capita standard utilization of TAR has increased by 670.8%, while in the same time frame, ankle fusion per-capita standard utilization has decreased by 15.6% (16). Saltzman et al reported similar pain relief when comparing ankle arthrodesis patients to ankle arthroplasty patients, also noting better functional results in the arthroplasty group (17). A systematic review by Haddad et al looked at clinical outcomes and revision rates between ankle arthrodesis and ankle arthroplasty. Outcomes and revision rates between the 2 groups were similar with a slightly higher revision rate of ankle arthrodesis group (18). With the latest generation implants, there has been an improvement in short and midterm outcomes over past generations of implants (19,20). This has led to a significant increase in the number of TARs being performed as surgeon experience and patient knowledge of the procedure continually expand (16,21).

ANKLE BIOMECHANICS

In the normal gait pattern, the ankle joint is critical to provide both absorption of energy and range of motion for propulsion. During the gait cycle, the ankle joint is initially plantarflexed at heel strike in order to provide a rocker to transfer the body weight to the forefoot during stance phase. Progressive dorsiflexion occurs as the foot then prepares for push off. Maximal dorsiflexion of the ankle is achieved just prior to the foot leaving the ground to enter swing phase (22). The primary motion of the ankle joint occurs in the sagittal plane with 43 degrees of flexion and 63 degrees of extension. Only 30 degrees of motion at the ankle joint, 10 degrees of dorsiflexion, and 20 degrees of plantarflexion, are needed for normal ambulation (23,24). The ankle joint also rotates an average 10 degrees within the ankle mortise; this motion makes the ankle joint a biplanar articulation (25). When there is a limitation of motion at the ankle joint, either by fusion of the joint or by OA, the hindfoot and forefoot compensate for the loss of sagittal plane motion. When compensation is needed, the midtarsal joint plantarflexes at heel strike to allow the foot to engage the ground. Then, during midstance, the heel rises early to transfer weight to the forefoot. This early heel rise increases the shear force to the midtarsal joints, possibly leading to ipsilateral hindfoot arthritis in patients with decreased or absent motion of the ankle joint (26-28). When the ankle joint is in equinus greater than 10 degrees, the needed motion is gained from the knee with increased extension and recurvatum. Maintenance of ankle joint motion or arthrodesis in a neutral position is critical for normal ambulation and decreasing the stress on the foot and surrounding joints.

A great deal of attention has been given to the effects of ankle arthrodesis on the surrounding ipsilateral joints (11,15,29) Thomas et al reported the results of functional outcomes in patients with ankle arthrodesis (30). They retrospectively reviewed 26 patients, clinically and radiographically, who underwent ankle arthrodesis at a mean follow-up of 44 months. The authors compared this surgical group with an age and sex match of 77 patients. Patients in both groups were evaluated with gait analysis, American Orthopedic Foot and Ankle Society (AOFAS) scores, the Musculoskeletal Outcomes Data Evaluation and Management Systems (MODEMS) questionnaire, and the Ankle Osteoarthritis Scale (AOS). Twenty of the 26 patients were either satisfied or completely satisfied with their surgical outcome with similar hindfoot pain and satisfaction scores. However, the functional outcome scores in the arthrodesis group were significantly lower. Gait, cadence, and stride length were all decreased in this patient population. In addition, 4 of the 26 patients demonstrated moderate to severe arthritis of the subtalar joint (Figure 1). The results of this paper demonstrate that ankle arthrodesis is an effective surgery for pain relief; however, it is less effective at restoring normal function and may have adverse effects on surrounding joints. Other authors have found similar surrounding joint impact after ankle arthrodesis. Coester et al evaluated 23 patients at a mean of 22 years post-ankle arthrodesis (27). They noted significant accelerated arthritic changes to the surrounding ipsilateral joints. Waters et al showed a decrease in gait velocity in arthrodesis patients to 84 percent of normal with an increased oxygen consumption of 3 percent with ambulation (31). These findings suggest that ankle range of motion should be preserved at all costs.

