Open Ankle Arthrodesis for Deformity Correction

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KEYWORDS

• Ankle arthritis • Ankle arthrodesis • Deformity • Technique

KEY POINTS

- Open ankle arthrodesis is a reliable way to correct deformity and achieve ankle arthrodesis
- Careful clinical and radiographic evaluation needs to be performed, keeping in mind the entire lower extremity above and below the ankle.
- Multiple approaches and fixation options are available to the surgeon, with the deformity often helping to determine which technique should be used.
- Both coronal and sagittal plane deformities are common in ankle arthritis, and achieving excellent deformity correction is paramount in achieving a plantigrade foot and successful outcome.

INTRODUCTION

Open ankle arthrodesis (OAA) is traditionally considered the most reliable way to correct deformity in ankle arthritis. This technique allows for better visualization, joint preparation access, and corrective osteotomies than other arthrodesis techniques. Open arthrodesis can be accomplished through anterior, posterior, or transfibular approaches depending on the deformity.[1–6] Other arthrodesis techniques such as arthroscopic or mini-open can be challenging to correct deformity.[7–9] Recent advancements and increased experience with total ankle replacement (TAR) implants have led some to challenge that TAR is now the gold standard for ankle arthritis even with significant deformity.[10–13] Although TAR has consistently been used with increasing frequency in the treatment of ankle arthritis over the past 15 to 20 years, OAA is still more commonly used to correct deformity and address ankle arthritis concurrently.[14–16] Surgeons should strongly consider deformity among other factors when deciding on a surgical plan to treat ankle arthritis.

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CLINICAL EVALUATION/PREOPERATIVE PLANNING

- Physical examination
  - Inspection
    - Every patient should be inspected from the hip to the foot even when the chief complaint is isolated to the ankle. Deformity can occur at multiple different locations, and the clinician might also pick up on other important diagnoses such as peripheral vascular disease or a previous incision or scar which might affect surgical treatment considerations. Foot deformity should be evaluated while standing to assess for cavovarus or planovalgus deformities.
  - Palpation
    - Palpating different anatomic structures of the foot and ankle allows for the confirmation of the etiology of pain. Anterior ankle joint line tenderness helps confirm ankle arthritis, but tenderness in other areas may lead the physician to another diagnosis to consider in surgical planning such as posterior tibial or peroneal tendinitis.
  - Range of motion
    - Restricted range of motion of the ankle should be evaluated, especially when deciding between TAR and OAA. Other joints, especially the subtalar joint, should be evaluated for restricted ROM. Subtalar arthritis might influence the treating physician to consider other surgical options such as TTC or TAR.
  - Sensory
    - Evaluation for neuropathy should be conducted in every patient especially those with diabetes. This includes gross sensation to light touch as well as Semmes-Weinstein monofilament testing. Dense neuropathy might influence the surgeon to consider tibiotalocalcaneal (TTC) fusion as opposed to isolated ankle fusion or TAR.
  - Special examination
    - Silfverskiold
      - Tendoachilles lengthening or gastrocnemius recession may be important adjunct procedures in the setting of Achilles or gastrocnemius contractures to achieve appropriate tibiotalar alignment when performing OAA.
    - Ankle laxity
      - Severe ankle laxity might sway the surgeon to consider fusion over other surgical treatment options due to the additional stability it provides.
- Imaging
  - X-rays
    - Standard weight-bearing radiographs of the ankle are the recommended initial imaging assessment of ankle arthritis. This includes three views—anteroposterior (AP), mortise, and lateral views. Due to the effect of the foot alignment on the ankle and vice versa, it is strongly recommended to include AP and oblique views of the foot as well to evaluate for additional or compensatory deformity.
    - Although it is easy to be distracted by the ankle and/or foot deformity, if there is any question about another area contributing to the deformity then long leg alignment radiographs should be used. Significant deformity through the hip or knee warrants consideration of referral to an adult reconstruction colleague for correction. Many surgeons prefer to correct the deformity proximally first before correction distally. Deformity through the tibia may warrant an extraarticular osteotomy concurrently or in lieu of correction through the ankle.

- The Saltzman view, a weight-bearing hindfoot alignment view, can be useful in assessing hindfoot deformity and aid in surgical planning for the consideration of calcaneal osteotomy or subtalar fusion.[17]
- Computed tomography (CT) is an important tool in assessing deformity as well as the extent of arthritic changes. CT gives a more accurate depiction of cyst formation, sclerosis, and subchondral collapse. Weight-bearing CT provides even more information regarding dynamic deformity and can help with surgical planning, but is not as accessible as standard CT.

- Evaluation of the deformity
  - Combination of physical examination, standard foot, and ankle radiographs, long length alignment films, as well as advanced imaging should be used to evaluate deformity.
  - Varus deformity
    - Varus ankle arthritis is the most common coronal plane deformity in ankle arthritis. Isolated wear of the medial tibial plafond occurs in the setting of posttraumatic arthritis, cavovarus foot deformity, peroneal tendon tear, or ankle instability/laxity. Evaluation of the knee coronal plane alignment for deformity is important to evaluate on physical examination as well as plain radiographs. Varus ankle arthritis can develop with ipsilateral valgus knee or tibia deformity due to compensatory hindfoot/ankle alignment.[18] (**Fig. 1** A,B)
  - Valgus deformity
    - Valgus ankle arthritis is the least common coronal plane deformity. Isolated wear of the lateral plafond can occur from posttraumatic arthritis, flatfoot deformity, or an incompetent deltoid ligament. Converse to varus ankle arthritis, compensatory valgus ankle/hindfoot alignment can develop with ipsilateral varus knee deformity (**Fig. 2** A,B).

