Post-Traumatic Ankle Arthritis

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Abstract
Post-traumatic ankle arthritis can be a very disabling condition especially in young patients. Localization of the pain is important to allow appropriate treatment. Non-surgical treatment options include anti-inflammatory medications and use of bracing. Multiple surgical options range from joint sparing procedures for the younger patient to total ankle replacement for the older, less active patient. Arthrodesis remains the gold standard and is the procedure of choice for younger patients who are heavy laborers and in patients with severe arthritis who are not candidates for a total ankle replacement. Joint sparing operations include allograft resurfacing, arthroscopic debridement and osteophyte resection, joint distraction arthroplasty, and supramalleolar osteotomy. In older low demand patients, the surgeon may consider a total ankle arthroplasty as an alternative to arthrodesis.

Ankle arthritis is a very common problem, and treatment decisions can be a challenge in young patients. Fifty-percent of elderly patients have some form of arthrosis involving the foot or ankle. Post-traumatic arthritis is the most common cause,\(^1\) representing 70% of cases among patients who present with osteoarthritis.\(^2\) The three most common causes of post-traumatic arthritis are rotational ankle fractures (37%), recurrent ankle instability (14.6%), and history of a single sprain with continued pain (13.7%).\(^2\)

Osteoarthritis in the knee is 8 to 10 times more common than osteoarthritis in the ankle.\(^3\)\(^,\)\(^4\) A cadaver study examined the prevalence of knee and ankle arthritis with an average age of 76, and the investigators found the prevalence of grade 3 and 4 degenerative changes in the knee was 66% compared to 18% in the ankle.\(^5\) Nonetheless, a substantial number of patients require treatment for debilitating ankle arthritis. According to industry experts, approximately 4,400 total ankle replacements and approximately 25,000 ankle fusions were performed in the United States in 2010.\(^6\) Thus, this condition has come to have significant orthopaedic relevance.

Anatomy
The bony anatomy of the ankle confers a high degree of stability and congruence when the joint is loaded. The ankle has firm anterior and posterior ligaments that bind the distal tibia and fibula together. Stability of the tibiotalar joint is provided by the joint capsule, the medial deltoid ligament, and the three lateral ligaments: the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL). The dome of the talus is wider anteriorly, which allows some rotatory movement in the ankle joint when the foot is plantarflexed. Conversely, only minimal tibiotalar rotation can occur when the foot is in maximal dorsiflexion.

The ankle has a smaller area of contact compared to the knee and the hip (350 mm\(^2\) compared to 1,120 mm\(^2\) and 1,100 mm\(^2\) in the knee and hip, respectively).\(^7\)\(^,\)\(^8\) This results in higher forces per area when the lower extremity is loaded. Ankle cartilage thickness ranges from less than 1 mm to slightly less than 2 mm\(^9\) compared to the thickness of the cartilage in the hip and knee, which is at least 3 mm in the load bearing areas.\(^10\) Despite ankle cartilage being thinner than hip and knee cartilage, a study by Kempson and coworkers found that the tensile fracture stress and stiffness of ankle cartilage deteriorates less rapidly with age than the
hip,\textsuperscript{14} and Aurich and colleagues found that when ankle cartilage is stressed it undergoes a higher turnover of cartilage matrix material making it more resistant to degradation than knee cartilage.\textsuperscript{15}

### Etiology

Typical causes of post-traumatic arthritis of the ankle include ankle, pilon, tibia, fibula, and talus fractures. Several factors have been implicated in the development of post-traumatic ankle arthritis, including fracture severity, extent of cartilage damage, and a non-anatomic reduction.\textsuperscript{16} Soft tissue injuries can contribute as well, including ankle dislocations, recurrent sprains, persistent ankle instability, and osteochondritis dissecans lesions (Table 1). Atraumatic causes include inflammatory arthritides, infection, Charcot, hemophilia, and crystalline arthropathies. Ankle arthritis can be idiopathic, as well.