The prevalence of ankle OA and its known effects on patient quality of life has given rise to the evolution of various total ankle implants that have continually evolved in the hopes of creating an implant that preserves motion, restores function, and decreases pain in the same way that we have seen with implants of the hip and knee. With ankle arthrodesis being the first, and time-tested procedure of choice for OA, multiple investigators have sought to compare outcomes between arthrodesis and TAR. Piriou et al compared gait patterns between patients who underwent ankle arthroplasty versus ankle arthrodesis (32). Of the 12 patients in each group, no patient had restored normal movement or walking speed. The arthrodesis group demonstrated a faster gait with a longer stride, while the arthroplasty group demonstrated greater movement of the ankle joint with a symmetrical gait and restored ground reactive force. Singer et al compared gait in arthrodesis and arthroplasty patients to a control group (33). They concluded that while both groups had significant changes when compared to the control, the arthroplasty group more closely resembled the normal gait pattern. Chopra et al compared the outcome of 12 ankle arthrodesis patients and 12 TAR patients on gait mechanics to that of 12 healthy controls and found the ankle arthrodesis group had persistently altered bilateral gait mechanics compared to that of the TAR group, who more closely resembled the control group at 2 years postoperative (34). These biomechanical studies maintain key points when discussing surgical options with patients. Regardless of procedure choice, it is important for the patient to realize that the surgical goal is not a "normal" ankle, but rather a more functional ankle with diminished pain. Overall restoration of foot biomechanics favors TAR, however the decision of whether to fuse or replace the ankle is multifactorial.

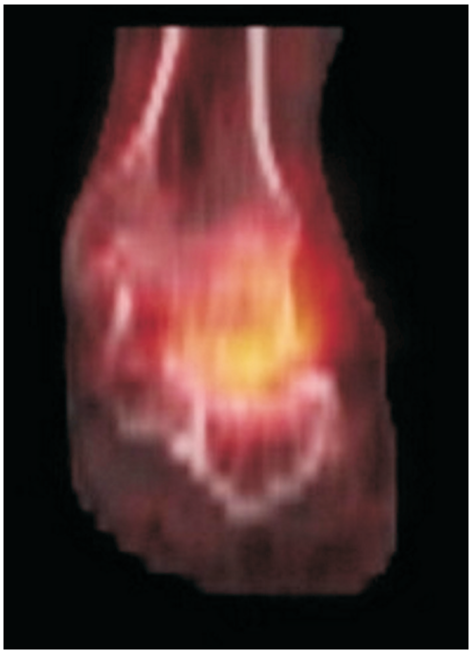

Figure 1. SPECT image demonstrating adjacent joint arthritis involving the subtalar joint after ankle arthrodesis.

Studies evaluating the functional outcomes of total ankle arthroplasty have shown significant improvement when compared to a patient's preoperative state. Dyrby et al compared patient gait pre- and post-arthroplasty (35). There was an improvement in walking speed, and movement and motion studies improved toward normal values. Ten patients with ankle arthroplasty were compared to a 10-patient control group by Doets et al (36). They noted near-normal gait patterns with regard to joint kinematics; however, there were decreases in walking speed and dorsiflexion. Lewis et al looked at 396 patients who underwent a total of 404 total ankle arthroplasties with and without an adjacent hindfoot arthrodesis. They found significant improvement in visual analog scale scores, walking speed, sit-to-stand time, and 4-square step test time in both TAR alone and TAR with hindfoot arthrodesis. However, the TAR group without hindfoot arthrodesis had significantly improved functional outcomes. The authors concluded that primary TAR without adjacent hindfoot arthrodesis has superior results (20). One group sought to compare functional outcomes and gait analysis of fixed and mobile-bearing TAR implants to one another. In this Level II study, 49 patients received mobile-bearing and 41 received fixed bearing implants.

Implant selection was at the discretion of the surgeon on a case-by-case basis and was not randomized. There were no significant differences between implant groups in regards to age, weight, height, or preoperative tibiotalar alignment. Results showed greater weight-acceptance and propulsive ground reactive force in the fixed bearing group, indicating that this group was more willing to place weight on the operative extremity than the mobile bearing group. However, the mobile bearing group demonstrated significantly faster sit-to-stand time, which suggests that this group was able to stand up and walk more easily than the fixed-bearing group. Significant improvements were also found in all measured spatiotemporal variables and were independent of implant selection (37).

