

5 Points on Total Ankle Arthroplasty

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End-stage ankle arthritis is a painful and functionally limiting condition that can significantly worsen quality of life.¹ Ankle arthrodesis, a common surgical procedure for ankle arthritis, provides good pain relief, patient satisfaction, and clinical outcomes when fusion is achieved.^{2,3} Potential disadvantages include malunion and nonunion,⁴ malalignment, limited range of motion (ROM), altered gait mechanics,⁵ and development of adjacent joint arthritis requiring reoperation.⁶

Over the past 2 decades, significant improvements in total ankle arthroplasty (TAA) surgical technique, implant design, surgeon training and education, and clinical outcomes have led to increased TAA popularity and use worldwide.⁷⁻¹³ Proposed advantages of TAA over arthrodesis include more normal joint ROM, superior gait kinematics, and decreased likelihood of subtalar arthritis, with equivalent pain relief and patient satisfaction.⁴ TAA has steadily gained acceptance as a safe, effective treatment option for ankle arthritis in select patient populations.¹⁴ In the United States from 2004 to 2009, the number of ankle fusions performed remained unchanged, but the number of TAAs increased by 57%, to 0.99 case per 10,000 patients.¹⁵

First-generation TAA implants had high failure rates at short-term follow-up because of nonanatomical designs, excessive bony resection, component malalignment, and improper soft-tissue balancing.¹⁶⁻¹⁹ Modern, second- and third-generation implants have improved features, including more anatomical designs, decreased bony resection, increased coronal and rotational stability, and enhanced modularity—decreasing tensile and shear forces at the bone–prosthesis interface and improving wear patterns.²⁰

In a prospective, controlled, multicenter trial of the Scandinavian Total Ankle Replacement (STAR) 3-part mobile-bearing prosthesis (Small Bone Innovations, Morrisville, Pennsylvania), Saltzman and colleagues¹¹ found that, compared with ankle arthrodesis, TAA had better functional outcomes and equivalent pain relief at 2-year follow-up. However, in a systematic review and meta-analysis of meniscal-bearing TAA implants, Stengel and colleagues²¹ found the rate of secondary surgery to be higher after TAA (12.5%) than after ankle arthrodesis. Brunner and colleagues⁸ reported long-term follow-up of the STAR prosthesis in a series of 62 TAAs with survival rates of 70.7% at 10 years and 45.6% at 14 years, with 38% of ankles requiring revision of at least 1 metallic component. Primary reasons for revision included aseptic loosening, talar component subsidence, progressive cyst formation, arthrofibrosis, and polyethylene insert fractures with an average time to revision of 7.4 years. A recent systematic review of 58 modern TAA implant studies (7942 TAAs) found an overall survivorship of 89% at 10 years with an annual failure rate of 1.2%.²² Overall, published survivorship data for TAA vary across studies, implant systems, and author-design teams and are influenced by surgeon familiarity with the procedure and surgeon case volume.

In this review, we highlight 5 key TAA aspects that can help guide treatment and improve outcomes, and we provide supporting evidence from the literature.

1 Patient Selection

Appropriate patient selection is crucial to obtaining good clinical results after TAA. However, the precise indications and contraindications for TAA remain controversial and continue to evolve with ongoing research. Traditional indications have included age over 60, body mass index (BMI) less than 35, low-impact daily activities, and minimal ankle and hindfoot deformity. These indications are now debatable, as surgical techniques and



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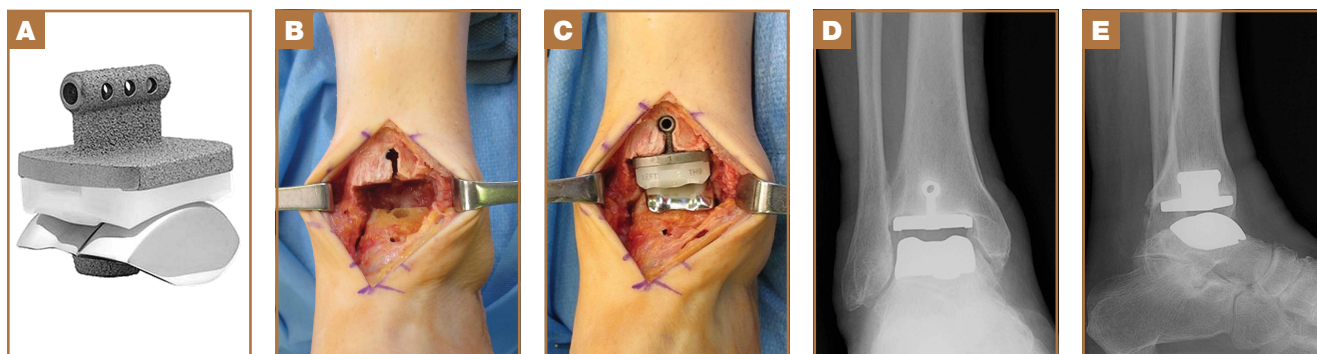


