Total ankle arthroplasty: the future of orthopaedic surgery?

Abstract

The ankle is a complex joint with multiple planes of motion, which we heavily rely on for locomotion, balance and independent functioning. Thus, when arthritis affects the ankle, there are serious consequences, which underline the importance of finding a viable treatment option. One such treatment option, total ankle arthroplasty, has been garnering much attention over the past 30 years as it continues to progress towards a level of effectiveness equivalent to knee and hip replacement surgeries. After many failed generations of implant design, we are finally reaching a level of understanding of how the ankle actually works to make anatomically accurate replacements. The implant design, combined with the knowledge of the injury mechanisms leading to the need for an ankle replacement, have made the success of ankle arthroplasty more likely. For ankle replacement to have the success level of the knee or hip replacement, surgeon technique and proper patient selection must be pursued. If these areas of weakness can be overcome, the total ankle arthroplasty may soon be the first choice among orthopaedic surgeons for management of end-stage ankle arthritis.

Keywords: Ankle anatomy; ankle arthritis; total ankle arthroplasty; ankle implants; arthrodesis; ankle complications; future of ankle arthroplasty.

Royal College of Surgeons in Ireland Student Medical Journal 2013; 6(1): 59-62.

Katharine Harper
RCSI medical student

Introduction

Anatomy

The ankle is composed of the ankle joint proper (or talocrural joint), the subtalar joint and the inferior tibiofibular joint (**Figure 1**).[1,2,3] The talocrural joint is a hinge joint found between the mortice formed by the malleoli and the lower end of the tibia, and the body of the talus.[2] This is the location at which flexion (dorsiflexion) and extension (plantarflexion) occur.[2] The subtalar joint is made up of two separate articulations: the talocalcaneal joint and the talocalcaneonavicular joint.[1] This is the location at which inversion and eversion occur.[2] They are referred to as one joint due to the fact that they function in unison and as a unit.[1] Lastly, the inferior tibiofibular joint is an articulation between a triangular facet on the talus and the lateral malleoli (which is the inferior aspect of the fibula), the lateral aspect of which serves as the attachment point for the anterior talofibular ligament.[1] With the anatomy in mind, this paper aims to review the indications, history and current status of total ankle arthroplasty (TAA), the evolution of the surgery towards the future and what variables could impact on the success of the implant.

Pathology

The ankle is subjected to the highest weight-bearing force per square centimetre of any joint in the body and, as such, it is the most commonly injured.[4] Primary osteoarthritis occurs much less frequently in the ankle than it would in the knee, hip, hand or spine, and is not the major contributor to end-stage ankle arthritis.[4,5] Instead, post-traumatic arthritis is the most common cause of ankle arthritis requiring surgical intervention, compared with primary osteoarthritis as the main indication for hip or knee arthroplasty.[4,5] Secondary post-traumatic arthritis often follows a rotational fracture or recurrent ligamentous instability[5] (which commonly results in medial side arthritis specifically).[5] Ankle arthritis prevalence is often difficult to quantify due to variations in clinical correlation,[4] but some studies indicate that it affects up to 6% of the population.[6] It often results in severe functional limitation and a decrease in quality of life.[7] Unfortunately, it gets less attention than the more common and more treatable knee and hip arthritides,[8] which dominate research in the area.[5]

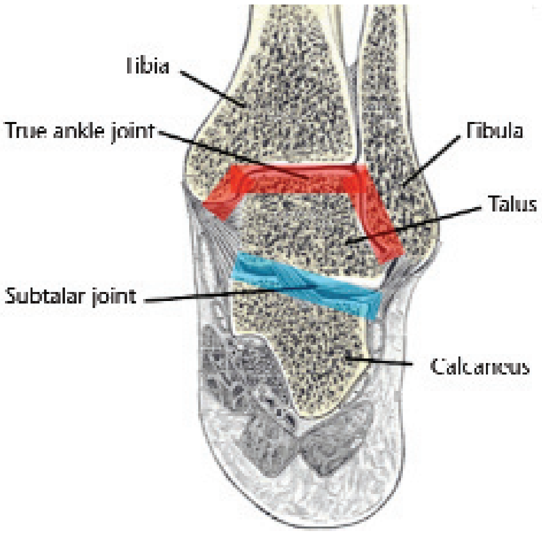

FIGURE 1: A coronal cross-section view of the distal lower limb, including the ankle and hind foot. The ankle joint proper (or true ankle joint) is highlighted in red, while the subtalar joint is highlighted in blue. ©Medscape

