Kelly L. Apostle, MD, FRCSC

What role does ankle replacement play in managing pain and disability?

Although advances in implant design have contributed to better outcomes in total ankle replacement, ankle arthroplasty is not for every patient and ankle arthrodesis may be the best option for many.

ABSTRACT: End-stage arthritis of the ankle causes significant pain and functional disability in affected individuals. Until the 1970s, arthrodesis was the standard treatment for symptomatic ankle arthritis. During the 1980s and 1990s, surgeons considered a number of different total ankle replacement designs. With improved understanding of ankle biomechanics and advances in implant design and surgical techniques, arthroplasty has become a reliable alternative to arthrodesis in some patients. Many factors must be considered when determining whether a patient is a good candidate for ankle replacement. The ideal patient is older than 50 and has a preserved range of motion, good ankle stability, and adequate bone quality. Absolute contraindications include active infection and peripheral vascular disease. A growing body of literature is providing information on implant survival, patient satisfaction, function, and complications. Possible complications include implant failure or aseptic loosening, polyethylene liner fracture, and deep infection. Evidence supports the need for careful patient selection, preoperative planning, surgeon experience, and familiarity with the chosen prosthesis.

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Ankle arthritis is a disabling condition that affects quality of life as much as arthritis of the hip[1] or congestive heart failure.[2] Arthrodesis has long been the mainstay of surgical treatment for when nonoperative treatment has failed. Today refined surgical techniques and improved biomechanical design have led to a significant increase in the volume of successful ankle replacements being done worldwide. Meanwhile, debate continues in the orthopaedic community about the ideal implant design, best surgical candidates, and relative contraindications to the procedure.

Unlike primary osteoarthritis of the hip or knee, up to 80% of ankle arthritis is caused by trauma or altered ankle biomechanics and loading caused by recurrent ankle instability.[3] In these instances, direct injury to cartilage or injury related to abnormal

Dr Apostle is an orthopaedic surgeon at Royal Columbian Hospital in New Westminster, BC, and a clinical assistant professor at the University of British Columbia.

cartilage loading leads to progressive degeneration and, ultimately, advanced osteoarthritis. Other causes of ankle arthritis are congenital deformity and inflammatory, neuropathic, or infectious conditions. Rare causes of ankle arthritis include hemochromatosis, hemophilia, gout, and pigmented villonodular synovitis.

We now know that differences in the properties of articular cartilage and joint biomechanics in the hip, knee, and ankle explain the lower incidence of primary osteoarthritis of the ankle and why the ankle is susceptible to degenerative changes after injury.

The ankle joint is highly congruent and has a dynamic axis of rotation that changes throughout the arc of motion, which occurs in three planes: dorsiflexion/plantar flexion, inversion/eversion, and internal/external rotation. To accommodate the high level of congruity, articular cartilage in the ankle is thinner than in the hip or knee and has a higher compressive modulus.[4,5] The ankle also has a smaller area of contact causing higher peak contact stresses.[6] In a well-balanced ankle, thinner cartilage with a high compressive modulus acts to equalize stress across the joint, which contributes to resistance from primary degenerative changes. However, this also means any small change in contact stress or contact area in the small, highly constrained joint increases the risk that the thin articular cartilage will fail and posttraumatic changes will follow. It has also been found that the tensile strength of ankle cartilage does not decrease dramatically with age as hip or knee cartilage does, and that this protects against age-related joint degeneration.[7] These unique biomechanical characteristics make it challenging to design ankle implants using principles borrowed from hip and knee replacement.

History

In the early 1970s, dissatisfaction with ankle arthrodesis related to development of arthritis at adjacent joints, altered gait mechanics, and elimination of motion led to the advent of ankle replacements. Despite discouraging initial results, the development of prostheses continued and knowledge was gained about soft tissue balancing.

The first implant was a cemented long-stemmed tibial component with a polyethylene talar-body-replacing component.[8] This device had a high early failure rate and even implants that did not fail received low scores for patient satisfaction. However, surgeons unhappy with the results of arthrodesis and encouraged by the advances in hip and knee replacement at the time continued to consider different total ankle replacement designs throughout the 1970s and 1980s. Small case series showed promising early results. Nevertheless, high failure rates at 10 years follow-up, implant survival of only 10% to 40%, and patient dissatisfaction with the prostheses that did survive led many surgeons to abandon the procedure altogether.[9]

The lack of success of these first-generation implants has been attributed to many design flaws. First, a large bony resection was required and this placed the tibial component adjacent to the soft metaphyseal bone of the distal tibia, causing inadequate bony support and high rates of subsidence and loosening. Second, prostheses were inserted with cement and designed to be either highly constrained, meaning they functioned like a simple hinge, or highly unconstrained, meaning they functioned like a ball and socket joint. Neither of these designs came close to simulating the function of the ankle joint and the result was poor stress distribution and failure at the cement-bone interface. Lastly, the two-component designs with incongruent tibial and talar bearing surfaces to allow for multiplanar motion caused point loading and early wear of the bearing surfaces.[9-11]