Figure 1. (A) Salto Talaris ankle implant (Tornier, Saint Ismier, France). Tibial component has keel along superior surface with tapered fixation plug on top for implantation, and talus has 2 distinct radii of curvature and hollow fixation plug inferiorly. Image published with permission from Tornier. Next, intraoperative photographs of bony tibial and talar cuts (B) before Salto Talaris implantation and (C) after both components are inserted into final position. Finally, postoperative (D) mortise and (E) lateral radiographs 6 months after surgery show proper component positioning and alignment without evidence of osteolysis or implant subsidence.

implant design have continued to improve, with many surgeons expanding TAA indications to include younger age and more deformity.²³⁻²⁶ Absolute contraindications include active deep joint infection, massive soft-tissue loss, insufficient bone stock for safe placement of implant, Charcot arthropathy, and absence of neuromuscular function in the extremity. As most modern TAA implant systems require an anterior surgical approach, it is crucial that the anterior soft-tissue envelope be viable and have an adequate vascular supply. If there is any suspicion of vascular insufficiency, a noninvasive Doppler study should be performed.

In its 2009 Position Statement on Total Ankle Replacement Surgery, the American Orthopaedic Foot and Ankle Society¹⁴ (AOFAS) noted that adults who have primary, posttraumatic, or rheumatoid arthritis with moderate or severe pain, loss of mobility, and loss of ankle function can all be considered for TAA. Before surgery, patients should first complete several months of conservative management and have adequate soft-tissue coverage and vascular perfusion in the involved extremity to ensure a safe surgical approach. Results from a recent systematic review showed that mean AOFAS scores reliably increased from an average of 40 before surgery to 80 at a mean follow-up of 8.2 years after surgery.²² Topics still debated—because of low levels of evidence in the literature on TAA indications—include patient age, activity level, weight, deformity, and medical comorbidities.

Data from the PearlDiver Patient Records Database (US orthopedic patients) showed that TAA is most commonly performed in 60- to 69-year-old patients (sex distribution is even).¹⁵ In a study of 5185 patients undergoing ankle procedures, SooHoo and colleagues²⁷ reported a mean age of 59 years for TAA patients—a finding supported by multiple other studies (age range, 50-60 years).^{4,11,13,22} Multiple studies have indicated that patients undergoing TAA tend to be older, predominantly female, and more likely to have posttraumatic or inflammatory arthritis.^{4,21,22,28} Henricson and colleagues²⁹ examined 531 TAAs from the Swedish

Ankle Arthroplasty Register and found that younger age at time of index TAA was associated with increased risk for revision because of increased wear over the lifetime of the prosthesis. Preoperative diagnosis and sex did not change the likelihood of revision surgery.

It is unknown what the effects of BMI are on polyethylene wear during multiplanar ankle joint motion through a normal gait cycle. A current but yet to be proved hypothesis is that higher BMI and increased high-impact activity levels may chronically increase contact forces and cause premature wear.³⁰ Penner and colleagues³¹ reported that mean BMI did not significantly change in patients after successful TAA, despite decreased pain and improved function. The authors found that preoperative BMI was the strongest overall predictor of postoperative BMI.

2 Implant Design

Improvements in implant design have significantly changed the outcomes of TAA, and it is vital for surgeons to have a thorough understanding of component characteristics to ensure proper placement. Saltzman and colleagues^{11,32} reported that there is a significant initial learning curve associated with TAA, regardless of training experience, that can significantly affect the incidence of intraoperative and postoperative complications. First-generation TAA implants, such as the Agility Ankle (DePuy, Warsaw, Indiana), had reported revision rates of 28% to 39% in large series at 3- to 4-year follow-up.^{16,33} Implant failure in part resulted from nonanatomical designs that required aggressive distal tibia and talar resection.