### Clinical Presentation

The cause of ankle arthritis can nearly always be identified from the patient’s history. Pain with uphill walking may indicate anterior ankle or talonavicular joint bony impingement. Pain with downhill walking may be related to a problem in the posterior ankle including soft tissue impingement, trigonal problems, or synovial chondromatosis. Pain with walking on uneven ground felt in the posterior or lateral ankle may be subtalar arthritis. If the patient complains of sub-fibular pain, it may be due to bony impingement from the calcaneus on the lateral process of the talus, the peroneal tendons, or the fibula.

A thorough clinical examination will help isolate the ankle pathology along with radiological investigations. Weightbearing radiographs are essential (Fig. 1). The hindfoot alignment view is important when the heel is in varus or valgus or when the ankle has coronal plane tilting. A CT scan may be beneficial in patients with an ankle or hindfoot deformity. It is less useful in patients with flexible deformities since it is a non-weightbearing exam. In patients with a history of trauma, an MRI can be useful to evaluate for the presence of subtle arthritic changes or other soft tissue pathology and may assist with identifying the source of the patient’s pain.

### Non-Surgical Treatment

In most cases of post-traumatic ankle arthritis, it is critical to exhaust an extensive course of non-surgical treatments prior to offering surgical options. The basic options in the physician’s armamentarium include NSAIDs, a cane, orthotics, orthoses, and injections, which include corticosteroids, hyaluronic acid, and platelet-rich plasma. A corticosteroid injection will be most beneficial to the patient who requires short-term relief. Hyaluronic acid is most commonly used in the knee, but it may be used in the ankle also, as the literature has shown that some patients do receive benefit from injections of this compound into an arthritic ankle.\textsuperscript{17,18} A study published in 2010 found favorable results with PRP injections in patients with osteoarthritis of the knee;\textsuperscript{19} however, its efficacy for ankle arthritis remains unproven. A variety of either custom or off the shelf braces may be prescribed initially. Braces can be a mechanical aid to limit painful motion and may function to correct flexible deformities. Some

### Table 1 Causes of Post-Traumatic Ankle Arthritis

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<td>Ankle Fracture</td>
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<td>Pilon Fracture</td>
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<td>Ankle Dislocations</td>
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<td>Recurrent Sprains</td>
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<td>Persistent Ankle Instability</td>
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<td>Osteochondritis Dissecans of the Talus or Distal Tibia</td>
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![Figure 1 Mortise and lateral ankle radiographs of a patient with ankle osteoarthritis.](image-url)
patients may benefit from shoe wear modifications, such as a wide heel or rocker bottom sole. Custom orthotics may be prescribed to improve the foot-shoe interface and relieve pressure from sensitive areas.

Surgical Treatment
The primary goals of any surgery on the foot or ankle are to establish a painless, plantigrade foot that fits in a shoe. Currently, surgical options include allograft resurfacing, arthroscopic debridement and osteophyte resection, joint distraction arthroplasty, supramalleolar osteotomy, total ankle replacement, and ankle arthrodesis. For the young patient who is a heavy laborer, the option with the most consistent results is ankle arthrodesis. In the older patient population, the two surgical options most commonly used are total ankle replacement and ankle arthrodesis. The most difficult patient to treat is the young adult with painful ankle arthritis who is not a heavy laborer but desires an active lifestyle. The surgical options for this patient include allograft resurfacing, arthroscopic debridement and osteophyte resection, joint distraction arthroplasty, and supramalleolar osteotomy.

