Ankle distraction arthroplasty (ADA): A brief review and technical pearls

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Ankle Distraction Arthroplasty (ADA): A brief review and technical pearls.

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Abstract
Ankle distraction arthroplasty (ADA) is a procedure based on the concept that mechanical unloading of an arthritic joint will initiate a healing response in the subchondral bone and articular cartilage. ADA utilizes the patient’s own healing response, preserves joint motion, and is a great option for patients with osteoarthritis who are not ready for prosthetic arthroplasty or fusion. The procedure is well described and technically simple and adjunctive biologic therapies are exciting for joint regeneration. Complications are minor, and more serious adverse events are avoidable. Supramalleolar osteotomy pairs well with ankle distraction but requires some analysis and planning.

Keywords
Ankle arthritis, Ankle distraction, supramalleolar osteotomy, arthroplasty, deformity

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Ankle distraction arthroplasty (ADA): A brief review and technical pearls

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Background
Ankle distraction arthroplasty (ADA) is a procedure that was introduced in an effort to salvage arthritic joints in the lower extremity. This biomechanical treatment modality is based on the concept that mechanical unloading of an arthritic joint will initiate a healing response in the subchondral bone and articular cartilage. Joint distraction was initially trialed in the hip [1] and was later expanded to foot and ankle articulations [2,3]. Ankle distraction arthroplasty was introduced in 1995 by van Valburg and van Roermund in an effort to reverse some of the clinical and radiographic findings commonly seen in post traumatic ankle arthritis [4]. The surgical procedure required application of a circular external fixator across the ankle joint followed by gradual traction across the joint to achieve a gap of 5mm on radiographs. (Figure 0) The external fixator was worn for three (or more) months to achieve the desired results. This group of clinical scientists went on to popularize the technique and publish numerous reports on the benefits of joint distraction including radiographic improvement, a reduction in subchondral bone sclerosis, and an increase in joint space [5]. Further research found positive changes in proteoglycan metabolism and a decrease in joint inflammation as a result of arthrodiastasis [6]. A randomized trial found that joint debridement combined with distraction produced superior results when compared with debridement alone [7]. Further study of this patient population yielded consistent results with success in the 70% range [8,9]. Ankle distraction arthroplasty continues to be utilized to improve pain and function in patients with post traumatic ankle arthritis as an alternative to prosthetic arthroplasty or fusion.

The mechanism of action for joint distraction has been studied clinically and in animal research. The procedure has been observed to reduce the density of the sclerotic subchondral bone as seen on radiographs [5] and CT scan [10]. The radiographic joint space has been noted to increase even years after completion of the procedure. [5, 11] Subchondral cysts have been seen to fill-in on pre and post procedure CT scans which correlates with clinical improvement. [10] MR changes have been studied with findings of mildly increased joint space [11, 12]. The distraction force across the joint seems to unlock the arthritic ankle’s natural ability to regenerate. This may be due to a combination of the absence of mechanical stress with intermittent fluid pressure created within the joint. A change in the cartilage proteoglycan metabolism was seen including an increase in proteoglycan synthetic activity [13, 14]. How much distraction to apply was studied in a cadaver model, and 5.8mm of distraction gap as seen on weight bearing radiographs would ensure no articular contact with weight bearing in an average weight person [15]. It is not known if having absolutely no joint contact is necessary to obtain good results as most studies site that 5mm of joint space is adequate to achieve lasting pain relief.

Demographics & Indications
Post traumatic osteoarthritis is the best indication for ADA. Hemophilic arthritis has been reported to respond well to joint distraction broadening indications [16]. Various risk factors for success and failure have been looked at in an attempt to predict who is the best candidate for this procedure. Female sex has been found to reduce success slightly [17, 18]. Osteonecrosis of the talus was associated with poorer outcome [17]. Ankle joint deformity greater than 5 degrees and
obesity were seen to negatively affect outcome [19] but when the deformity was corrected with supramalleolar osteotomy the results improved dramatically [20]. Increasing age has not been seen to correlate with failure. [9, 21]. Ankle distraction is too new to have contraindications. I do not recommend this treatment in inflammatory arthritis unless the ankle has clear signs of an osteoarthritic component. ADA surgery is unlikely to work in an actively infected joint.

Osteonecrosis of the talus or tibial plafond can present challenges for distraction surgery. In situations where the bone is collapsed, grossly misshapen, and ankle motion is poor, fusion may be a better option. If the shape of the talus and plafond are intact then the necrotic areas may be amenable to autografting or even local vascularized pedicle grafting to re-perfuse the damaged bone. In arthritic joints that are very stiff, fusion may be the best course of action.