Modern TAA implants have improved survivorship²² but, compared with ankle arthrodesis, are still more likely to require reoperation because of malalignment and hardware failure.^{27,34} Glazebrook and colleagues³⁵ examined complication rates across 20 series and found that revision TAA was most often necessary to treat aseptic loosening, subsidence, osteolysis, impingement, arthrofibrosis, infection, or fractures. The majority of TAA implant systems

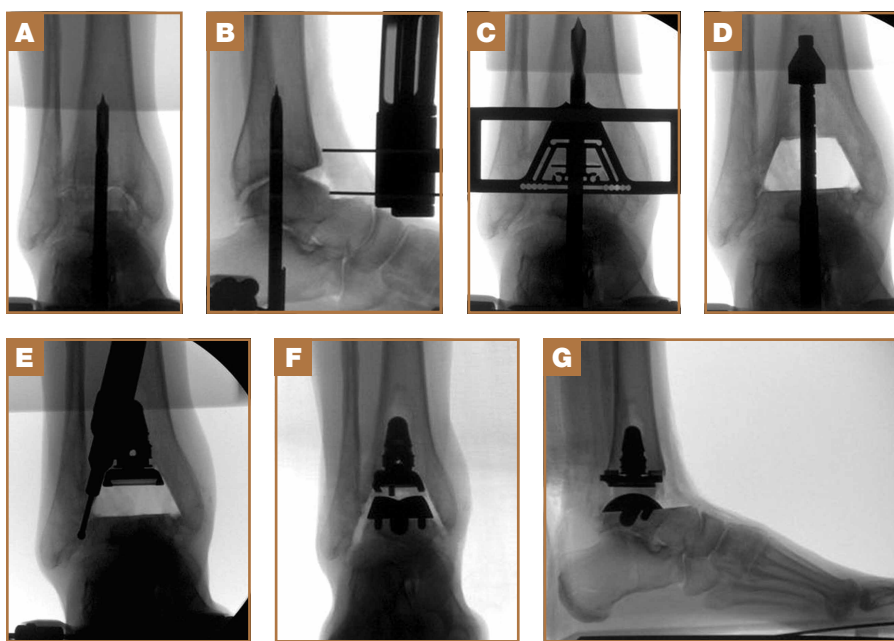


Figure 2. Intraoperative (A) anteroposterior and (B) lateral radiographs of Inbone II (Wright Medical Technology, Arlington, Tennessee) total ankle arthroplasty implant system using intramedullary reference guide and drill through plantar aspect of foot to direct tibial component placement. Anteroposterior radiograph shows tibial and talar cutting jig in place (C) before cuts are made and (D) after bony resection during intramedullary reaming before tibial stem insertion. (E) Lateral gutter débridement using high-speed burr after insertion of tibial stem components. (F) Medial gutter débridement followed by placement of final talar implant. (G) Lateral radiograph of final implant position shows appropriate sagittal alignment.

being used rely on extramedullary alignment guides for tibial component placement (STAR, Salto Talaris [Tornier, Saint Ismier, France]) (Figure 1). One available system uses intramedullary referencing to guide implant insertion (Inbone II; Wright Medical Technology, Arlington, Tennessee) (Figure 2).

In a series of 317 TAAs, Barg and colleagues³⁶ found that patients with talar body implants aligned with the longitudinal axis of the tibia had improved pain, functional outcome, and ankle motion compared with patients with talar component malpositioning. Relative anterior or posterior component placement may result in inferior outcomes, and anteroposterior talar offset may be a useful prognostic tool. However, the long-term implications of component malalignment are still largely unknown. Many surgeons align the tibial component perpendicular to the tibia mechanical axis in the coronal plane and perpendicular to or with a small anterior opening slope in the sagittal plane.³⁷

In a series of 83 tibial components placed with an extramedullary-referencing system (Salto Talaris) compared with 153 implants using intramedullary referencing (Inbone), Adams and colleagues³⁸ found that intramedullary guides had significantly better sagittal plane alignment accuracy (average improvement, 1.6°) with similar coronal plane accuracy compared with extramedullary guides. An additional advantage of the newer, second-generation Inbone II system is a sulcus-articulating geometry between the talar

dome and the polyethylene insert bearing surface to increase coronal stability and joint motion without overconstraining the joint.³⁹ This feature permits a more aggressive medial and lateral gutter débridement that may improve ankle motion while limiting residual ankle pain. Although intramedullary-referencing TAA implants may potentially offer more anatomical restoration of joint mechanics, their short- and long-term clinical and radiographic outcomes require further investigation.