Allograft Resurfacing
Allograft resurfacing is indicated for young active patients. Resurfacing involves the use of fresh allografts to replace damaged articular surfaces. Two important considerations are the necessity of anatomic matching of the allograft to the host bone and the limited supply of donor ankles. Hahn and colleagues in 2010 reported on 18 patients with 13 completing 4 years of follow-up. The investigators concluded that fresh talar allograft transplantation for osteochondral lesions is a reasonable procedure in younger patients with a focal defect. Another recent study reviewed 12 ankles in 11 patients with an average patient age of 35.5 years that underwent osteochondral grafting with fresh talar allografts with significant improvement in outcome scores, and 5 of 12 patients reported good to excellent results. They had two graft failures, and one patient went on to arthrodesis. Similarly, Raikin and colleagues published a series of 15 patients with a minimum of 2 years of follow-up, and the investigators found 2 of 15 patients were converted to arthrodesis, and 11 patients reported good to excellent results with significant improvement in post-op AOFAS and pain scores. It is contraindicated in patients with vascular disease, varus or valgus malalignment of greater than 10°, ankle joint instability, and obesity.

Arthroscopic Debridement and Osteophyte Resection
Arthroscopic debridement and osteophyte resection may be helpful in patients with mild arthritis with a large osteophyte restricting motion or causing painful impingement at the extremes of motion. Patients with soft tissue impingement can also benefit from arthroscopic debridement. Prior to undergoing the procedure, patients should be counseled that any pain they have at rest will most likely not be relieved by this operation. In a study of 105 patients who underwent arthroscopic debridement for either anterior bony or soft tissue impingement, the investigators reported that 65 patients at 2-year follow-up were pain free, and another 28 had their level of pain improved. Thirty-three had resumed sports, and 92 out of 105 reported good to excellent results. A more recent study examined 105 patients with osteochondral lesions that underwent arthroscopic debridement and microfracture. The investigators reported zero failures in lesions smaller than 15 mm and found that lesions larger than 15 mm, older age, higher BMI, a history of trauma, and presence of osteophytes were all predictors of a negative outcome. Overall, arthroscopic debridement can be a successful operation in patients with isolated bony or soft tissue impingement and mild ankle arthritis.

Joint Distraction Arthroplasty
Joint distraction arthroplasty, also referred to as arthrodiastasis, employs an external fixator to mechanically unload the joint. It is theorized that mechanical unloading of the joint allows for intermittent flow of intra-articular synovial fluid when the patient bears weight on the extremity, which gives the articular cartilage a chance to repair itself. Joint distraction arthroplasty is a joint sparing alternative for young patients with a congruent and painful arthritic joint. Typically, the external fixator is kept on for 3 months. The procedure may also be combined with adjunctive procedures such as osteophyte resection and Achilles lengthening. Tellisi and associates published a retrospective review in 2009 looking at 25 patients with an average follow-up of 30 months who had undergone joint preservation using distraction arthroplasty in patients with ankle osteoarthritis. The investigators reported that 91% of the patients had improvement in their pain, with a significant number of patients having an improvement in their AOFAS scores. Two out of 25 patients had undergone fusion.

Supramalleolar Osteotomy
Patients with mild to moderate osteoarthritis with tibiotalar malalignment and reasonable ankle range of motion may be indicted for a supramalleolar osteotomy. This may also be the first stage procedure prior to undergoing a total ankle replacement or arthrodesis. A study in 2003 reviewed 13 feet in 12 patients with a distal tibial deformity and ankle arthritis that underwent a supramalleolar osteotomy. The patients had an average follow-up of 33.6 months, and the osteotomies healed at a mean of 14 weeks. The investigators reported that there was no radiographic progression of arthritis, and the AOFAS score improved from 56.7 to 82.

Total Ankle Arthroplasty
Total ankle replacements were first approved by the FDA in the mid-1980s. Total ankles are indicated in patients with painful ankle arthritis secondary to a significant loss of artic-
ular cartilage caused by trauma, inflammatory arthropathy, or joint instability. Relative contraindications include younger patients, extremely active or heavy individuals, prior ankle infection, or skin ulcers. Absolute contraindications include large areas of osteonecrosis, Charcot arthropathy, absence of muscle function in the lower leg and foot, uncorrectable tibiotalar malalignment, vascular insufficiency, severe loss of bone stock, osteoporosis that may lead to inadequate component fixation, and current infection (Table 2). Short-term results were initially encouraging, but subsequent studies with long-term follow-up showed rates of radiographic loosening to be in the range of 22% to 75%. Other reported complications included superficial and deep infections, resection arthroplasty, attempted re-implantations or fusions and below-knee amputations.