Throughout the late 1980s and 1990s, substantial improvements in implant design were seen with the introduction of three-component prostheses (tibial component, talar dome component, and a polyethylene insert between the two, similar to that used in knee replacement) and cementless fixation with porous coating for bony ingrowth. In addition, more conservative bone resection preserved the stronger subchondral bone and resulted in lower mechanical failure rates. Renewed interest in ankle arthroplasty to treat end-stage arthritis followed the promising clinical results and lower failure rates for three second-generation prostheses: the Agility (DePuy), the Buechel-Pappas (Endotec), and the STAR or Scandinavian Total Ankle Replacement (Waldmar Link).[12-16]

Many of the third-generation ankle replacements introduced in the late 1990s were three-component designs with a mobile bearing, which meant they had a mobile surface between the tibia and polyethylene liner and a second mobile surface between the polyethylene and talus. There is currently no established advantage for mobile-bearing designs over fixed-bearing designs, despite the theoretical advantage of multiplanar motion more closely resembling anatomic motion at the native ankle joint and decreasing sheer stress through both mobile interfaces creating a more favorable environment for bony ingrowth. Mobile-bearing designs, however, continue to be used in knee replacements without any proven advantages, and it is likely that advantages will not be found for mobile-bearing ankle replacement either.

During the development of third-generation implants, better understanding of soft tissue balancing and its contribution to failure has led to better survival rates for total ankle replacements. Today, designs and surgical techniques continue to advance and many historical relative contraindications to ankle replacement are being challenged.

Patient selection

Patient selection has clear implications for the success of ankle replacement. The ideal patient for ankle arthroplasty is older than 50, not obese, and has low physical demands. The ideal patient also has a preserved range of motion, neutral alignment, good ankle stability, adequate bone quality, and a good soft tissue envelope (Figure 1). By contrast a young patient with isolated end-stage ankle arthritis, severe joint stiffness, and high activity demands is not ideal and is instead a good candidate for ankle fusion (Figure 2). Between these two patients there are patients occupying a large gray zone, and the treating surgeon must weigh the advantages and disadvantages for each individual to determine the best surgical option to achieve a successful result.

Absolute contraindications to ankle arthroplasty are active infection, peripheral vascular disease, inadequate soft tissue envelope, and Charcot arthropathy (neroupathic joints). Relative contraindications are younger age (less than 50 years), high activity demands, previous infection, marked osteoporosis, obesity, avascular

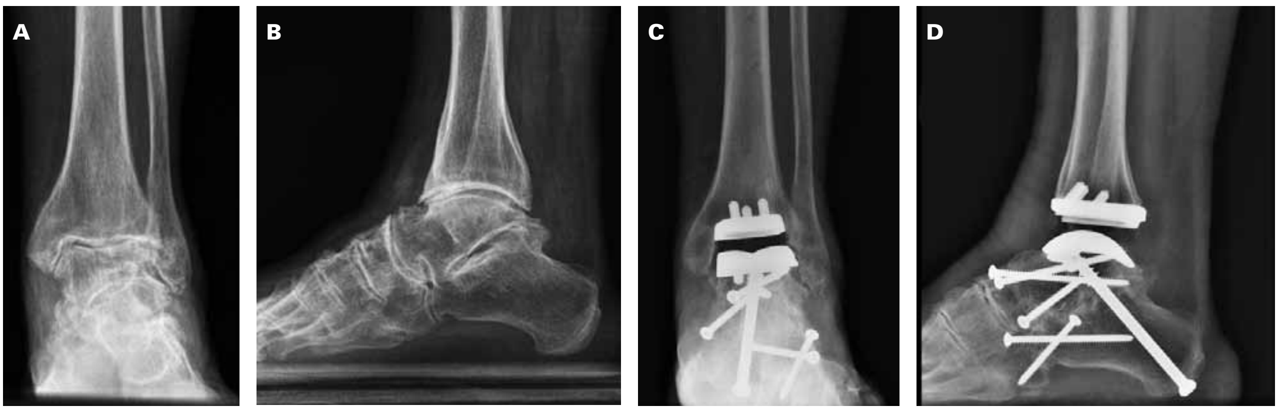

Figure 1. Radiographs of a 64-year-old female who underwent an ankle replacement with an Infinity implant and a hindfoot triple arthrodesis.

Preoperative images: The anteroposterior view **(A)** and lateral view **(B)** reveal multiple joints affected by rheumatoid arthritis. Postoperative images: The anteroposterior view **(C)** and lateral view **(D)** show the prosthesis in position and five screws placed to facilitate bone fusion.