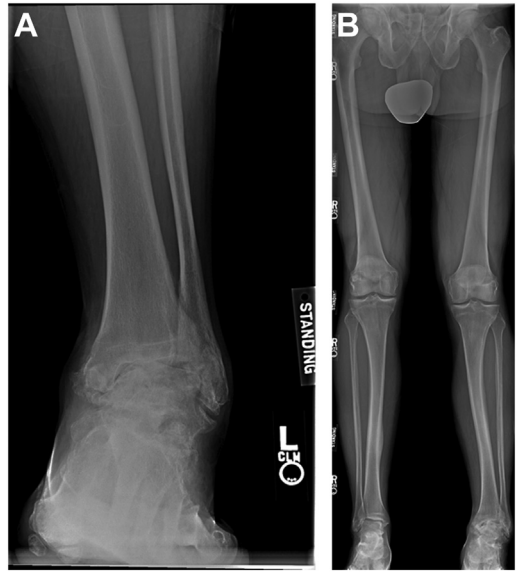

Fig. 1. (*A*) Varus ankle arthritis seen on anteroposterior (AP) ankle radiograph, with proximal deformity as potential cause seen on long-leg alignment views (*B*).

- Extraarticular deformity
  - Extraarticular deformity such as tibia vara/valgum would be picked up on standing clinical examination or long leg alignment films.
- Concomitant foot deformity
  - Evaluation of the foot deformity and its effect on the ankle cannot but understated. A standing physical examination is used to assess hindfoot valgus or varus as well as pes cavus or planus. The foot deformity can also be thoroughly assessed on weight-bearing AP and lateral foot radiographs with talar head uncoverage, talo-first metatarsal angle, and talar declination among many other parameters.

TREATMENT OPTIONS/CONSIDERATIONS

Once the decision to proceed with OAA has been made, there are several aspects of the procedure that need to be considered and carefully planned. Often the deformity will help to dictate the specific techniques that will be used. Other considerations include any prior surgery, hardware that may have to be removed, and associated skin or soft tissue concerns such as scars or flaps.

APPROACHES

- Anterior approach:
  - The anterior approach has become a workhorse approach for ankle arthritis with the increased popularity of anterior plating for ankle arthrodesis and total ankle arthroplasty. Many deformities can be addressed and corrected through a standard anterior approach between the tibialis anterior (TA) tendon and extensor hallucis longus (EHL) tendon. This approach also allows for debridement of both the medial and lateral gutter which can be important to achieve intraarticular reduction in coronal plane deformity. In addition, the fibula is easily preserved with this approach to ensure future revision options.

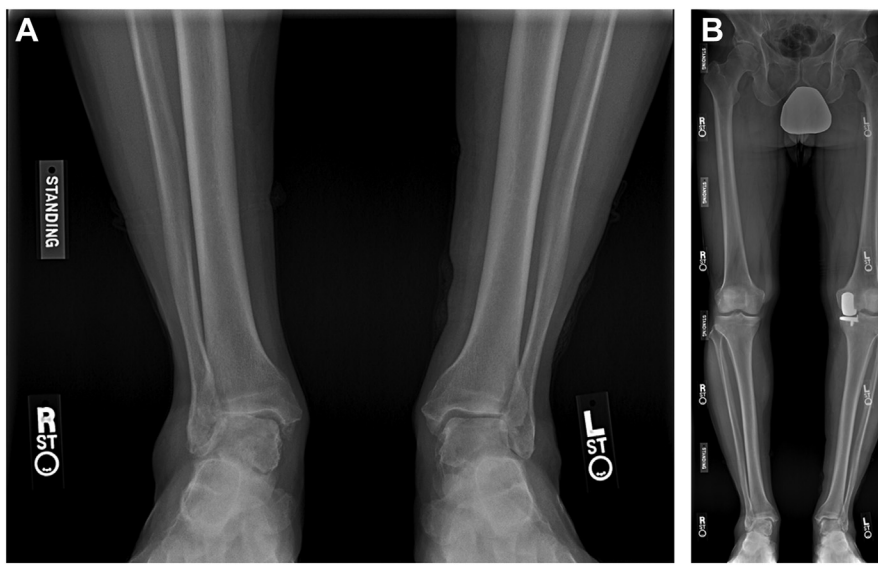

Fig. 2. (*A*) Valgus ankle arthritis seen on anteroposterior (AP) ankle radiograph, with varus knee deformity as potential cause seen on long-leg alignment views (*B*).

- Lateral approach
  - The lateral approach to the ankle offers an extensile approach with excellent access to the tibiotalar joint, as well as distal access to the subtalar joint when indicated. A fibular osteotomy is typically performed to gain access, though access can be achieved with anterior soft tissue release and posterior retraction of the fibula. Resecting the medial 1/3rd of the fibula after osteotomy, and then using the fibula as a lateral strut incorporated into the fusion can be a helpful technique. Alternatively, the fibula can be resected and used as bone graft, though this is typically only done if TTC arthrodesis is performed and conversion to total ankle arthroplasty in the future is unlikely. A separate medial incision is typically required to access the medial gutter for complete joint preparation.
- Posterior Achilles-splitting approach
  - Though less commonly needed, a posterior Achilles-splitting approach is a useful technique in particular with anterior skin or soft tissue defects that prevent other approaches. A direct posterior incision is used, followed by splitting the Achilles tendon in the coronal plane with long flaps. Access to both the tibiotalar joint and subtalar joint is achieved (Fig. 3).