Technical considerations
ADA requires some technical considerations in order to ensure safety and maintain diastasis throughout the post op period. The size of the patient and stiffness of the ankle should be considered. These two factors will increase the force needed to be generated by the external fixator to carry out the distraction. It is recommended to use more fixation in larger patients. The external fixator can be fixed or articulated. (Figure 1) Both have achieved similar results, and the findings of two investigations specifically looking at this factor were contradictory [21, 22]. The joint can be minimally debrided [7] or aggressively cleaned out [23] with routine microfracture or subchondral drilling [17]. (Figure 2) A tight gastrosoleus tendon should be lengthened in order to achieve the desired distraction and allow for ankle motion. [17,23,24] This can be done with a percutaneous lengthening of the Achilles or using a gastrosoleus recession. Bone marrow aspirate concentrate has been shown to improve clinical results, and microfracture may negatively impact results [25]. (Figure 3) Recombinant human growth hormone [26], stem cell injection [24], and hyaluronic acid have all been trialed to improve the outcomes of ankle distraction without any direct comparisons. Platelet rich plasma may improve results over distraction alone [27]. The distraction can be placed across the joint acutely or gradually. While it is tempting to simply “crank” the frame out 5-6mm in the operating room, there is no patient feedback to notify the surgeon if the tibial nerve is being over-stretched. A technical tip is to start the distraction on post surgery day one at a rate of 1mm per day. The patient is instructed at the bedside on how to adjust the nuts and can even video this tutorial session for later reference. It will typically require 7 days of distraction to achieve 5mm of joint space on a standing radiograph. The patient will obtain xrays after completing the 7-day distraction course, and further distraction can be applied as needed. Ankle range of motion is typically started the day after surgery by unlocking the hinged external fixator. Weight bearing as tolerated ambulation is started immediately after surgery. Some patients prefer to keep the external frame unlocked during ambulation, and this is allowed. Patients are given a modified post operative shoe to walk with. Alternatively, the frame can be rigged with a walking plate bolted underneath the foot to allow weight bearing without the foot touching the ground or experiencing any load [28]. The talus must be captured with a wire to prevent unwanted subtalar distraction. This is especially important when correcting equinus as well as distracting the ankle joint. This wire is typically inserted transversely through the talar neck. A very powerful option is inserting a talus wire posterior to the fibula and exiting the anteromedial talus. The external fixator is kept on the leg for a total of three months at which point it is removed in the operating room under sedation. (Figure 4)
Results
The results of this procedure have been variable in multiple meta-analyses, but the consensus is that ankle distraction arthroplasty has a role in the treatment of post traumatic ankle arthritis with the understanding that the benefits will wear off over time. [24,29,30] (Table 1).

Table 1 Outcomes of Ankle Distraction Arthroplasty

<table>
<thead>
<tr>
<th>Author</th>
<th>N patients</th>
<th>Findings</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li 2021 [27]</td>
<td>106</td>
<td>98% success PRP &amp; ADA 77% success ADA</td>
<td>none</td>
</tr>
<tr>
<td>Gianakos 2020 [25]</td>
<td>95</td>
<td>Use of MFX with ADA reduced FAOS scores, reduced joint space, reduced motion</td>
<td>34% superficial pin infection</td>
</tr>
<tr>
<td>Greenfield 2019 [17]</td>
<td>144</td>
<td>ADA survival 84% at 5 years 60% at 10 years</td>
<td>Female sex and osteonecrosis had worse prognosis</td>
</tr>
<tr>
<td>Herra-Perez 2018 [31]</td>
<td>50</td>
<td>ADA survival 59% at 5 years Debridement alone survival 34% at 5 years</td>
<td>High rate of revision surgery in debridement alone group</td>
</tr>
<tr>
<td>Zhang 2017 [32]</td>
<td>96</td>
<td>ADA with MFX yielded better results than ADA alone</td>
<td></td>
</tr>
<tr>
<td>Nguyen 2015 [21]</td>
<td>29</td>
<td>ADA survival 55% at 5 years</td>
<td>52% superficial pin infection</td>
</tr>
<tr>
<td>Marijnissen 2014 [18]</td>
<td>111</td>
<td>ADA survival 56% at 12 years</td>
<td>Female 30% failure by 2 years</td>
</tr>
<tr>
<td>Paley 2008 [26]</td>
<td>32</td>
<td>78% success</td>
<td></td>
</tr>
</tbody>
</table>

PRP = platelet rich plasma, ADA= ankle distraction arthroplasty, MFX= microfracture,

Pearls
An open, anterior approach to the ankle joint provides the best exposure for a thorough osteophyte resection and re-shaping of the anterior ankle joint. This also provides excellent access to the subchondral bone for drilling and bone marrow injection, microfracture, and open grafting of large subchondral cysts.
Gradual distraction is less painful for the patient, avoids nerve injury, and empowers the patient to add further distraction at home if needed. This has been very useful in the era of virtual medicine.
Patients that need to stand at work will be well served working no more than 3 days a week throughout the 3 month distraction period. The off days will be best spent with the leg elevated above the heart.
Non steroidal anti inflammatory drugs NSAIDs and acetaminophen have been adequate to provide pain control and help reduce the need for narcotics. It is preferred to have patients stop NSAIDs after one month if possible due to unknown effects on regeneration.
When correcting equinus with the ankle distraction frame be sure to place wires in the midfoot and metatarsals. This will make walking quite uncomfortable and shoe wear difficult. Strong
talar fixation is recommend when correcting significant ankle contractures to prevent damage to the subtalar joint.