Recently, there has been a resurgence in the use of total ankle replacements secondary to improved designs, better fixation, and a better understanding of the modes of failure from the previous generation of implants. Performing an adequate medial and lateral gutter debridement is of paramount importance. Intra-operative malleolar fracture and deltoid ligament insufficiency are potential pitfalls. It is important to have solid bony support. Post-operative complications of total ankle replacement include infection, loosening, progressive intra-component instability or deformity, subsidence, and polyethylene failure. Proper patient selection is a critical factor in reducing the rate of infection. Caution is advised in patients with a history of prior ankle infection or skin problems. During surgery, meticulous handling of the soft tissues, hemostasis, and a multilayer closure are critical in preventing infection and wound complications. Patients should be immobilized postoperatively and instructed to elevate the extremity to assist in wound healing. Weightbearing may be initiated at approximately 6 weeks postoperatively or when bony consolidation is seen. As in total hip and knee arthroplasty, deep acute (less than 6 weeks) infections can be treated with irrigation and debridement and poly exchange whereas deep chronic infections should be treated with resection arthroplasty with placement of a cement spacer and possible subsequent revision total ankle replacement or arthrodesis. The rate of subsidence of the talar component has decreased with the use of non-cemented components. In cases of severe subsidence, treatment includes revision of the talar component or fusion. The polyethylene component may fail by either catastrophic fracture, wear, or particle induced osteolysis. Thin bearings have the highest risk of catastrophic fracture. Patients should be appropriately counseled about the risk of acute fracture and should refrain from high impact activities on the implant. Patients should be followed regularly with radiographic evaluation to observe for the development of osteolysis. Multiple studies have been published which

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<td>Post-traumatic OA</td>
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<td>Inflammatory Arthritis</td>
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<td>Arthritis secondary to chronic ankle instability</td>
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**Figure 2** Immediate postoperative antero-posterior and lateral radiographs after a STAR (Scandinavian Total Ankle Replacement, Small Bone Innovations, Inc, New York, NY, USA) total ankle arthroplasty.
indicate that, as with many procedures, there is a learning curve with performing total ankle replacements.\textsuperscript{40,42,43}

Currently, the STAR (Scandinavian Total Ankle Replacement, Small Bone Innovations, Inc, New York, NY, USA) is the only FDA-approved mobile bearing device with bony in-growth potential (Fig. 2), and several studies have been published recently on its results. Saltzman and coworkers in 2009 performed a prospective multicenter trial comparing the STAR total ankle replacement and ankle fusion with 2-year follow-up. The investigators concluded that, at two years postoperatively, patients with a total ankle replacement had better function and equivalent pain relief compared to fusion.\textsuperscript{44} A study in 2004 looked at the STAR total ankle replacement in patients with 3 to 8 year follow-up and reported the estimated 5 year survival rate was 70% with 12 out of 51 ankles that had to be revised and another 8 with radiographic signs of loosening.\textsuperscript{45} More recently, Bonnin and colleagues in a 7 to 11 year follow-up on the Salto Total Ankle Replacement (Tornier, Inc., Montbonnot, Rhone-Alpes, France) reported an initial implant survival rate of 65% with 6 out of 85 patients converted to arthrodesis.\textsuperscript{46}

\textbf{Arthrodesis}

Arthrodesis currently remains the gold standard and the most common treatment of ankle arthritis. Arthrodesis is a successful operation in patients whose pain is isolated to the ankle joint. The results and complication rates have greatly improved through modern surgical techniques. Secondary operations, such as hardware removal, are rare while initial fusion rates have been reported to range between 60% and 100%.\textsuperscript{7,26,47,57} Despite this, patients may have persistent pain postoperatively if other sources of pain were not treated by the fusion. Postoperative functional limitations are common after arthrodesis, and postoperative shoe modifications may be necessary to improve the mechanics of the gait cycle. Over time adjacent joints, such as the sub-talar and talonavicul joints, may become arthritic.\textsuperscript{48} Patients should be told that they may need bracing or more surgery in the future especially in young patients.