FIXATION STRATEGIES/GRAFTING

As with many aspects of orthopedic surgery, which implants are chosen is secondary to good, sound surgical technique. This includes obtaining deformity correction before implantation and excellent joint preparation before fixation. Once this is achieved, then decisions on fixation strategies can be made.

Fig. 3. Posterior approach to the ankle using a coronal split technique through the Achilles tendon.

- Screws only
  - Screw fixation alone for ankle fusion has been performed for decades and remains a viable option.[19] Considering the deformity is important when planning screw configuration, such as holding a valgus deformity corrected with a screw along the medial column of the tibiotalar joint. Currently, cannulated partially threaded screws are the most commonly used implant, though this is surgeon dependent. Other considerations include the type of metal (typically stainless steel or titanium), size of the screw, and headed or headless screws.
- Plating
  - Ankle arthrodesis plating techniques have significantly increased in popularity with the advent of ankle arthrodesis specific plating options.[19] Most current systems include anterior, lateral, and some posterior plating options, with anterior plating being the most common. Choosing which plate to use is typically dictated by the specific deformity or the preferred approach, with soft tissue considerations included in this decision-making process. Most systems have options for tibiotalar arthrodesis alone versus TTC arthrodesis. While plating can achieve a stable construct, creating excellent compression across the tibiotalar joint is paramount for a good result. Most surgeons will use lag screw fixation in addition to plating either through the plate itself, or outside of the plate, to create compression (**Figs. 4** A,B). Many systems also have the option to create compression through the plate with screws placed in a compression slot.

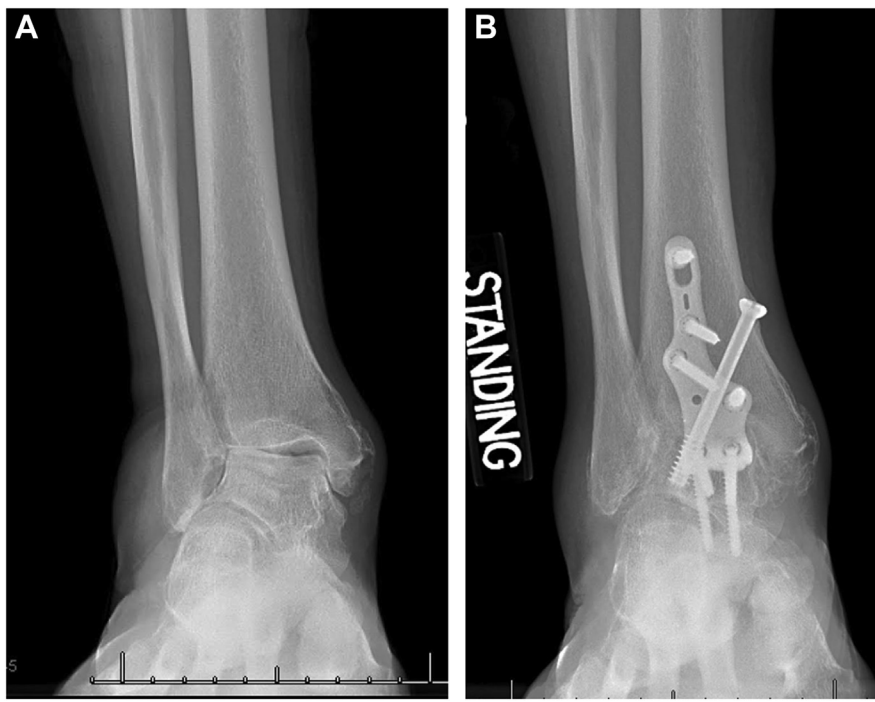

Fig. 4. (*A*) Valgus ankle arthritis treated with (*B*) anterior plate and lag screw placed medially to achieve compression and help hold the talus in a corrected position.

- Intramedullary nail
  - Some deformities or clinical conditions warrant TTC arthrodesis as opposed to isolated tibiotalar arthrodesis. In these situations, using a retrograde intramedullary nail can be an excellent option. The load sharing quality of a retrograde intramedullary nail can provide good biomechanical stability, as long as the surgeon feels sacrificing the subtalar joint is indicated or necessary Joint Preservation Surgery for Varus and Posterior Ankle Arthritis associated with Flatfoot Deformity.
- Thin-wire external fixation
  - Using a thin-wire external fixator is indicated in the setting of chronic infection, for revision when multiple other internal fixation techniques have been used, or potentially for deformity correction at the same time as ankle arthrodesis (**Fig. 5**).[20]
- Grafting options
  - To achieve solid arthrodesis, most surgeons include bone graft into the fusion construct. Options for bone graft include autograft, allograft, or a combination of both. The most common autograft options are cancellous bone taken from the calcaneus, proximal tibia, or the iliac crest. Over the past several years, a plethora of bone graft substitutes have been developed by industry and a full analysis of these options is beyond the scope of this review. When the deformity