PATIENT SELECTION FOR TOTAL ANKLE ARTHROPLASTY

General requirements and indications for TAR include primary osteoarthritis, secondary osteoarthritis and post-traumatic osteoarthrosis; adequate bone quality, ligamentous stability; proper vascular status and immunologic conditions; and well-aligned hindfoot with sufficient preoperative range of motion (38). Relative contraindications include status after major trauma (open ankle fractures, fracture-dislocations of the talus, segmental bony defects); eradicated infection; avascular necrosis of the talus (25-50% involvement); severe osteopenia or osteoporosis; longstanding steroid treatment (either systemic or local); diabetes mellitus (depending on control); and moderate physical demands. Absolute contraindications include neuropathic feet; active joint infections; major avascular necrosis of the talus (>50% involvement) (Figure 2); severe hypermobility of the joints and hyperlaxity; periarticular compromise of the soft-tissues (Figure 3); and high physical demands.

Age Considerations

In the past, ankle replacements have been reserved for patients over the age of 50 years. This was based on the fact that the lower physical demands of older patients would cause less stress on the implant, which would in turn prevent premature failure as well as reports of low clinical scores and early failure rates in young, active patients with previous generations of ankle implants (39,40). The previously cited literature challenges the belief that younger patients have higher early failure rates, higher major complication rates, and lower clinical scores (18,41-43). However, literature does exist to substantiate the use of TAR in younger patients and current generation ankle prostheses demonstrate improved implant design and survivorship data (17,18,39,44-46). Koefed et al demonstrated 75% implant survival in patients younger than 50 years and 81% in patients older than 50 years. Statistically, there was no significant difference in clinical outcome, frequency of revision, or conversion to fusion (45).

Rodrigues-Pinto et al completed a prospective multicenter study using a third-generation implant comparing clinical outcome data, range of motion, and complication and survivorship rates in patients younger than 50 years old to those older than age 50 (39). One-

Figure 2. Anterior-posterior radiograph demonstrating avascular necrosis involving greater than 50% of the talar body.

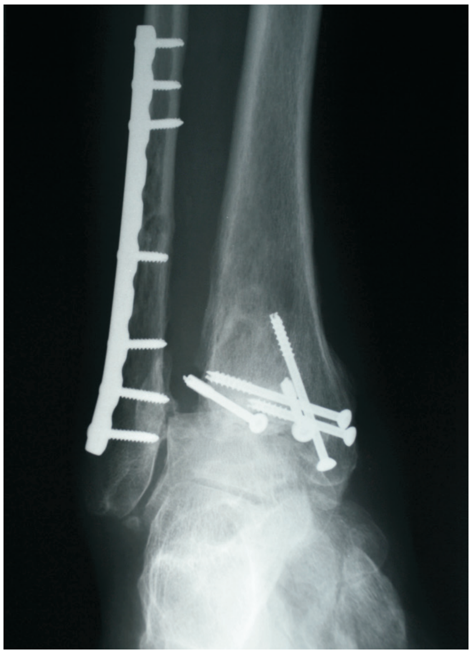

Figure 3. Anterior-posterior radiograph demonstrating significant syndesmotic instability status post open reduction internal fixation of a trimalleolar ankle fracture. Note the absence of syndesmosis fixation.

hundred and three patients met inclusion criteria with an average follow-up of 40 months. The mean age was 43 years in the <50 age group and 61 years in the >50 age group. The preoperative AOFAS scores were equivalent in both groups (26.7 in the <50 group and 27.0 in the >50 group). The postoperative AOFAS scores in the <50 group increased to 93.5 versus 89.8 in the >50 group. The rate of major complications was equivalent in both groups and no significant differences were found in the survivorship rates between both groups. The survivorship rate was 93.5% (95% confidence interval [95% CI]) in patients younger than 50 and 93.1% (95% CI) in patients older than 50. The authors conclude that at medium-term, ankle replacement is at least as effective in patients younger than 50 as those older than 50. The younger patients demonstrated better clinical and functional scores. This is in contrast to previously-reported studies that demonstrate survivorship in patients younger than 50 are poor (18,40-43,45). Of note, these studies compared first- and second-generation implants.