To have a successful outcome, it is imperative that the surgeon establishes the proper alignment of the entire lower leg including the foot. The optimal position for ankle fusion is neutral dorsiflexion, 5° of valgus, and rotation equal to the other side (or slightly more externally rotated than the other side). The anterior aspect of the talar dome should be brought to the anterior aspect of the tibia. Occasionally, selective osteotomies or fusion of the forefoot may be required to make the foot plantigrade. Multiple surgical options are available including a standard open or mini-open approach, arthroscopy, and external fixation. The classic approach is trans-fibular with or without an accessory medial portal. Some surgeons reattach the fibula to act as a buttress against lateral talar migration (Fig. 3). The optimal screw pattern is controversial, but the typical pattern is parallel or crossed screws with or without a homerun screw (Fig. 4). The “homerun” screw is a lag screw that travels from the posterior malleolus into the plantar medial talar head and neck. The addition of a lateral plate, such as a blade plate or locking plate, is optional. Other approaches include the anterior and posterior approaches.\textsuperscript{58} The anterior approach allows anterior plating, which in theory uses the Achilles tendon as a tension band. One advantage is that the incision can be re-used in the future to convert the fusion to a total ankle replacement. It also maintains the fibula, which is necessary for future conversion to a total ankle. However, a drawback of the anterior approach is that it carries the risk of anterior talar subluxation.\textsuperscript{59} The posterior approach is used when the patient has poor blood supply or the skin in the region of other approaches has been compromised. With the posterior approach, though, the surgeon must be mindful of the neurovascular structures.\textsuperscript{60}

\textbf{Figure 3} Anteroposterior and lateral postoperative ankle radiographs of a patient status-post ankle arthrodesis.
Buchner and coworkers in a study of patient status-post ankle fusion with an average follow-up of 9.3 years found that 92% of patients had good subjective results. Patients did worse with greater than 5° of plantar flexion. Also, patients had a high incidence of adjacent arthrosis with subsequent decreased mobility in their adjacent tarsal joints. Forty-seven percent of patients had moderate to severe subtalar osteoarthritis. Other investigators looking at long-term follow-up in patients with ankle fusion for post-traumatic arthritis also found an increased incidence of adjacent foot joint arthritis as well as significant differences between the fusion and normal side in regards to activity, pain, and disability. A retrospective database review compared 4,705 ankle fusions versus 480 total ankle replacements, and the investigators reported that major revision was required in 9% of the total ankles after one year and 23% by 5 years compared to 5% and 11% for ankle fusions, respectively, but patients who underwent ankle replacement had a decreased rate of subsequent subtalar fusion (0.7%) compared to arthrodesis (2.8%).

Ankle fusion may be successfully performed arthroscopically in the patient with tibiotalar arthrosis but no significant deformity. Patients with inflammatory, hemophilic, or post-septic arthritis, or patients who have a poor vascular supply or compromised soft tissue are not good candidates. Myerson and colleagues in a comparison of 17 patients that underwent arthroscopic fusion versus 16 patients that underwent open fusion reported an average fusion time of 8.7 weeks in the arthroscopic group compared to 14.5 weeks in the open group.