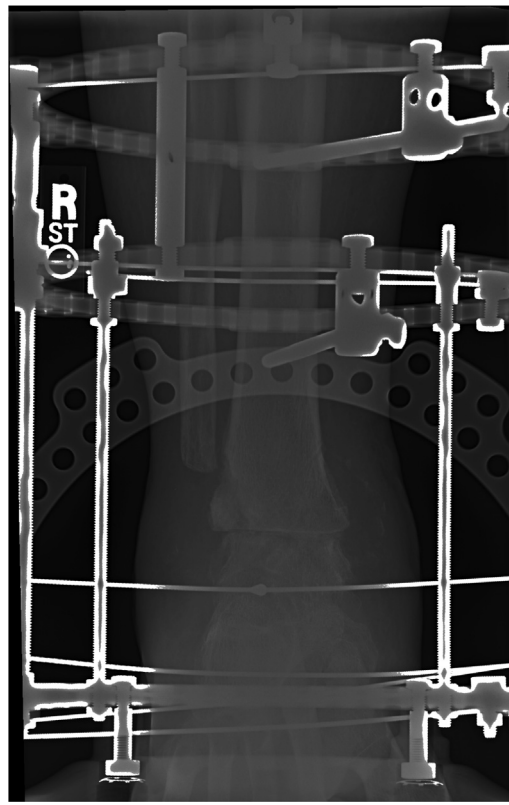

Fig. 5. AP ankle radiograph 3 weeks after thin-wire external fixator placement used for revision ankle arthrodesis.

results in bone loss, the structural bone graft may be required to help with deformity correction and stability of the construct (see Specific Techniques section).

DEFORMITY CORRECTION

Regardless of the approach or fixation options used, achieving deformity correction is paramount to achieving a good result. Ideal hindfoot position after ankle fusion is neutral in the sagittal plane, 0 to 5° of hindfoot valgus, and 0 to 5° of external rotation.[21] Intraarticular deformity is most common, though evaluating for tibia deformity proximally should also be done. Similarly, there is often compensatory foot deformity that occurs after longstanding ankle or tibia deformity. After the proximal deformity is corrected, the surgeon must be ready to correct any foot deformity or instability present to achieve a plantigrade foot underneath the ankle arthrodesis.

- Intraarticular deformity
  - Coronal plane deformity
    - Intraarticular varus and valgus deformity are the most common ankle deformity seen in ankle DJD. Most of the time this deformity can easily be corrected through the joint with good reduction and stable fixation constructs.
    - Varus deformity is very common. Once the deformity is reduced and the tibiotalar joint is in a neutral position, a lag screw can be placed along the lateral column of the joint to hold it in position as part of the construct. Alternatively, if anterior plating is being utilized the plate itself can hold the joint reduced (**Figs. 6** A–D). If a lateral approach is preferred, the fibula can be used as a strut or a lateral plate can be used similar to tension side fixation in fracture management.
    - Valgus deformity is also seen with some regularity, often secondary to deltoid ligament insufficiency from prior injury or longstanding flatfoot deformity. Similar to varus, a medial column-based tibiotalar lag screw can hold the valgus deformity reduced as part of the fixation construct (see **Fig. 4** A,B).
    - Technique tips:
      - Plafond defects: In longstanding deformity, the tibial plafond can erode asymmetrically. To achieve good deformity correction, this defect needs to be addressed. Options include removing bone from the opposite side to even out the plafond to achieve the neutral position, or placing the structural graft in the defect to accommodate for the deformity and hold the talus in neutral (**Fig. 7 A-**G). The authors' preference is to use a prefabricated Evans or Cotton allograft soaked in bone marrow aspirate concentrate as a wedge graft on the side of the defect (**Fig. 8**A,B)
      - Gutter spurs: Evaluating the CT scan closely for medial or lateral gutter osteophytes is important to achieve good deformity correction (**Fig. 9**). Aggressive gutter debridement may be required to allow the talus to correct into a neutral position.
  - Sagittal plane deformity
    - Careful evaluation of the talus position in the sagittal plane is very important and can be difficult intraoperatively due to the motion at the talonavicular joint. Large anterior osteophytes can prevent dorsiflexion and cause a subsequent equinus contracture of the ankle. If the neutral ankle position cannot be achieved after anterior debridement, a tendo-Achilles lengthening with or without a posterior capsular release may need to be performed.