Ankle arthritis can cause significant morbidity and functional impairment in its advanced stages.[7] In patients with severe post-traumatic arthritis, decreased range of motion, step length, plantarflexion power and power absorption were noted when compared to the non-affected side.[6] While conservative management for ankle arthritis can be considered, it is often less effective than similar modalities used for other joints. For example, corticosteroid injections of the ankle have much shorter efficacy times than when used in the knee, often not exceeding eight weeks of pain relief.[4] Patients with ankle arthritis are often younger than patients with arthritis of the knee or hip,[6] and conservative management is not a sustainable option, leaving surgical management as the only long-term option for functionally disabling disease.[4,5,6]

Intervention

Orthopaedic surgeons have achieved great results from total hip and total knee arthroplasty procedures. Unlike hip and knee arthroplasty, though, for the last 30 years complications and unsatisfactory outcomes have gone unresolved for TAA. Despite the advantages a replacement could bring in functionality and pain relief, ankle arthrodesis (fusion of the subtalar joint) remains the treatment of choice for end-stage ankle arthritis.[9] At the onset of ankle arthroplasty in the 1970s, failures requiring revisions or fusions were as high as 72% 10 years post operatively.[10] While TAA outcomes have vastly improved since this time,[11] they still have very high revision rates (23% five years post operative).[7] As failure rates continue to decrease though, the surgery will gather more interest from younger and more active patients, requiring a better understanding of how the replacements work, and where issues may arise.[10]

Evolution of the replacement

Total ankle replacement was first attempted 40 years ago, but after poor results, it was not used extensively until the late 1980s and early 1990s.[12,13] These re-attempts at ankle replacement were undertaken due to dissatisfaction in results from ankle arthrodesis, and the previous successes of hip and knee arthroplasty, combined with designs that began to more closely resemble the natural anatomy of the ankle.[8,12]

First generation designs originally functioned under the assumption that the ankle joint was a simple hinge joint,[12] but researchers soon discovered the many complex planes in which the ankle can move.[1,2,12,13] The original design had cemented tibial and talar components that were either constrained or totally unconstrained, though the unconstrained designs were quickly abandoned due to instability.[13] The initial constrained device results were promising though, and thus development into a viable ankle implant was continued.[8,12,13] Unfortunately, the long-term outcomes of these devices showed short-term implant survival with high failure rates. Implant design appeared to be the major contributing factor.[13]

Second-generation designs addressed the flaws of earlier ones and aimed to be more anatomically correct.[12] They also tried to recreate the stability provided by ligaments, and reproduce the natural axis of rotation.[12,13] Second generation implants were classified as "semi-constrained" and went through several stages of revision through the 1990s.[13] Three major implants made contributions towards the development of semi-constrained devices: the Buechel-Pappas modification; the Scandinavian Total Ankle Replacement (STAR); and, the Agility ankle system.[13] The Buechel-Pappas model developed a low contact stress implant, which contained uncemented porous ceramic tibial and talar components with a mobile "meniscal" polyethylene disc.[8,13] The STAR system contained a flat tibial component, an anatomical talar cap, and a polyethylene insert that interacts with the tibial glide plate.[8,13,14,15] The Agility system is unique in that it contains three components but is essentially a two-component design. The system incorporates an arthrodesis of the tibiofibular syndesmosis, with the goal of providing a larger surface area for force transfer and stability.[13,16] These models remain available today, and have brought about the development of the newest generation of implants.[8,13]