External fixation may be the best choice for fusion in patients with complex hindfoot deformities, soft tissue compromise, significant shortening, or septic arthritis. A circular or hybrid fixator is often used. External fixation

Figure 4. Postoperative radiographs of a patient who required revision left ankle fusion. The patient originally underwent bilateral ankle arthrodesis for post-traumatic arthritis, which developed from prior pilon fractures. Because of failure of bony fusion on the left side, he was indicated for the revision procedure.
offers the advantage of gradual correction of complex deformities that minimizes soft tissue complications. High union rates have been reported, though pin site complications are common.\textsuperscript{64-66} Typically, external fixation is performed by surgeons with experience in this technique. Of the 17 patients that underwent Ilizarov ankle arthrodesis for either post-traumatic arthritis or a Charcot ankle joint, the investigators reported that all ankles fused, and 11 of 17 patients reported good to excellent results.\textsuperscript{64}

The three most common postoperative complications of ankle arthrodesis are non-union, mal-union, and secondary subtalar arthritis. Non-union rates have been reported to range between 0% and 40%.\textsuperscript{57,63,67-73} Non-union is more common in smokers, the elderly, the non-compliant, and those with neuroarthopathy, history of open trauma, or poor soft tissues.\textsuperscript{49,71} The most common position of malunion is varus or valgus with equinus. Malunion may be treated with either an opening or closing wedge osteotomy, double osteotomy, dome shaped osteotomy, or a circular external fixator.\textsuperscript{74}

The subtalar joint is the most common joint to develop arthritis after an ankle fusion. Degenerative changes occur secondary to increased stress on the subtalar joint. After ankle fusion, most patients will walk with the foot externally rotated in order to vault over the foot at the end of the stance phase of gait. To vault over the foot, a patient will roll through the subtalar joint in an unnatural medial to lateral direction. This unnatural motion may result in localized area of increased load on the articular cartilage, which ultimately leads to arthritic changes. After 20 years, all patients can be expected to have radiographic evidence of subtalar arthritis, but the rate of symptomatic arthritis is low.\textsuperscript{81}

**Bone Grafting**

The need for bone grafting is controversial. However, since non-union can be a devastating complication, most surgeons use bone grafting with primary arthrodesis.\textsuperscript{75-77} Potential sites to obtain autograft are iliac crest, proximal tibia, distal tibia, and calcaneus.\textsuperscript{76-78} To date, no large studies have been published comparing primary fusion with and without bone graft.

**Achilles Contracture**

Patients with tibiotalar arthritis may develop an isolated gastrocnemius or Achilles contracture secondary to altered joint motion or gait mechanics. It is essential to recognize a contracture preoperatively, so that it can be addressed at the time of surgery, thus ensuring the patient has a plantigrade foot postoperatively. Patients with an isolated gastrocnemius contracture will lack dorsiflexion only with the knee extended, but an equinus position in both knee flexion and extension indicates a combined gastrocnemius-soleus contracture. An open or percutaneous release of the Achilles tendon is necessary in this situation. When an isolated gastrocnemius contracture is present, it can be treated with a release of the gastrocnemius alone such as a Strayer procedure.\textsuperscript{78}

**Summary**

Post-traumatic ankle arthritis can be a challenging problem to treat, especially in younger patients. Isolating the exact location of the patient’s pain and in what positions of motion is critical in determining the correct treatment option. Non-surgical treatment options should be exhausted prior to proceeding with surgical treatment. Many surgical procedures have been described, and the surgeon should be familiar with the indications and contra-indications of each before proceeding with a specific operation. Ankle arthrodesis remains the gold standard for the treatment of ankle arthritis, especially in young laborers, but total ankle replacement may be a good option in older, less active, patients. Ankle arthroplasty may avoid the development of adjacent joint arthritis almost always seen after ankle fusion. In young patients with ankle arthritis, joint sparing operations, such as arthroscopic debridement, joint distraction arthroplasty, or supramalleolar osteotomy, may be performed. Bone grafting as an adjunct to ankle fusion is commonly used, despite there being no clinical trials showing an advantage to using bone graft. In all cases, Achilles tendon contracture should be addressed at the time of surgery to enable the surgeon to achieve a plantigrade foot.

**Disclosure Statement**

None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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