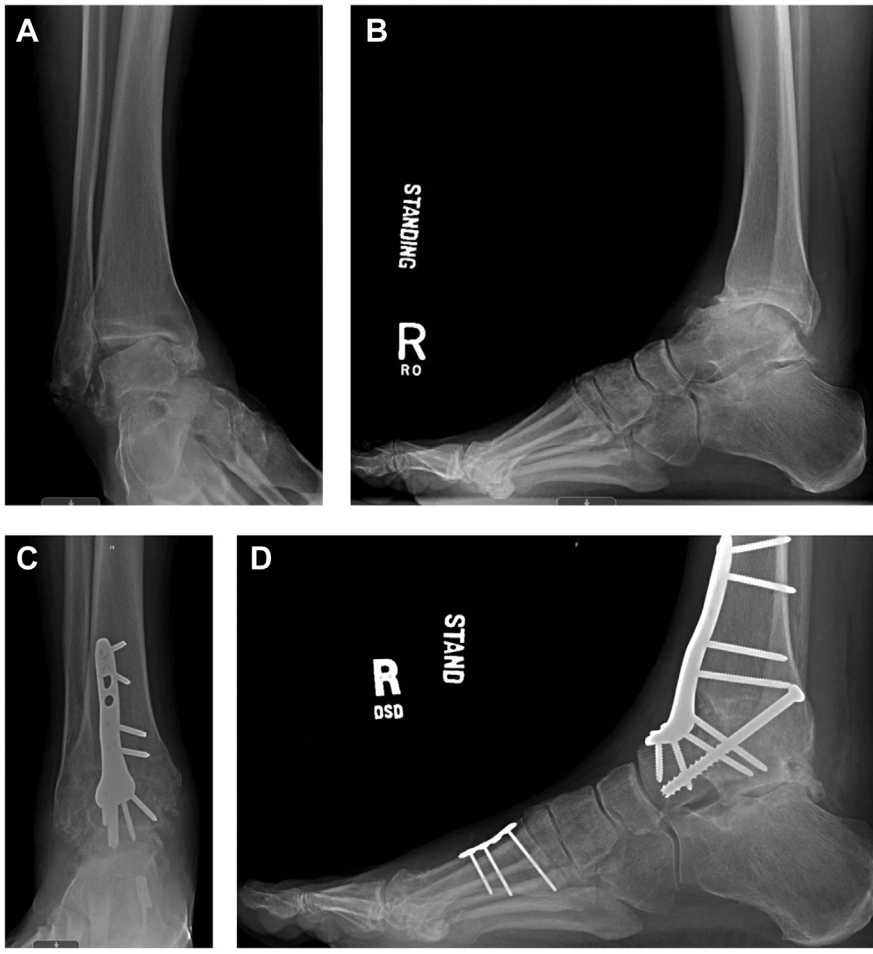

Fig. 6. (*A*, *B*) Preoperative radiographs showing varus ankle arthritis with associated anterior translation of the talus. (*C*, *D*) 6-months postoperative radiographs showing anterior plate and lag screw construct correcting both deformities.

Fusing the tibiotalar joint in equinus can result in a poor long-term outcome due to adjacent joint stress and hyperextension at the knee.

- Translation of the talus in the sagittal plane is common. Anterior translation is more common than posterior translation, likely secondary to longstanding ankle instability as the cause of arthritis (see **Figs. 6B and 7**B). However, posterior translation may be seen in posttraumatic settings secondary to posterior malleolus fracture displacement (**Fig. 10** A,B). Recognizing this translation and correcting it before fixation is important to achieve a functional position of the fusion.

- Extraarticular deformity
  - Tibia deformity
    - Deformities in the tibia can be present along the entire length of the tibia. As noted in the Evaluation section, the lower extremities should be inspected from above the knee, and long leg alignment films should be used if there

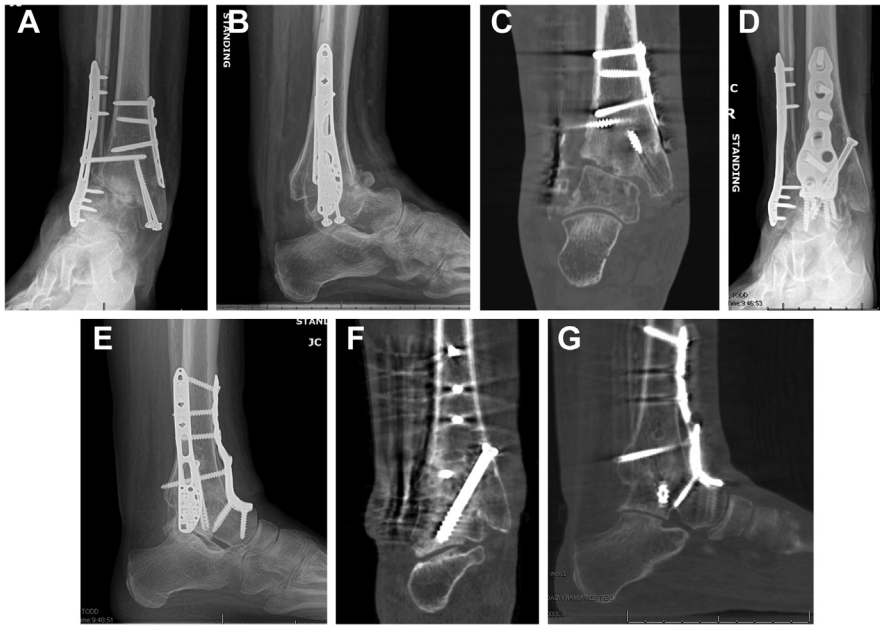

Fig. 7. (*A*, *B*) Preoperative radiographs demonstrating valgus posttraumatic ankle arthritis with anterior translation of the talus. (*C*) Coronal CT scan showing a collapse of the lateral tibial plafond. (*D*, *E*) 6-months postoperative radiographs demonstrating deformity correction in both planes with the use of a plate and screw construct. Structural allograft was used in the lateral tibiotalar joint to help correct the deformity. (*F*, *G*) Coronal and sagittal CT scans showing incorporation of the graft and solid arthrodesis.

is suspicion of tibial deformity or to evaluate the overall mechanical axis from hip to ankle.