The current generation of replacements has continued to build on the second-generation successes and can be divided into two subcategories: two-component fixed-bearing implants; and, three-component mobile-bearing implants.[8,12] **Figures 2a, 2b** and **2c**[12,14] outline the different implant models over time. In recent years, trends have moved more towards the development of three-component mobile-bearing designs,[8,11,12] with mobile-bearing implants being used more in Europe and fixed-bearing used more in the USA.[8] The modern three-component implants have vastly improved and are currently demonstrating a 10-year survival rate of greater than 90%.[17] **Table 1** provides a non-inclusive overview of available brands.[8,11,13,14,15,16]

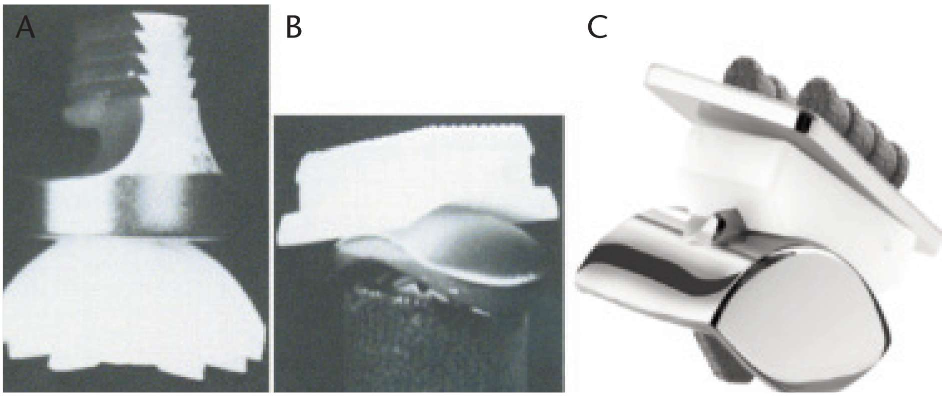

FIGURE 2 (a, b and c): Figures 2a and 2b are examples of the first-generation unconstrained devices, which were quickly discontinued due to instability and failure rates. Figure 2c is the second-generation STAR™ model, which is still in production today.

Table 1: Overview of major ankle arthroplasty implants (not inclusive).

Brand name	Manufacturer	Type of replacement	Components
Agility[8,13,16]	DuPey Orthopedics	Fixed-bearing, two-component	Tibial component with associated arthrodesis of the tibiofibular joint, talar component, which slides side to side
Salto™ Talaris[8,11]	Tornier	Fixed-bearing, two-component	Tibial component with incorporated polyethylene and talar component
STAR[14,15]	Waldermar Link	Mobile-bearing, three-component	Tibial component, talar component and polyethylene gliding core (6-14mm)
Salto™ [8,11]	Tornier	Mobile-bearing, three-component	Tibial component with hollow fin and hollow end talar facets covered by a talo-fibular facet replacement. Note: smaller medial radius of talar component allows for inversion and eversion
Buechel – Pappas[11]	Endotec	Mobile-bearing, three-component	Tibial component with stem, talar component and polyethylene gliding core

Patient selection

Selecting appropriate patients for TAA is vital in trying to maximise the success of the implant in the long term.[18] Currently, acceptable results have been reported in older, low-demand patients with rheumatoid arthritis or osteoarthritis.[18] Rheumatoid arthritis is the number one underlying indication for performing TAA, while trauma is the indication for arthrodesis.[13,19] Patients undergoing TAA are slightly older than those undergoing arthrodesis and are predominantly female.[19] Research suggests that younger patients should undergo arthrodesis due to higher demands on the ankle, while older patients should consider TAA with return to low-impact activity post surgery.[20] TAA is preferable to arthrodesis in patients who have established ipsilateral subtalar joint arthritis, or in patients who would be unable to tolerate long periods of immobility.[13] Immobility for an extensive amount of time is required for arthrodesis.[13]