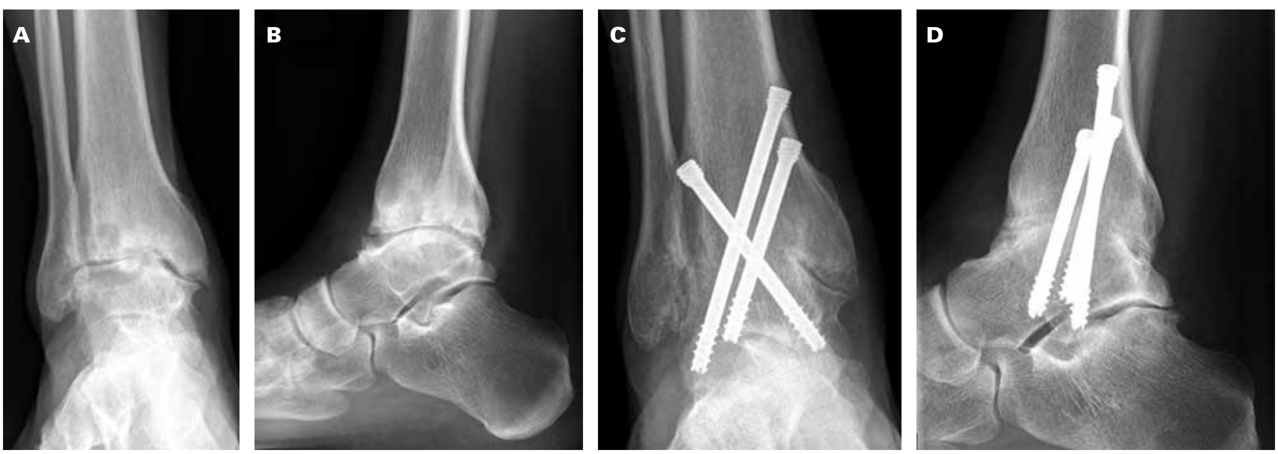

Figure 2. Radiographs of a 35-year-old male who underwent an arthroscopic ankle arthrodesis.

Preoperative images: The anteroposterior view **(A)** and lateral view **(B)** show degeneration caused by arthritis secondary to pigmented villonodular synovitis. Postoperative images: The anteroposterior view **(C)** and lateral view **(D)** show three screws placed to facilitate bone fusion.

necrosis of the talus, and diabetes. Marked instability and coronal plane deformity over 15 degrees have previously been considered relative contraindications; however, with improved understanding and implementation of periarticular osteotomies and soft tissue balancing techniques, many surgeons would no longer exclude arthroplasty as an option in these patients.[17]

Special consideration should also be given to patients with ipsilateral subtalar, midfoot, hip, and knee arthritis, as well as patients presenting with bilateral ankle pathology. These patients seem to benefit more from ankle arthroplasty than arthrodesis, as fusion has been shown to accelerate degenerative changes at neighboring joints (Figure 3). It has also been shown that 50% of patients with ankle fusion will have symptomatic hindfoot arthritis at 8 years and nearly 100% will have arthritis at 22 years.[18]

The key message to patients considering an ankle replacement is that many factors must be weighed by the surgeon to determine if a patient is a good candidate for the procedure. The final decision regarding replacement versus fusion will be made by the surgeon after these factors are taken into account along with the indications and contraindications, relative risks, and patient preferences.

Outcomes

While validated patient-reported outcomes data are lacking, a growing body of literature is providing information on implant survival, patient satisfaction, function, and complications.

Implant survival

Several survival analyses by the manufacturers of various second-generation implants have shown promising mid- and long-term outcomes. Buechel and colleagues reported a 92% 12-year survival rate for one of the Beuchel-Pappas prostheses.[19] Kofoed reported a 95% 10-year survival rate for the uncemented STAR implant,[15] and Knecht and colleagues found an 85% 10-year survival rate for the Agility.[20] Subsequent studies by other authors have reported less favorable results, although still found substantially improved survival rates over first-generation designs. The Swedish Ankle Arthroplasty Register reported on 531 prostheses implanted between 1993 and 2010 and found a 10-year survival rate of 69%.[21] Likewise, the Norwegian Arthroplasty Register found a 10-year survival rate of 76% in 257 arthroplasties between 1994 and 2005.[22] Two recent meta-analyses, each including studies of eight different second- and third-generation prostheses, found global survival rates of 90% at 5 years and 89% at 10 years.[23,24] Although it is difficult to draw discrete conclusions from these studies of heterogeneous patient populations receiving different implants and being assessed using various outcome measures, the analyses do provide compelling evidence that ankle replacements are now performing better than they were previously, regardless of the patient demographics, implant used, and cause of degeneration, albeit not as well as hip and knee replacements.