Multiple authors suggest that in order to maximize the success of an implant, the ideal patient will have minimal or no coronal plane deformity, excellent bone quality, good sensation, no medical comorbidities, and a healthy psychological profile (Figure 4) (17,18,44,46). These factors lend to the idea that the younger patient would be a good candidate for a TAR. The issue of TAR in the younger patient is survivorship of the implant, which will be addressed subsequently. With the modern ankle implants showing equivalent pain relief and improved function compared to an ankle fusion (2), future long-term studies will need to be performed to determine the effectiveness of total ankle replacements in the younger patient population.

Total Ankle Arthroplasty in Patients With Rheumatoid Arthritis

Rheumatoid arthritis (RA) often affects the hindfoot, which when associated with ankle arthritis can lead to disability in 50% of patients (47). In the past, an ankle fusion was considered the standard of care in RA patients with end-stage arthritis (8,11,48,49). However, complications associated with ankle fusions in the RA patient have been reported, such as nonunion, wound dehiscence, and a rigid foot due to surrounding arthritic joints (50). Due to the fact that hindfoot motion is often limited with the surrounding arthritis, patients are not able to fully compensate with a fused ankle (51). Associated metatarsalgia, gait disturbances, anterior tibial pain, and tibial stress fractures have been reported in patients with an ankle fusion with ipsilateral hindfoot arthritis (51-54). As a result, procedures that preserve joint motion like TAR have been explored (47).

RA with multiple joints involved is not a contraindication for TAR (49). In fact, comparable outcomes have been reported when looking at TAR in OA and RA (55). Pedersen et al compared 50 patients with RA to 50 patients with non-inflammatory arthritis. These patients were matched with age within 10 years, prosthesis type, and follow-up time. All patients received a total ankle replacement, and revisions and major complications were recorded. The average follow-up was 63.8 months for the RA group and 65.6

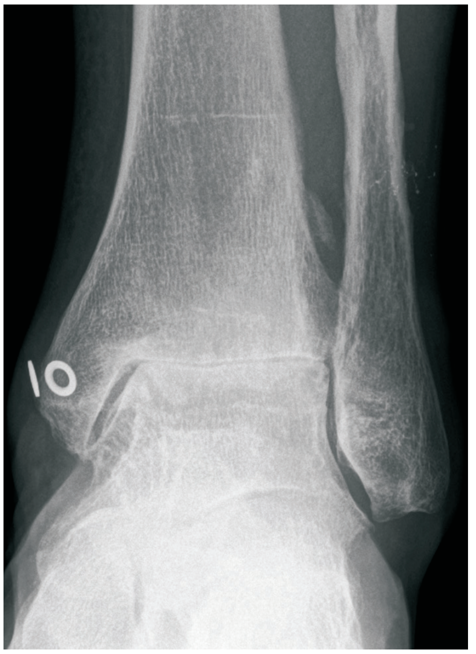

Figure 4A. Preoperative anterior-posterior radiograph demonstrating well-aligned ankle joint with post-traumatic arthritis in a 68-year-old female (note the retained hardware at the medial malleolus after prior open reduction internal fixation and subsequent hardware removal).

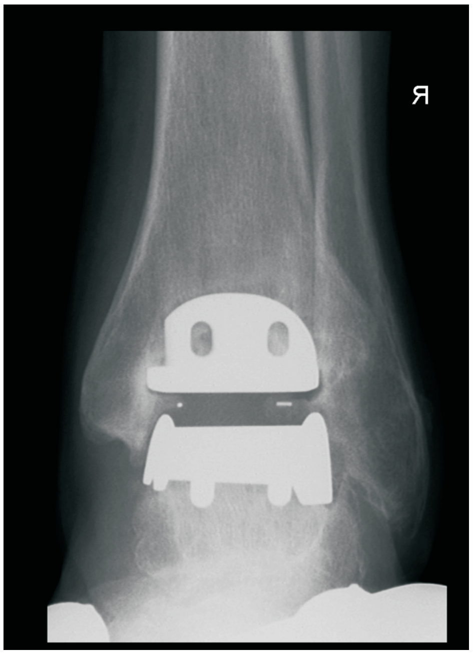

Figure 4B. Postoperative appearance after total ankle arthroplasty.