Implant features that may negatively affect survivorship are lack of sufficient bony ingrowth surfaces, incorporation of grit blasting, high levels of constraint, and increased bony resection required for implantation.^{40,41} Degenerative changes at long-term follow-up of the bone–prosthesis interface with the STAR implant are thought to be caused by the single hydroxyapatite coating used on the tibial and talar components, as it may partially resorb over time.⁸ In a systematic

review of 49 primary studies evaluating TAA and ankle arthrodesis in a total of 2114 patients, Haddad and colleagues⁴ found that TAA had a 5-year survival rate of 78% and a 10-year survival rate of 77%. The revision rate for TAA was 7%, with the primary reason for revision being component loosening and/or subsidence (28%).

Further research is needed to clarify the optimal TAA implant placement for long-term survival and the clinical effects of various amounts of component malpositioning. In addition, studies are needed to evaluate the potential advantages and disadvantages of patient-specific alignment guides that may reduce procedural complexity and increase surgical efficiency (Prophecy; Wright). Direct comparisons between TAA implant systems are needed to determine what clinical benefits are achieved with each design and what contributes to these differences.

3 Joint Alignment

Moderate to severe tibiotalar malalignment in the coronal plane was once considered a contraindication for TAA and is currently a controversial topic.^{24,42} Mann and colleagues⁴³ examined coronal alignment in TAA and found an association between amount of coronal plane deformity and number of postoperative complications. However, expanded indications for TAA to include increasing varus or valgus deformity have been suggested, as many patients with end-stage ankle arthritis

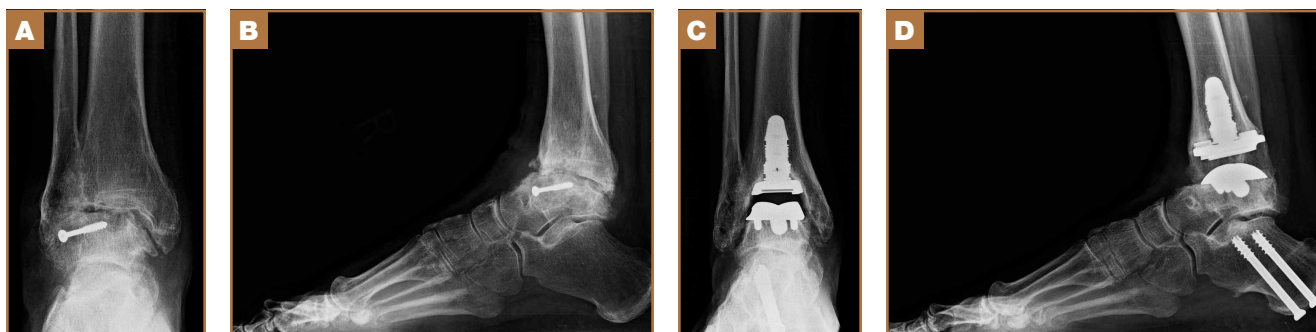


Figure 3. (A) Preoperative anteroposterior radiograph of patient with posttraumatic ankle arthritis and 10° varus coronal deformity after previous talus fracture open reduction and internal fixation. (B) Preoperative lateral radiograph shows anterior talar subluxation and erosions along articular surface. Postoperative (C) anteroposterior and (D) lateral radiographs 1 year after total ankle arthroplasty (Inbone II; Wright Medical Technology, Arlington, Tennessee) show successful deformity correction with neutral ankle joint alignment, hardware removal, and placement of two 7.0-mm cannulated calcaneal screws at time of total ankle arthroplasty for fixation of closing-wedge osteotomy.

who would benefit from TAA have associated deformity from asymmetric joint deterioration (**Figure 3**). Failure to correct coronal plane deformity and/or ankle instability can cause edge loading on the polyethylene liner, leading to increased wear, component loosening, and fracture as early as 2 years after surgery.^{24,40} Continued joint malalignment can result in early failure of both the tibial and talar implants, necessitating revision surgery.

