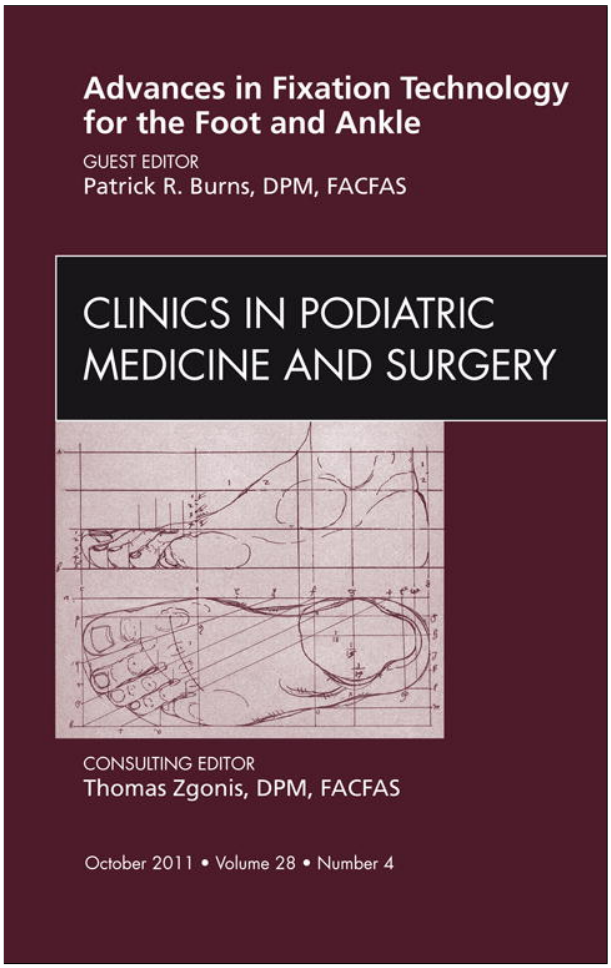

Total Ankle Replacements: An Overview

Lawrence A. DiDomenico, DPM[a,b,c,*], Michelle C. Anania, DPM[c]

KEYWORDS

• Total ankle replacement • Ankle arthroplasty • Ankle arthritis
• Ankle arthrodesis

First performed in the early 1970s, the total ankle replacement (TAR) gives patients who are affected by end-stage ankle arthritis an alternative to fusion. Like an ankle arthrodesis, the purpose of an ankle arthroplasty is to eliminate pain; however, the arthroplasty also looks to maintain function.[1–5] Total joint replacement, whether it is the hip, the knee, or the ankle, involves the removal of the arthritic joint and substituting it with an artificial joint to retain motion. Because of the biomechanics involved at the ankle joint, the TAR is a much more challenging procedure when compared with the hip and knee replacements. In addition, various conditions, if present, add to the level of surgical difficulty and decrease the chance of a successful outcome. These conditions include deformity from posttraumatic arthritis, diabetic neuropathy, and inadequate soft tissue envelope.[4,6,7] Coetzee and DeOrio[8] thought that the TAR will never become as commonplace as the knee and hip replacements because of the level of difficulty and the number of conditions that can adversely affect the outcome.

Since the first TAR was implanted, its short- and long-term benefits have been compared with those of an ankle arthrodesis, the traditional gold standard for end-stage ankle arthritis. Saltzman and colleagues[6] pointed out that the primary indication for both the TAR and the ankle arthrodesis is pain. In their study, they compared the clinical findings of both procedures. They found a better outcome in pain relief and retained motion in those patients who had a TAR at the 2- to 6-year postoperative mark. In another study, the same authors showed a better level of function and a greater level of pain relief in those patients with a TAR compared with those with an arthodesis.[9] Furthermore, Barg and colleagues[10] claimed that most patients with a TAR report favorable outcomes regarding pain relief and ankle function.