months for the noninflammatory arthritis group. The RA group was younger with a mean age of 58.5 years compared to 61.2 years in the non-inflammatory arthritis group. Interestingly, AOS pain scores were significantly different in the rheumatoid arthritis group and noninflammatory group preoperatively. The pain level in the RA group was higher preoperatively and showed a significant reduction in pain postoperatively with pain levels equivalent to the noninflammatory group after surgery. Both groups showed significant improvement with regard to the AOS scores for pain and disability and Short-Form 36 physical component summary scores following surgery. There were 7 revisions in the RA group and 5 revisions in the noninflammatory arthritis group. There was one major wound complication in the RA group and no major wound complications in the noninflammatory group (50).

Wood reported results of TAR in young patients with severe polyarticular RA. A total of 24 TARs were performed in patients with an average age of 33 years. Of the 24 TAR performed, 12 of the patients demonstrated coronal plane deformities preoperatively. All had associated hindfoot disease. Twenty-one replacements had good pain relief and function with only three failures, one of which was an ankle with 25-degrees of valgus preoperatively. The AOFAS hindfoot score for pain improved from 0 to 36 (max 40) and for function from 25 to 35 (max 60). The author recommended TAR to patients with severe polyarticular rheumatoid disease, particularly in a stiff but well-aligned hindfoot. Valgus or varus deformity of greater than 20 degrees was determined to be a contraindication to TAR due to recurrence, which led to pain, loosening and failure (46).

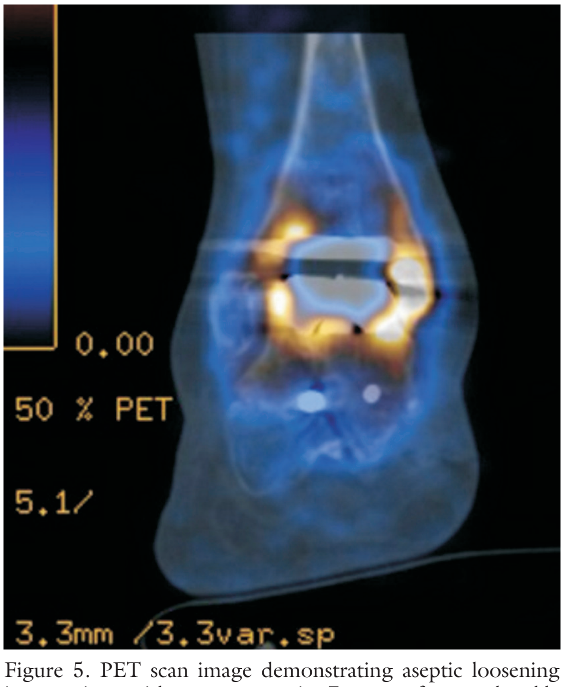

Figure 5. PET scan image demonstrating aseptic loosening in a patient with recurrent pain 7 years after total ankle arthroplasty.

Special consideration needs to be given to RA patients and their individual characteristics when considering TAR in this population. Careful assessment for severe ligamentous instability, cystic lesions, or significant deformity is imperative. Additionally, use of immunosuppressive medications should also be recognized as a risk factor for compromised wound healing, and perioperative management of these medications requires good communication with other members of the patient's healthcare team (46) Systemic factors in the rheumatoid patient have shown compromised healing potential, which puts the patient at risk for nonunion or delayed union when fusion is being considered for end-stage OA (50) . Recent comparable outcomes between RA patients and non-RA patients who undergo TAR have been shown, thus making TAR a viable option in RA patients with end-stage arthritis.