Kim and colleagues²⁶ compared 23 TAAs with preoperative varus deformity of more than 10° with 22 neutral ankles and found no clinical or radiographic outcome differences between the groups at 27-month follow-up. All cases used the Hintegra total ankle system (Newdeal, Lyon, France), and varus TAAs required deltoid ligament release to achieve neutral alignment. There were no group differences in congruent and incongruent varus ankle alignment. Similar results were reported by Queen and colleagues⁴⁴ using the Inbone and Salto Talaris systems. In a series of 103 TAAs with excessive deformity (> 15° varus/valgus), moderate varus or valgus (5°-15°), or neutral alignment (< 5° varus/valgus), the authors found that TAA improved clinical and functional outcomes independent of preoperative tibiotalar deformity.⁴⁴ Nearly all patients (95%) achieved neutral alignment after TAA through use of adjunctive procedures, such as deltoid ligament release, lateral ligament reconstruction, and posterior soft-tissue releases. Although recent studies have indicated that satisfactory results can be achieved with TAA in patients with coronal malalignment of more than 10° to 15°^{26,42,44,45} and even more than 20°,^{42,45} these results are achievable only with meticulous surgical technique and careful osteophyte débridement, deformity correction, and ligament balancing.

4 Balancing

Soft-tissue and bony procedures for balancing the ankle joint during TAA are paramount to restore the mechanical alignment of the ankle and achieve a plantigrade foot below the prosthesis. Continued

ankle instability and deformity after TAA are major factors associated with poor clinical outcomes and the need for revision surgery.²⁴ Soft-tissue contractures from varus or valgus coronal plane deformity are common in end-stage arthritis. Techniques for achieving joint symmetry include osteotomies, ligament reconstructions, soft-tissue releases, and tendon transfers (**Figure 4**).^{23,25,26} Concurrent hindfoot procedures are particularly important in managing varus ankle deformity, as these cases typically require calcaneus osteotomy, ligament reconstruction, peroneus longus-to-brevis transfer, first metatarsal osteotomy, and possible lateral transfer of the anterior tibial tendon.

Small amounts of unaddressed coronal malalignment can create an asymmetric joint articulation leading to edge loading, eccentric wear, and early component wear and failure. However, overly aggressive soft-tissue releases can also create instability on the contracted side of the joint and an increased tibiotalar gap. Several TAA systems allow for size mismatch of the tibial and talar components, making it possible to insert a larger talar implant to compensate for bone loss and increase the force distribution across the remaining talus.⁴⁰ Care must be taken to not overstuff the joint with too wide a talar component, as the prosthesis can create medial and lateral gutter impingement and ultimately limit motion. Impaction grafting combined with use of a thicker polyethylene liner after coronal balancing can be used to address loss of bone height.

In the preoperative period, it is important to thoroughly assess ankle and hindfoot alignment, ankle instability, equinus contracture, and forefoot pronation on physical examination and radiographic imaging. Weight-bearing views of the ankle are required, along with hindfoot alignment, lower extremity, and varus/valgus stress views, to evaluate flexible and rigid deformities and joint congruency. Ankle alignment can be assessed using the angle between the anatomical axis of the tibia and a line perpendicular to the articular surface of the talus on radiographs.²³ Malalignment of more than 10° in any plane in

the distal tibia generally requires a corrective supramalleolar osteotomy before TAA.^{46,47} Magnetic resonance imaging can be used adjunctively to evaluate associated soft-tissue pathology, such as tears of the posterior tibial or peroneal tendons and/or deltoid ligament insufficiency.

In chronic varus ankle deformity, the medial structures (eg, deep deltoid ligament anteriorly, posterior tibial tendon posteriorly, and joint capsule) are often contracted, causing talar tilt and an incongruent joint. All bony cuts of the distal tibia should be performed along with osteophyte resection before specific medial releases, as removal of bony impingement alone can often produce a balanced tibiotalar gap. Intraoperative techniques for assessing anteroposterior and mediolateral stability include use of spacer blocks, laminar spreaders, tensioning devices, and insertion of trial components followed by stress testing. Gradual release of the deep deltoid ligament components at their distal insertion allows precise balancing while avoiding medial instability and potential damage to the neurovascular bundle.²³