Figure 3. Radiographs of an ankle 12 years after arthrodesis was performed.

The anteroposterior view **(A)** shows the screws placed to facilitate bone fusion. The lateral view **(B)** shows the screws as well as end-stage symptomatic arthritis at the anterior and middle facet of the subtalar joint (black arrows) and moderate arthritis of the posterior facet of the subtalar joint (white arrow).

Patient satisfaction

Unfortunately, the ankle replacement literature is lacking in studies with prospective data on validated patient-reported outcome scores. The Canadian Orthopaedic Foot and Ankle Society (COFAS) recently published data from a prospective study of patients in the COFAS Ankle Reconstruction Database who had been followed for a minimum of 4 years after ankle replacement or fusion.[25] Although the diverse group of patients studied had various conditions and received four different prostheses, after the authors adjusted for baseline patient characteristics they found a significant improvement from preoperative scores in both the arthroplasty and arthrodesis groups. At most recent follow-up, no difference was found between the arthrodesis and arthroplasty groups based on the Ankle Osteoarthritis Scale (AOS) total or pain and disability scores, or on the Short Form-36 (SF-36) physical and mental component scores.[25]

In a separate prospective study comparing ankle arthrodesis with ankle arthroplasty using the STAR prosthesis at 2-year follow-up, researchers found that equivalent pain relief was achieved for fusion and replacements based on visual analog pain scores. Using the Buechel-Pappas outcome score, the ankle arthroplasty group was found to be superior to fusion in terms of function.[26] A weakness of this finding of functional superiority is that the Buechel-Pappas score is not validated and it gives 15% credit for ankle motion, thereby almost by definition favoring ankle replacements. It is also not patient-derived and is scored by the surgeon, leading to potential bias.

Finally, a recently published study found that patients undergoing ankle arthroplasty had higher preoperative expectations than those undergoing fusion,[27] were more likely to report that their expectations had been met, and had higher postoperative satisfaction scores than patients undergoing arthrodesis. Satisfaction and expectation scores did not, however, correlate with AOS outcome scores, suggesting that these variables may not be adequately captured in the current scoring systems.[27]

Despite the paucity of evidence, these recent studies would suggest that appropriately chosen patients undergoing ankle replacement using new techniques and implant designs have outcomes at least as good as patients undergoing ankle fusion.

Function

Another argument for ankle arthroplasty over arthrodesis is that preserved tibiotalar motion more effectively normalizes gait patterns. Studies that have independently looked at gait analysis in patients before and after total ankle arthroplasty have found that walking velocity improved in terms of both cadence and stride length, as did motion at the ipsilateral hip and knee.[28] A separate case control study (nonrandomized) comparing gait in 17 patients 1 year after ankle fusion or arthroplasty found that patients undergoing ankle arthroplasty had more normal gait patterns than those who underwent arthrodesis; however, this improvement was not reflected in the self-reported clinical outcomes scores, which were similar for both groups.[29]

Complications

Ankle arthoplasty is a technically demanding procedure. To minimize complication and failure rates, ankle replacements should be undertaken by subspecialty foot and ankle surgeons who perform a high volume of this procedure. Multiple studies have shown a significant learning curve effect and have recommended more restrictive patient selection for the first 50 replacements done by a single surgeon.[30] Multiple studies have also shown complication rates for ankle replacements to be higher than those for ankle arthrodesis. Complications include implant failure or aseptic loosening, polyethylene liner fracture, deep infection, wound healing delay, and malalignment requiring revision.[25,26] Intraoperative complications such as malleolar fracture and tendon injury have also been reported. Revision ankle arthroplasty and conversion of failed ankle arthroplasty to fusion are challenging procedures and have worse outcomes than primary ankle replacement or fusion.[31,32] This should be considered when recommending ankle replacement over fusion.

Summary

End-stage ankle arthritis causes significant pain and disability. Historically, ankle replacements had an unacceptably high failure rate. Advances in implant design and surgical techniques since the 1970s have led to ankle replacements becoming a viable and desirable option for many patients. Indications for ankle replacement rather than fusion continue to be refined as newer designs address previous pitfalls, as longer-term outcome data become available, and as results from higher-quality studies are published.

Ankle arthroplasty is not for every patient and arthrodesis may be the best option for many. It is important to consider an individual patient's needs and expectations. Careful patient selection along with a comprehensive understanding of ankle anatomy and biomechanics, thorough preoperative planning, surgeon experience, and familiarity with the chosen prosthesis is required for successful outcome. Ankle replacement is best undertaken by subspecialty foot and ankle surgeons who perform a high volume of this procedure.

Competing interests

None declared.

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