Failed Total Ankle Arthroplasty:
Revision Versus Fusion

The survivorship of the TAR is considerably less compared to those of the hip and knee despite improvements in design and instrumentation over the last several decades (Figure 5). In 2015, Kamrad et al found an 84% survival rate of ankle implants at 5 years with the rate diminishing to 74% at 10 years upon reviewing the Swedish Ankle Registry (56). Options after failed TAR include revision ankle replacement, conversion to isolated ankle arthrodesis, conversion to tibiotalocalcaneal (TTC) arthrodesis, or below-knee amputation (41,57-60). The decision to proceed with revisional ankle arthroplasty or salvage arthrodesis is complex and is based on the degree of bone loss and quality of remaining bone, particularly of the talus. Revisional arthroplasty of first generation implants remains a challenge as earlier systems required significantly more bone resection compared to second and third generation implants. Consideration should be given to salvage arthrodesis with these first generation implants, whereas revisional arthroplasty is a more viable option with second and third generation implants. The radiographic and clinical characteristics of each case must be individualized, and the desires of the patient strongly considered. A revision ankle implant arthroplasty will fail at some point, and the patient must be fully cognizant of the risks, benefits, and possible outcomes of each potential salvage option. For example, a patient experiencing significant subsidence of the talar component with substantial bone loss faces a very difficult salvage with a prolonged and unpredictable recovery. In this case, the surgeon must consider whether a revision TAR with extensive bone grafting is an equivalent or better option than salvage arthrodesis when considering all factors (Figure 7).

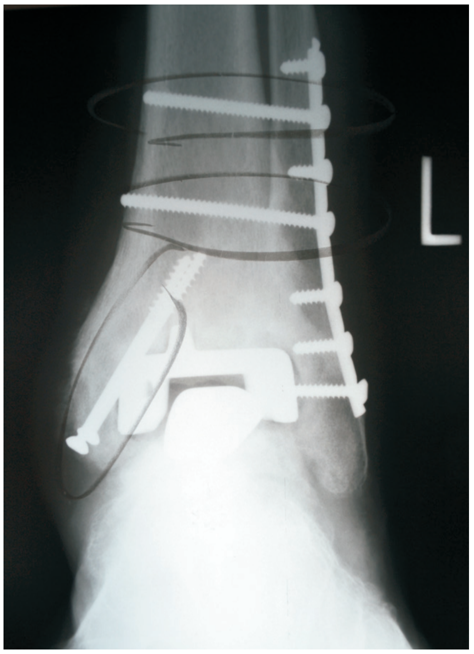

Figure 6A. A 71-year-old patient demonstrating failure 5 years post implant arthroplasty with lysis surrounding the tibial component and mild subsidence of the talar component.

Figure 6B. Lateral radiograph demonstrating revision arthroplasty using a modular stem implant with radiographic evidence of lysis surrounding the talar component and mild subsidence suggesting infectious process.

Figure 6C. Anterior-posterior radiograph demonstrating removal of tibial and talar components with antibiotic impregnated cement spacer after intraoperative frozen section and gram stain confirmed deep infection. Revision with conversion to arthrodesis performed 3 months after.

Figure 6D. Postoperative radiograph obtained 4 months after conversion to tibiotalocalcaneal arthrodesis demonstrating stable union without evidence of residual infection.

Figure 6E. Lateral view.

Figure 7A. In this case of talar subsidence, the decision was made to perform revision TAR with talar component exchange and subtalar joint arthrodesis.

Figure 7B. Lateral view.