Residual talar tilt after medial releases indicates that the lateral structures are loose, and therefore additional plication or augmentation procedures are required.²⁶ Lateral balancing can be achieved using a modified Brostrom procedure, lateral ligament reconstruction, or fibular shortening osteotomy. Transfer of a nonanatomical peroneus longus tendon to the base of the fifth metatarsal can also be used to stabilize lateral laxity while reducing first metatarsal plantarflexion.²³ If varus deformity is present in a congruent joint, a neutralizing tibial plafond bony cut (2-4 mm) at the level of the most proximal defect is needed in addition to medial release. Varus deformity can often be associated with concurrent hindfoot varus/valgus, heel cord tightness, and forefoot pronation. The need for additional procedures addressing these deformities should be determined during surgery, after insertion of all trial components. A lateral calcaneal closing-wedge osteotomy can correct heel varus with 2 partially threaded cannulated screws for fixation. Equinus contracture of more than 10° can be addressed using percutaneous Achilles tendon lengthening or a gastrocnemius recession. Forefoot pronation with plantarflexion of the first metatarsal can be corrected with a dorsiflexion osteotomy of the first metatarsal removing a dorsal wedge of bone followed by screw fixation.

Valgus deformity can largely be attributed to tibial/fibular malunion and/or posterior tibial tendon (PTT) insufficiency. Lateral malleolus malunion after fracture can be corrected using a suprasyndesmotoc lateral opening-edge osteotomy with bone graft interposition fixed with plate and screws through a transmalleolar approach.²³ Similarly, tibial malunion can be fixed using a medial closing-wedge osteotomy. PTT-related deformity can be addressed after standard TAA distal tibial cuts using a combination of a medial sliding calcaneus osteotomy, medial soft-tissue repair, and plantarflexion osteotomy of the first metatar-

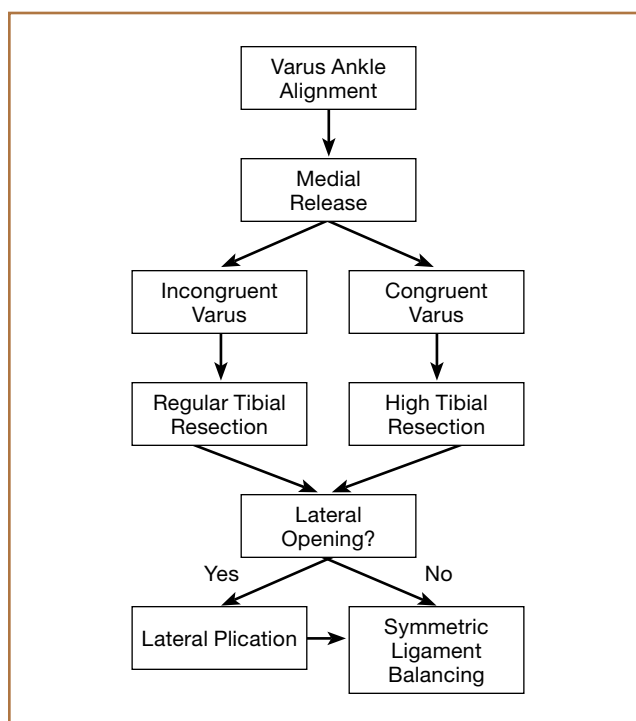


Figure 4. Treatment algorithm for soft-tissue balancing in cases of varus ankle alignment in total ankle arthroplasty incorporating medial release, bony tibial resection, and lateral plication. Modified with permission from: Kim BS, Lee JW. Total ankle replacement for the varus unstable osteoarthritic ankle. *Tech Foot Ankle Surg.* 2010;9(4):157-164. Copyright 2010 Wolters Kluwer Health/Lippincott Williams & Wilkins.

sal or medial cuneiform if subtalar motion is present.²³ Corrective subtalar or talonavicular arthrodesis is recommended in cases of rigid forefoot-induced pes planovalgus deformity with no subtalar motion. Surgeons need to use an algorithmic and methodical approach to correct varus or valgus deformity during TAA with a variety of different surgical techniques. Failure to recognize and correct an abnormal foot position or ligament laxity often leads to poor short-term clinical and radiographic results.