- Tibial shaft deformities can be present in any plane and may be multiplanar (Fig. 11 A, B). If the shaft deformity will ultimately affect the foot position after ankle arthrodesis, a concomitant tibial osteotomy may be required.
- Tibial plafond and supramalleolar deformities may be seen after severe distal tibia and pilon fractures. Careful preoperative evaluation needs to

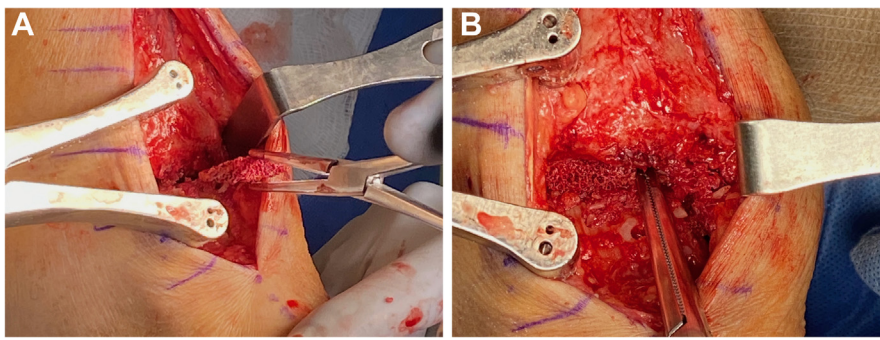

Fig. 8. (*A*, *B*) Clinical photograph depicting the wedge allograft soaked in bone marrow aspirate concentrate placed in the lateral side of the joint to hold the tibiotalar joint in the neutral position.

Fig. 9. Coronal CT scan showing both lateral and medial gutter osteophytes on the talus that will need to be removed to achieve the neutral position of the talus within the ankle mortise.

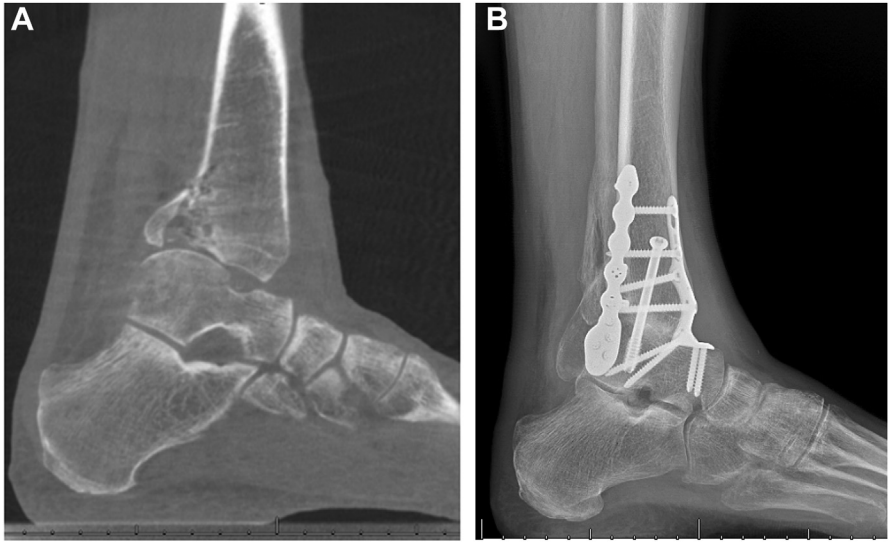

Fig. 10. (*A*) Lateral ankle radiograph showing posttraumatic ankle arthritis and significant posterior translation of the talus secondary to untreated posterior malleolus fracture (*B*).