We know that patients who undergo revision TAR do not have the same level of outcomes that they did when undergoing the primary TAR. Ellington et al performed a retrospective review of 53 patients who underwent revision total ankle replacement with a mean follow-up of 49.1 months (61). The average time from primary arthroplasty was 51 months and the most common indication for revision total ankle replacement was talar subsidence (63%). At the time of revision arthroplasty, 54% of patients underwent simultaneous subtalar arthrodesis. Postoperatively, the mean visual analog pain scale score was 4.4 of 10 possible points, 65 of 100 possible points on the AOFAS hindfoot scale, 93.5 of 100 possible points on the Short-Form 12, and a 137.9 of 204 possible points on the Revised Foot Function Index. The authors state that revision arthroplasty may be considered as an alternative to arthrodesis; however, they noted that only 44% returned to their previous activity levels. Kamrad et al found that the revision TAR group with second and third generation implants had a 10-year survival rate of only 55% compared to 74% in primary TAR. Only half of patients undergoing revision were satisfied with the outcome. They conclude that revision arthroplasty might not be the treatment of choice for failed TAR. The authors noted differences in outcome with revision in certain groups, including those whose primary TAR failed for technical reasons and patients with rheumatoid arthritis. They suggest further investigation into which patients may do better with revision or if conversion to arthrodesis is the most appropriate next step for failed primary TAR (56). A prospective study by Daniels et al looked at 111 ankles undergoing STAR prosthesis implantation. They found 12% required metal component revision, and 18% required poly exchange over a mean follow-up of 9 years. The revision rate was substantially higher in the first 20 cases, alluding to the learning curve, which has been previously reported by several other authors for TAR (17,62). Adams et al looked at early and midterm results of 194 primary Inbone I TARs to find a 6% revision rate at a mean of 1.6 years. Talar subsidence was a noted reason in 6 revision cases, and the authors recommend continued investigation into the reason for subsidence, which may include the introduction of surgical instrumentation into the subtalar joint with Inbone I and II, which may damage vascularity of the talus leading to this particular complication (19).

Options for TAR revision are dependent on the pathology, which must be addressed at the time of the second surgery. In the past, the standard for revision has been arthrodesis. However, arthrodesis for failed TAR has been reported to have a high rate of complications such as nonunion and overall poor outcomes (63-65). The improved design of later generation implants and instrumentation that have come about due to a better understanding of ankle joint kinematics and critical analysis of earlier failed implant designs has allowed for revision TAR to still be a part of the treatment algorithm in the attempt to preserve ankle range of motion and stave off the development of OA in adjacent joints (28). The surgeon must carefully evaluate why the implant failed in the first place. Any underlying structural deformity must be corrected with a combination of hindfoot osteotomies, arthrodesis, and soft tissue balancing. This can be done in a 1 or 2-stage approach. Horisberger et al recommended a 1-stage revision when bone defects on the tibial or talar side did not compromise the stability of the components. Autologous iliac crest was used and fixated when appropriate at the time of revision TAR. A 2-stage approach was recommended by the authors when the osseous defect was in the weightbearing area of the tibial plafond. Grafting the defect was followed by revision TAR 3 to 4 months later (66). While autogenous grafting for osteolysis is a good option for revision TAR, it comes with the potential for donor site morbidity.

Prissel and Roukis reported good results for the management of extensive tibial osteolysis using polymethylmethacrylate reinforced with coiled Kirschner wires in 9 patients undergoing revision TAR. The authors note their series had limited follow-up time, so the integrity of their proposed construct must be looked at again to further assess if this procedure endures the test of time (67). Familiarity with newer generation implants is crucial when considering revision TAR as some implant components may not be amenable to a simple exchange. For example, talar subsidence is one of the most commonly encountered issues requiring revision. Limited real estate of the talar dome after resection during primary TAR typically requires a flat cut talus implant in order to resect necrotic bone. The surgeon must have experience with these different implant systems when it comes time for revision in order to select the correct implant. Williams et al converted 35 Agility TAR to Inbone II TAR. They conclude that revision TAR is a viable option for the failed TAR, but caution that perioperative complications (31.4% of patients in their study) remain high in this group of patients (68).