Pitfalls
Ankle distraction is a procedure that does not “burn any bridges” as there is no permanent fusion of articular surfaces or resection of the joint. When the benefits of the surgery wear off then the patient is afforded the full array of treatment options available for ankle arthritis ranging from prosthetic replacement to arthrodesis to repeat distraction. Pin infection is quite common after any procedure that requires an external fixator and is easily treated with a short course of oral antibiotics. Prophylactic antibiotics are not recommended [33]. Broken wires and loosening of the half pins can occur but are not common. Broken wires can be managed in the office by reattachment to the ring or removal if not critical. Adding an extra wire at the index surgery will allow for later removal of a broken wire in the case of wire fracture without affecting frame stability. Loose Schantz pins are uncommon during treatment. Loose pins are usually seen at the time of frame removal and are benign. Tibial nerve stretch injury is possible but not well documented in the literature. A numb plantar foot can be treated with immediate reversal of distraction and waiting for return of sensation. If this is not successful, then tarsal tunnel release should be done soon after. Loss of distraction can occur later in treatment which will be recognized by a reduction in joint space on radiographs. The solution is periodic x-ray evaluation and educating the patient in the proper execution of distraction frame adjustments. It is not uncommon to have the patient dial in 1-2 mm of extra distraction at a virtual 8-10 week follow up appointment, for example.

Supramalleolar Osteotomy with Ankle Distraction
Supramalleolar Osteotomy (SMO) is often performed in conjunction with ankle distraction to treat existing periarticular deformity. [17,34] This technique is used to correct varus, valgus, and sagittal plane deformity distal tibia deformity and intra articular deformity with reliable functional improvement. [20,35]. The osteotomy can be performed acutely with a plate and grafting, and the circular fixator applied around the plate avoiding direct contact. Alternatively, the SMO can be performed percutaneously using a fixator-assisted gradual correction technique. The distraction can also be applied gradually in this case. The benefit of an all-external fixator technique is consistent bone healing with little concern for deep infection as there is no competing internal fixation. The downside of the all-external method that the fixator will likely need to be used beyond the prescriptive three months which is discouraging for many people.

How much to correct the alignment must be considered for any SMO. If the deformity is entirely in the distal tibia, then a full correction is correct and will not negatively impact the ankle joint or future procedures. If the deformity is created by joint obliquity yet is being corrected through the tibia, then the SMO will deform the tibia in order to reorient the joint. This osteotomy gets tricky because it requires translation at the tibia osteotomy site and mal-aligns the malleoli both of which will make future total ankle replacement potentially complicated. SMO for intraarticular deformity may burn bridges in the long run. Often ankle deformity will be partially due to distal tibia malalignment and partially due to joint obliquity. SMO can be used to overcorrect the tibia deformity to improve the articular alignment. The surgeon must consider how much overcorrection of the tibia is acceptable to prevent jeopardizing future prosthetic arthroplasty. (Figure 5)
Conclusion
Ankle distraction arthroplasty is a great option for patients with osteoarthritis who are not ready for prosthetic arthroplasty or fusion. Adjunctive biologic therapies are exciting for joint regeneration but lack good data. The procedure is well described and technically simple. Complications are minor, and more serious adverse events are avoidable. Supramalleolar osteotomy pairs well with ankle distraction but requires some analysis and planning. Ankle joint distraction arthroplasty utilizes the patient’s own healing response and preserves joint motion which avoids burning bridges making it a safe option for all ages.


Figure 0
This AP radiograph depicts a 2-ring external fixation construct used for ankle distraction arthroplasty. A gap of 5mm is seen in the ankle joint.

Figure 1
The universal hinges are seen lined up with the natural hinge of the ankle joint on this intra operative fluoroscopic image (a). A typical hinged external fixator is seen (b).

Figure 2
This intra operative image shows drilling of the subchondral bone with a K-wire to stimulate an inflammatory response.

Figure 3
Bone marrow aspirate concentrate harvested from the patient’s iliac crest is being injected into the arthritic ankle joint under fluoroscopic guidance (a). The bone marrow can be injected into the subchondral bone via metaphyseal drill holes (b).

Figure 4
The pre operative AP (a) and Lateral (b) radiographs show an osteoarthritic ankle joint one year following a pilon fracture in a young female adult. The patient underwent ankle distraction arthroplasty surgery and three months of distraction treatment (c). Radiographs taken one year later (d,e) show improved joint space which was accompanied by a dramatic reduction in pain with improvement in function. A one year post surgery MRI (f) shows fill of the tibiotalar space with reparative cartilage.

Figure 5
The pre operative AP (a), Mortise (b) and Lateral (c) radiographs show an osteoarthritic ankle joint in a middled aged male with valgus deformity stemming from both the joint and the distal tibia. An external fixator with automatic struts was used to correct the deformity gradually through an SMO while also applying gradual joint distraction (d). The post correction images show a well aligned osteotomy and 6mm of joint space (e,f). Final weight bearing images taken nine months post surgery show maintenance of the alignment correction and increased joint space (g,h,i). Clinically the patient is reaching high levels of activity including plyometrics without pain.
Conflicts

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