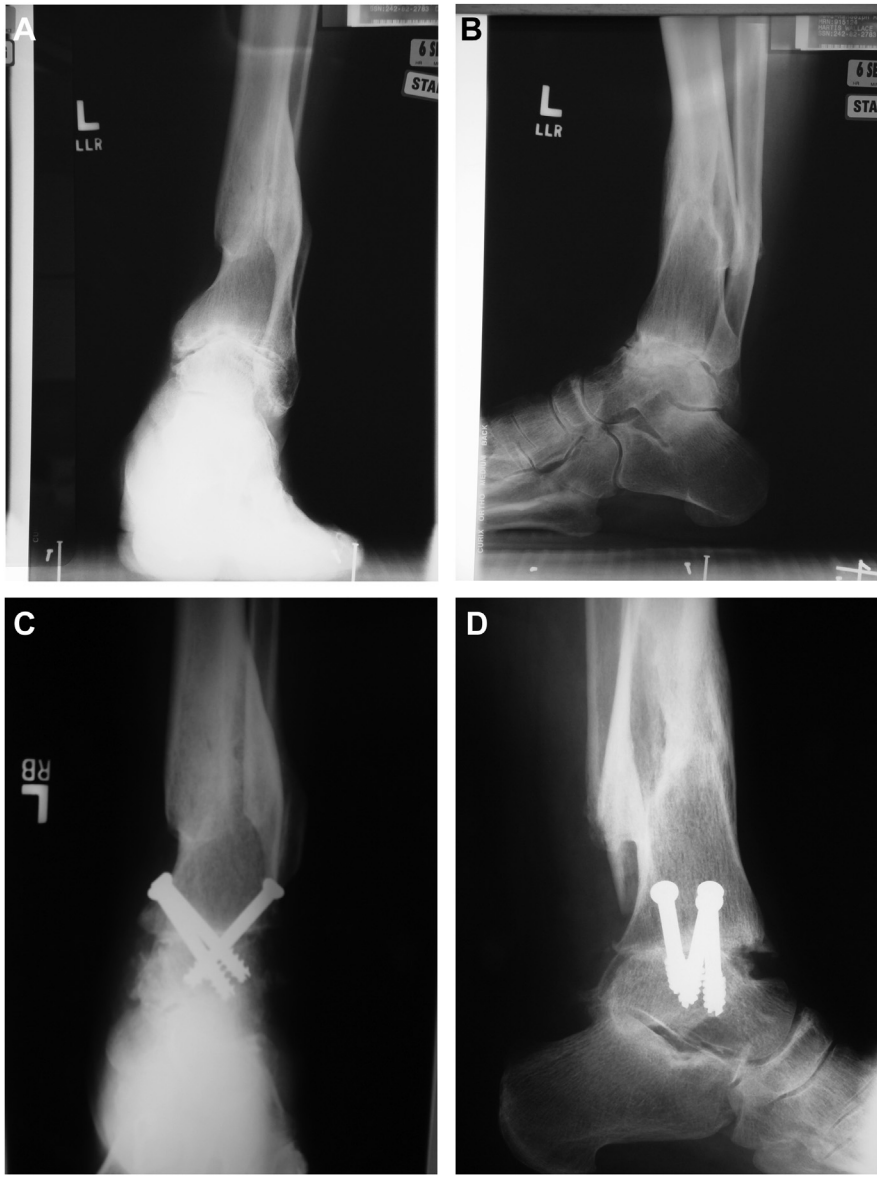

Fig. 11. (*A*, *B*) Severe ankle arthritis secondary to distal tibia and fibula fracture malunion. (*C*, *D*) Deformity correction and ankle arthrodesis achieved through flat cuts in the tibia and talus with screw fixation.

be performed before arthrodesis to understand the deformity and plan for its correction.

- Technique tip:
  - In the setting of severe plafond or supramalleolar deformity, performing flat cuts through the tibia and/or talus can be an effective technique to correct the deformity and remove unhealthy or nonviable bone (see Fig. 11 C,D).

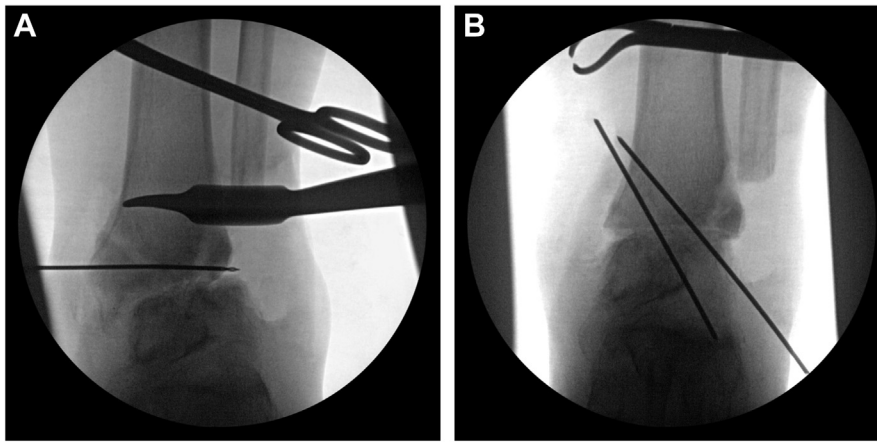

Fig. 12. (*A*, *B*) Intraoperative radiographs depicting the use of a kirschner wire to determine the appropriate orientation of the flat cut orthogonal to the longitudinal axis of the tibia.

- This technique will inevitably shorten the limb so care must be taken to minimize how much shortening is performed.
- Using a k-wire as a guide, and confirming in both the A-P and lateral fluoroscopic views before bone resection is a helpful technique to avoid pitfalls (**Fig. 12** A,B).

◦ Foot deformity
- Compensatory foot deformity is common after longstanding ankle deformity. Anticipating the foot position after ankle joint correction is important for preoperative planning.
- Varus ankle deformity may result in or exacerbate a cavus or cavovarus foot position. In most cases, the hindfoot will be corrected through the ankle joint fusion once that deformity is addressed. After the ankle joint is corrected, it is important to evaluate the position and flexibility of the first ray in relation to the other metatarsal heads. When the first metatarsal is plantarflexed, a dorsiflexion first metatarsal osteotomy should be performed (see **Fig. 6**D).
- Valgus ankle deformity can result in similar foot deformities seen in a progressive collapsing foot deformity, or adult-acquired flatfoot. The subtalar joint needs to be closely evaluated in this situation. If there is concomitant subtalar instability or DJD seen radiographically, then converting to a TTC arthrodesis may be required. Sometimes performing the ankle arthrodesis alone will be enough to correct the flatfoot deformity, assuming good deformity correction is achieved. If there is residual forefoot supination or first ray instability, then performing medial column stabilization may be required to achieve a plantigrade foot. The most common procedures performed in this setting are a Cotton opening wedge osteotomy through the medial cuneiform or a 1st tarsometatarsal joint arthrodesis.

RECOVERY – POSTOPERATIVE PROTOCOL

Patients are placed into a short-leg well-padded splint at neutral for the first 2 weeks postoperatively and kept non–weight-bearing. The authors prefer transitioning to a short-leg cast at the first postoperative visit, though some surgeons prefer a prefabricated tall boot at this stage. Patients are kept non–weight-bearing or toe-touch

weight-bearing only for the first 6 weeks postoperatively. At 6 weeks, patients are placed into a prefabricated tall boot and allowed to transition to full weight-bearing as tolerated. Wean out of boot into regular shoewear after 12 weeks. Ankle radiographs are typically checked at 2 weeks, 6 weeks, 12 weeks, and 6 months postoperatively. Standing CT scan is ordered between 4 and 6 months postoperatively if there is a concern for delayed or nonunion clinically. Formal physical therapy is not typically required. Rocker bottom shoewear is recommended to accommodate for the loss of tibiotalar motion.