[a] Ohio College of Podiatric Medicine, Cleveland, OH, USA
[b] Section of Podiatric Medicine and Surgery, St Elizabeth's Medical Center, Youngstown, OH, USA
[c] Ankle and Foot Care Centers, Youngstown, OH, USA
* Corresponding author. 8175 Market Street, Youngstown, OH 44512.
E-mail address: LD5353@aol.com

Clin Podiatr Med Surg 28 (2011) 727–744
doi:10.1016/j.cpm.2011.08.002 **podiatric.theclinics.com**
0891-8422/11/$ – see front matter

The short-term results of an ankle fusion are generally very good, but the long-term results are not as clear and tend to be riddled with complications such as pseudoarthrosis, malunion/nonunion, gait abnormalities, and a long period of recovery. The most common complication is the development of arthritis in the adjacent joints, that is, the calcaneocuboid joint, talonavicular joint, subtalar joint, and knee. The subsequent arthritis may necessitate the need for further surgical intervention.[1,9,11–13] Hintermann and colleagues[13] pointed out that the chances of a young patient with an ankle arthrodesis developing premature degenerative arthritis in the hindfoot are very likely. This is because of the increase in the amount of stress and demand on the surrounding joints.[4,13] Lagaay and Schuberth[14] explained the manner the more distal joints compensate changes when the motion is taken away at the ankle, as in the case of a fusion. This has a significant effect on gait.

Because the outcomes of TAR are significantly improving, surgeons who are trained in TAR are more likely to perform a TAR than a fusion. For some surgeons, TAR is actually viewed to be superior over an arthrodesis because of the preserved motion and, more importantly, the decrease in stress and demand on the distal joints.[3,15] The current ankle implants are proving to be a valuable treatment option for those patients with severe arthritis and those who meet the criteria for ankle replacement. Some surgeons now consider an ankle arthrodesis a salvage procedure.[3,11] Even regarding patients with rheumatoid arthritis, Bonnin and colleagues[16] recommended using a TAR over a fusion because of the increased chance of returning to normal or near-normal activity level. Steck and Anderson[17] also recommended a TAR on patients who have already undergone a triple arthrodesis; however, they explained that a TAR can only be performed in those patients in whom a malaligned triple is not the reason for the ankle arthritis. If deformity is present, then the patient will need a pantalar fusion.

ADVANTAGES AND DISADVANTAGES

A major advantage of the TAR is the preservation of ankle motion. However, TAR typically only preserves the current level of motion in the ankle at the time of surgery. Other advantages include the decreased stress across the distal joints, which decreases the risk of developing premature degenerative arthritis; restoration of the dynamics of the ankle; increased comfort and functional recuperation; and having the option to revise the prosthesis or convert the prosthesis to a fusion if the original replacement fails.[4,7,16,18] Bonnin and colleagues[16] discovered that the use of a TAR can actually improve the patient's quality of life. TARs allow the return to recreational and/or light-impact activities and sports. A return to high-impact activities and sports, however, is not recommended and highly unlikely.

The risk of TAR includes significant complications and failure that may still then necessitate an arthrodesis.[16] Patients who experience significant complications such as deep infection and wound problems require significant intervention, and the subsequent need for a below-knee amputation is a possibility.

INDICATIONS AND CONTRAINDICATIONS

TAR is indicated for patients with end-stage ankle arthritis. The pathologic condition of the arthritis can be either primary or secondary. Secondary osteoarthritis, that is, posttraumatic arthritis, accounts for most of the cases of ankle arthritis. Posttraumatic arthritis is the leading cause of ankle arthritis and can be because of a history of a fracture involving the ankle joint or even a history of ankle sprains leading to chronic lateral

ankle instability. Chronic inflammation in the ankle joint because of gout, rheumatoid arthritis, psoriatic arthritis, infection, hemophilia, hemochromatosis, and osteochondritis dissecans can also lead to severe damage of the ankle joint.[3,4,8,17,19–26] Patients with hemophilia typically have a target joint in which recurrent episodes of hemarthrosis eventually cause severe damage to the joint. Typically, the standard of care for a patient with hemophiliac arthritis is an ankle fusion; however, the TAR is proving to be a valuable option although it is still considered controversial.[11] Charcot neuroarthropathy and tumors can also lead to arthritis; however, at present, these conditions are contraindicated for TAR surgery.