Absolute contraindications for TAA include avascular necrosis of the talus, Charcot's foot, any cause of an insensate foot, poor lower limb muscle function or an acute/chronic infective state.[13] Previous procedures on the ankle, including a previous arthrodesis with a malleoli excision, are also an absolute contraindication.[13] Relative contraindications include long-term steroid use, vasculitic ulcers on the leg, a previous septic ankle on the affected side and a previously fused ankle.[13]

Complications and issues

Complications that can arise from TAA are similar to other joint replacement surgeries and include infection, impaired wound healing, non-union and peri-operative fractures in the early post-operative period, while aseptic loosening, osteomyelitis, periprosthetic fractures, osteolysis from polyethylene wear, spacer migration and heterotropic bone formation can occur in the delayed post-operative period.[21,22] TAA failure rates, as mentioned previously, remain high at 23% five years post operatively.[7] This value is particularly high when compared to knee arthroplasty (0.19% annual failure and a 98.75% seven-year survival)[23] and hip arthroplasty (considered one of the most cost-effective and successful operations ever introduced).[24] Studies comparing arthrodesis to TAA complication rates have found that replacements have higher failure rates comparatively, with the most common complication needing revision being loosening of the prosthesis.[21] Surgeon technical error was also significantly larger in the TAA subset than in the arthrodesis subset (15% and 2%, respectively).[21] Technical error is equal to implant loosening as the most likely cause of failure in the TAA.[21] A particularly severe complication that can result from a TAA is talar necrosis and collapse associated with the talar component of the implant (what is known as a talar "cap" in some devices).[25] This complication is most commonly seen in patients who have rheumatoid arthritis and requires a total talar replacement to fix. Of note, the total talar replacement is capable of being integrated into the greater total ankle replacement system to salvage the replacement.[25]

Future of the replacement

As TAA outcomes continue to improve, so will development of newer implant models. Studies have found TAA to be a cost-effective alternative to arthrodesis, and if models become more efficient, it may soon surpass arthrodesis as the most cost-effective treatment option.[26] This will further support the use of TAA from an administrative and insurance point of view.[26] From a functional standpoint, if a TAA is performed successfully there are better overall outcomes.[19,27] These better outcomes include decreased energy expenditure and improved post-operative activity levels when compared to arthrodesis[19,27] and will continue to make it a popular choice among certain patient populations. As more mobile-bearing implants are developed, the Food and Drug Administration (FDA) will continue to approve new models that have built upon the basics laid out from previous generations.[28]

Conclusion

The complexity of the ankle and the unique causes of arthritis led to initial design difficulties and high failure rates. In recent years, as implants moved from a constrained design to a mobile-bearing design, many of these flaws have been eliminated. As implants continue to be improved upon, TAA will gain popularity. The continuing focus on proper patient selection is important in the success of the surgery. For the future, the key to success will be continuing mastery of the procedure by surgeons to ensure the best possible outcomes. If these goals can be accomplished, TAA could move to the forefront of treatment of end-stage, debilitating ankle arthritis in older, low-activity adults in years to come.