OUTCOMES

- Fusion rates
  - Ankle arthrodesis is such a successful, reliable surgery in large part due to its high union rates, ranging from 91% to 100% in many studies.[2,3,5,6,19,22,23] Similar union rates have been reported specifically in OAA, although many studies have reported higher union rates in AAA when directly compared with OAA.[9,23–28] Fixation method has not been shown to change union rates in OAA.[19] A systematic review of ankle fusion for failed TAR by Gross and colleagues demonstrated the ankle fusion rate after failed TAR was 89.4% in 193 patients overall, with the most common failure due to rheumatoid arthritis.[29–31]
- Patient-reported outcomes
  - Significant pain improvement and functional outcomes have been consistently shown after OAA, especially in patients who achieve successful bony union.[2,3,5,6,28,32–35]
- Complications
  - Overall revision rates in the literature range from 7% to 20%.[3,5,22,34,36–38] Soohoo and colleagues reported a major revision surgery rate in OAA of 5% at 1 year and 11% at 5 years, including a subtalar fusion rate of 2.8% at 5 years. Patients undergoing OAA had a higher nonunion rate with previous subtalar fusion or preoperative varus deformity.[22] The rate of subtalar arthrosis significantly progresses after ankle arthrodesis, ranging from 32.5% of patients 7 years after OAA and 91% 22 years after OAA.[32,39] Even addressing subsequent subtalar arthritis after ankle arthrodesis has increased complications. Zanolli and colleagues showed a significantly decreased subtalar fusion rate after ipsilateral ankle fusion than a native ankle, and Gross and colleagues showed a significantly decreased subtalar fusion rate after ankle arthrodesis than after TAR.[40,41]
- TAR versus fusion
  - The debate continues on which treatment is superior for end-stage ankle arthritis. More recent studies have shown improved clinical outcomes with TAR than fusion even in large deformities, but other studies have shown no difference between the 2 treatment options. In reality, patient selection is crucial for both methods. Ankle arthrodesis has a significantly higher progression to subtalar fusion and subsequent subtalar fusion nonunion rate as noted above.
  - Studies comparing OAA to TAR with intermediate and long-term results collectively have failed to show a significant difference between the 2 regarding complication rate and patient-reported outcomes; however, many report a higher reoperation rate but higher satisfaction rate with TAR.[34,37,38,42–47] Schuh and colleagues report no difference in activity level with sports or recreational activity between the 2 groups.[48] Gait in OAA with significant preoperatively deformity was similar to that in TAR without preoperative deformity but

neither were as good as controls.[49] Piriou and colleagues showed a reduction in limp but slower gait with TAR versus ankle fusion.[50] Patients with TAR preserve more anatomic and overall sagittal ROM than ankle arthrodesis. Some sagittal ROM of the foot is maintained although limited after OAA through the talonavicular joint. This supports the theory of increased stress and thus progression of arthritis of adjacent joints after fusion.[51,52]

- Open versus arthroscopic
  - Although many studies report shorter tourniquet time, less estimated blood loss, shorter hospital length of stay, increased fusion rates, and decreased time to fusion with AAA when compared with OAA, most do not compare preoperative deformity.[8,9,23–28,33,35,53,54] However, other studies are inconclusive on treatment superiority and note that OAA is much more likely to be performed in the setting of deformity than AAA.[9,35]
- Gait
  - Ankle fusion improves parameters in gait including temporal-spatial, kinematic, and kinetic measures.[55] As mentioned above, gait function was similar in patients treated with arthrodesis for deformity when compared with arthroplasty in nondeformed ankles, but neither returned to normal compared with unaffected ankles[49]

SUMMARY

OAA remains a very reliable solution for ankle arthritis, in particular in the setting of deformity. Careful preoperative evaluation needs to be performed, both clinically and radiographically. The specific deformity present helps determine the approach used as well as the fixation choices. Deformity is most commonly seen intraarticularly, though deformity can also be present anywhere along the lower extremity, including compensatory deformity in the foot. Multiple different techniques can be used to address both the deformity and achieve a successful ankle arthrodesis. Patient outcomes reported in the literature are generally good, with high union rates and improved functional outcomes, though subtalar arthritis is a common long-term complication.

CLINICS CARE POINTS

- Evaluate all aspects of the extremity for deformity including the tibia, supramalleolar, ankle joint, and any concomitant foot deformity.
- Use lag screw fixation across the medial or lateral column of the ankle joint to correct valgus or varus intraarticular deformity, respectively.
- Structural graft can be used to fill in intraarticular defects prior to definitive fixation.
- Remove medial and lateral gutter osteophytes to allow the talus to achieve neutral fixation prior to fixation.
- Avoid equinus positioning of the tibiotalar joint at the time of fixation.
- Address any compensatory foot deformity after the ankle joint fixation is performed in order to ensure a plantigrade foot.

DISCLOSURE

T.A. Irwin: Paragon 28, Consultant/Royalties; Medline, Consultant/Royalties; GLW, Consultant, AOFAS committee chair. D. Vier: Nothing to disclose.

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