Conversion to arthrodesis after failed TAR is a technically challenging procedure with high rates of complication and often results in considerable shortening (69). When revising a failed total ankle arthroplasty via conversion to salvage arthrodesis, the key to achieving a successful outcome is to maintain length of the limb, utilize appropriate fixation, and consider structural or nonstructural bone graft augmentation depending on the degree of bone loss present (57) (Figure 6). Culpan et al demonstrated a high rate of union in TAR converted to salvage ankle arthrodesis using vertically-oriented corticocancellous grafts, a technique described by Campbell et al (69,70). The mean age of patients was 54 years, and 15 of 16 experienced successful union and height restoration. The postoperative AOFAS hindfoot score improved from a mean preoperative score of 30 to a mean postoperative score of 70 out of 100 possible points. These results demonstrated similar AOFAS scores to patients who underwent primary TAR (30). The authors do note, however, that AOFAS scores are not a validated scoring system (71). Overall, the union rate of salvage ankle arthrodesis after failed TAR is reported to be as high as 100% (63,72) . Haddad reported similar results with the union rate of primary ankle arthrodesis noted to be 90% in a meta-analysis (18). The mean time to radiographic union after conversion from failed TAR to ankle arthrodesis was 3 months compared to 14.5 weeks for primary open-ankle arthrodesis, and 8.7 weeks for arthroscopic fusion (69,73,74).

Deleu et al reported their results of revision for failed TAR by salvage with ankle arthrodesis or TTC arthrodesis (75). Seventeen patients met inclusion criteria, the average follow-up was 30.1 months, and average time to revision was 49.8 months. Primary union was achieved in 13 of 17 patients with 3 requiring revision. Average time to radiographic union was 3.7 months and the mean postoperative AOFAS score was 74.5. The authors concluded that tibiotalar and TTC arthrodeses were effective salvage procedures for failed TAR. Large cancellous allografts were effective at addressing large bone defect after removal of the prosthesis and preserved limb length.

Extended arthrodesis is not without risk, and studies have shown decreased function after combined TTC fusion (76). Specific biomechanical issues with TTC arthrodesis include a stiff foot with reduced propulsion, loss of shock absorption and inability to adapt to ground reactive forces (77). However, Tenenbaum et al demonstrated statistically significant improvement in gait symmetry and objective improvement in ambulatory function after combined arthrodesis of the ankle and subtalar joint (78). Regardless of the known outcomes of TTC arthrodesis, this procedure at times is the only remaining viable option outside of below-knee amputation. Talar subsidence or talar AVN can preclude fusion at the level of the ankle alone in an attempt to spare the subtalar joint. Concomitant arthritic changes in the subtalar joint are no longer amenable to isolated ankle fusion in the salvage TAR, and TTC fusion would be the next step. Results have been promising. For patients undergoing salvage of failed TAR with conversion to TTC arthrodesis, Kotnis et al noted mean time to fusion was 3.5 months with no cases of nonunion, malunion, or wound breakdown (79). The type of fixation used for TTC fusion is driven by hardware, which may already be present in the subtalar joint from previous fusion. If this is the case, isolated tibiotalar fusion fixation construct is at the discretion of the surgeon. Removal of the hardware from the subtalar joint in order to place an intramedullary rod is also an option and can be used when primarily fusing the subtalar joint as well. Significant bone loss may be present at the time of salvage and extensive bone grafting may be needed. A more recent article by Mulhern et al discusses the use of a custom titanium truss when performing a TTC fusion on a failed TAR. The study group only consisted of 1 patient, but the authors note that at the 9-month follow-up, the patient had osseous ingrowth of the truss, markedly improved AOFAS and visual analog scale scores from the preoperative scores, and he was ambulating in a sneaker with a brace (80).

Survivorship of TAR continues to be an issue when compared to implants of the hip and knee. It is important to note that increased surgeon experience and careful patient selection improves outcomes and decreases failure rates (62). Long-term studies on the newest generation of implants have yet to be published, and these results will continue to drive evolution on implant design and technique for improved outcomes as these data become available.

The literature summarized in this section demonstrates that despite the complex nature of a failed ankle arthroplasty, successful outcomes can be achieved with both revision implant arthroplasty, and salvage arthrodesis. This evidence supports the option to consider expanding the indications for ankle arthroplasty to include nontraditional candidates, such as younger patients, and knowing that successful outcomes, as well as viable salvage options, exist. Evolution of ankle implants with several model changes over time has made it difficult to evaluate relevant long-term data. With the newest generation of implants showing the most promising midterm results compared to previous generations, long-term data of current generation implants will eventually elucidate the role of TAR when compared to that of ankle arthrodesis.

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