References

1. Rockar Jr PA. The subtalar joint: anatomy and joint motion. J Ortho Sports Phys Ther. 1993;21(6):361-72.
2. Ellis H. Clinical Anatomy: A Revision and Applied Anatomy for Clinical Students (11th ed.). Blackwell Publishing; 2006:233-5.
3. Medscape. Ankle Injuries. Available from: http://reference.medscape.com/features/slideshow/ankle-injuries.
4. Thomas RH, Daniels TR. Ankle arthritis. J Bone Joint Surg Am. 2003;85-A(5):923-36.
5. Saltzman CL, Salamon ML, Blanchard M *et al.* Epidemiology of ankle arthritis: report of a consecutive series of 639 patients from a tertiary orthopaedic centre. Iowa Orthop J. 2004;25:44-46.
6. Segal AD, Shofer J, Hahn ME *et al.* Functional limitations associated with end-stage ankle arthritis. J Bone Joint Surg Am. 2012;94-A(9):777-83.
7. SooHoo NF, Zingmond DS, Ko CY. Comparison of reoperation rates following ankle arthrodesis and total ankle arthroplasy. J Bone Joint Surg Am. 2007;89-A(10):2143-9.
8. Gougoulias NE, Khanna A, Maffulli N. History and evolution in total ankle arthroplasty. Brit Med Bull. 2009;89:111-51.
9. Easley ME, Adams Jr. SB, Hembree C, DeOrio JK. Results of total ankle arthroplasty. J Bone Joint Surg Am. 2011;93-A(15):1455-68.
10. Gougoulias NE, Khanna A, Maffulli N. How successful are current ankle replacements? A systemic review of the literature. Clin Orthop Relat Res. 2010;468(1):199-208.
11. Wood PLR, Clough TM, Smith R. The present state of ankle arthroplasty. Foot Ankle Surg. 2008;14:115-9.
12. Vickerstaff JA, Miles AW, Cunningham JL. A brief history of total ankle replacement and a review of current status. Med Eng Phys. 2007;29:1056-64.
13. Jackson MP, Singh D. Total ankle replacement. Curr Orthopaed. 2003;17:292-8.
14. Mann JA, Mann RA, Horton E. STAR™ Ankle: long-term results. Foot Ankle Int. 2011;32(5):473-84.
15. Nunley JA, Caputo AM, Easley ME, Cook C. Intermediate to long-term outcomes of the STAR total ankle replacement: the patient perspective. J Bone Joint Surg Am. 2012;94-A(1):43-8.
16. Criswell BJ, Douglas K, Naik R, Thomson AB. High revision and reoperation rates using the Agility™ total ankle system. Clin Orthop Relat Res. 2012;470(7):1980-6.
17. Rippstein PF, Huber M, Coetzee JC, Naal FD. Total ankle replacement with use of a new three-component implant. J Bone Joint Surg Am. 2011;93-A(15):1426-35.
18. Clare MP, Sanders RW. Preoperative considerations in ankle replacement surgeries. Foot Ankle Clin. 2002;7(4):709-20.
19. Haddad SL, Coetzee JC, Estok R *et al.* Intermediate and long-term outcomes of total ankle arthroplasty and ankle arthrodesis: a systematic review of the literature. J Bone Joint Surg Am. 2007;89-A(9):1899-1905.
20. Schuh R, Hofstaetter J, Krismer M *et al.* Total ankle arthroplasty versus ankle arthrodesis. Comparison of sports, recreational activities and functional outcome. Int Orthop. 2012;36:1207-14.
21. Krause FG, Windolf M, Bora B *et al.* Impact of complications in total ankle replacement and ankle arthrodesis analysed with a validated outcome measurement. J Bone Joint Surg Am. 2011;93-A(9):830-9.
22. Bestic JM, Peterson JJ, DeOrio JK *et al.* Postoperative evaluation of the total ankle arthroplasty. AJR. 2008;190:1112-23.
23. Scuderi GR, Insall JN, Windsor RE, Moran MC. Survivorship of cemented knee replacements. J Bone Joint Surg Am. 1989;71-B(5):798-803.
24. Maichau H, Herberts P, Ahnfelt L. Prognosis of total hip replacement in Sweden. Acra Orthop Scand. 1993;64(5):497-506.
25. Tsukamoto S, Tanaka Y, Maegawa N *et al.* Total talar replacement following collapse of the talar body as a complication of total ankle arthroplasty. J Bone Joint Surg Am. 2010;92-A(11):2115-20.
26. Courville XF, Hecht PJ, Toeteson ANA. Is total ankle arthroplasty a cost-efffective alternative to ankle fusion? Clin Orthop Relat Res. 2011;469:1721-7.
27. Doets C, Vergouw D, Veeger HEJ, Houdijk H. Metabolic cost and mechanical work for the step-to-step transition in walking after successful total ankle arthroplasty. Hum Movement Sci. 2009;28:786-97.
28. Johnson AR. A closer look at the future of total ankle arthroplasty. Podiatry Today. 2009;22(5):28-32.