5 Postoperative Rehabilitation

In general, a return to light recreational activities and nonimpact athletics has been reported after TAA,⁴⁸ but high-impact activities, particularly in younger patients, are discouraged because of concerns over implant wear. Recent gait analysis results demonstrated that, compared with patients with ankle arthrodesis, patients with TAA have higher walking velocities because of increases in stride length and cadence as well as more normalized vertical ground reaction force curves.⁴⁹ However, ankle ROM has been found to variably improve (by 1°-10°) over preoperative motion in different TAA series.^{8,10,13,43} In a review of 119 TAAs using 3 different implant designs, Ajis and colleagues⁵⁰ found no significant increase in total ankle ROM from before TAA to 1 year after. Mean dorsi-

flexion improved significantly, by 5.5°, at 6 weeks after surgery, and plantarflexion improved by 2.9°, but there were no notable improvements in ROM after 6 months. It is important to recognize that preoperative factors (eg, age, activity level, body habitus, disease type, deformity) can all significantly influence postoperative ROM. In addition, intraoperative component placement, joint-line restoration, and ligament balancing can affect ROM along with postoperative factors, including pain control, physical therapy,⁵⁰ and development of heterotopic ossification.⁵¹

Response to physical therapy can vary widely, but providing early supervised, focused, hands-on therapy is recommended to maximize functional outcomes in the initial postoperative weeks and months. It is important to have open patient–therapist communication regarding goals for stretching, strengthening, and ROM exercises in the early follow-up period in order to increase motion while minimizing risk of wound breakdown or component subsidence. At least 25° of ankle motion is needed to walk on a flat surface without a limp, and, during the normal gait cycle, the ankle is in dorsiflexion longer compared with plantarflexion.³⁹ Therefore, residual equinus contracture after TAA can lead to difficulty with ambulation and pathology in other body parts, including knee hyperextension and low back pain. Vigilant follow-up is crucial for TAA, as a gradual loss of motion may indicate implant aseptic loosening, gutter impingement, heterotopic ossification, and/or arthrofibrosis requiring surgical intervention.

Wound-healing problems after TAA are common and can significantly impair postoperative mobilization and clinical outcomes. Wound complications can stem from patient factors (eg, diabetes, malnutrition, vasculopathy, immunosuppression) and are often multifactorial in nature. Compared with patients having noninflammatory causes of arthritis, patients with inflammatory arthritis are at up to 14 times higher risk for major wound complications with a standard anterior incision requiring reoperation.⁵² Postoperative swelling can decrease tissue perfusion and microcirculation, causing impaired healing in the foot and ankle. Therefore, close monitoring of incision healing is crucial during scheduled repeat examinations in the early postoperative period. Serial compression dressings with strict elevation and protected weight-bearing for 4 to 6 weeks can be used to decrease pressure over the anterior surgical incision, increase venous and lymphatic return, and reduce surrounding tissue edema.⁵³ This technique can promptly address rebound edema and may help facilitate early motion and limit the amount of postoperative scar-tissue formation after TAA.

Conclusion

Modern TAA can significantly reduce pain, improve function, and enhance quality of life in select patients with end-stage ankle arthritis. Advances in surgical technique, component design, and instrumentation have improved

long-term implant survivorship, clinical outcomes, and functional return to normal activity.

We believe that the 5 points discussed here can help surgeons achieve optimal results with TAA and improve understanding of the major principles surrounding ankle replacement. Because of the lack of long-term randomized controlled trials, there is still considerable debate about TAA indications and the future implications of prosthesis survival and potential revision surgery. The role of TAA in the treatment of ankle arthritis is constantly being explored, expanded, and redefined. Future large-scale trials and registry studies are needed now more than ever to clarify the long-term benefits of TAA compared with arthrodesis and other treatment options.

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This paper will be judged for the Resident Writer's Award.

Commentary

There are considerable differences in the design and implantation technique of the current total ankle implants available in the United States, eg, mobile vs. fixed bearing, intramedullary vs. extramedullary guidance, anterior vs. lateral surgical approach, flat vs. curved bone cuts, natural articular design with minimal bone resection (Zimmer Trabecular Metal Total Ankle; Zimmer, Warsaw, Indiana) vs. larger implant construct with more bone resection (Inbone II; Figure 2). There is no evidence that one implant design is superior, and, as the authors conclude, "Direct comparisons between TAA [total ankle arthroplasty] implant systems are needed to determine what clinical benefits are achieved with each design and what contributes to these differences."

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