Increasing comfort with the implant designs and techniques is making TAR a more viable treatment option in patients with pain because of a failed ankle arthrodesis. Whether failure is because of a nonunion, malunion, continued pain after fusion, or pain associated with osteoarthritis of the adjacent joints, TAR may be an option.[27] However, in this patient population, it is mandatory for the patient to have their fibula intact when the arthrodesis was performed. Revisions in the case without the fibula can have a significant negative effect on outcomes and, therefore, are not recommended.

One of the most critical steps in achieving a successful outcome is proper patient selection. There are no clear-cut guidelines regarding the inclusion and exclusion criteria.[8,17] General indications include an older patient, one who is near the age of 55 years, with a low physical demand, good bone stock, intact neurovascular status, an intact immune system, good alignment of the ankle, and no ligamentous laxity.[17]

Van Den Heuvel and colleagues[3] divided the contraindications for a TAR into absolute and relative.

Absolute contraindications

1. An active or recent infection in or around the ankle joint.
2. A neuropathic joint, which may lead to further breakdown and instability.
3. Poor bone stock of the talus because of severe osteoporosis or avascular necrosis of more than 50% of the talar body.
4. Poor quality of the skin and soft tissue envelope surrounding the ankle, including skin disease, which will lead to a greater chance of wound dehiscence and infection.
5. Any type of neurologic dysfunction of the affected limb such as paralysis.
6. Severe irreducible malalignment of the leg, ankle, or foot.
7. Chronic ankle instability.
8. Peripheral vascular disease. Many surgeons do not recommend surgery on patients with digital pressures less than 70 mm Hg.
9. Noncompliance.
10. Chronic pain syndrome.[1,3,4,8,23–25]

Suggestions as to the cutoff point for performing a TAR in the presence of a varus or valgus hindfoot deformity range from 10° to 30° in either direction.[1] Many surgeons consider a varus or valgus hindfoot deformity of more than 20° to be an absolute contraindication for a TAR.[1,3,4,8,20,21,23,28] Some surgeons suggest stricter guidelines, that is, the degree of deformity should not be greater than 10° to 15° of either varus or valgus.[29] Coetzee recalled a series of 200 patients who had a TAR with a preoperative varus deformity of more than 20°. Postoperatively, the failure rate was 50% and the failed TARs were converted to an arthrodesis. Because of the unacceptably high failure rate, the author avoids performing a TAR on any patient with more than 20°

of varus deformity.[21] Mendicino and colleagues[4] first observed the ankle joint as being either congruent or incongruent. If the patient has more than 15° of varus or valgus deformity in a congruent ankle joint, or if there is more than 10° of varus or valgus deformity in an incongruent joint, then a TAR should be avoided. They explained further that any deformity that will not allow the foot to be plantigrade will cause the implant to fail because of the increase in stress and strain across the device; thus, a TAR should also be avoided in these cases. If malalignment is present, it needs to be corrected either before a TAR, making this a 2-stage procedure, or at the time of the TAR, a 1-stage procedure.[3]

Regarding relative contraindications, Steck and Anderson[17] strongly advised considering an alternate form of treatment if multiple relative contraindications exist with a patient.

Examples of relative contraindications:
1. Young age
2. High physical demands
3. Obesity
4. Diabetes
5. Previous open ankle fracture or dislocation
6. History of osteomyelitis that was successfully treated
7. Malnutrition
8. Smoker
9. Immunosuppression therapy, that is, long-term steroid use.

In their study of patients with a mean age of 44 years or younger who had a TAR, Spirt and colleagues[30] found these younger patients to be 1.45 times likely to require further surgery. In addition, the risk of failure was more than 2.5 times greater in the younger patients compared with the patients older than 54 years. Lagaay and Schuberth[14] discovered in their study a significant association between high patient satisfaction levels and those patients aged at least 60 years with a body mass index of less than 30. However, they explained that the level of satisfaction may be related more to the length of time a patient has been in pain than to the actual age of the patient. For example, a 65-year-old patient who has been in pain for 20 years may report a higher level of satisfaction than a 40-year-old patient who has been in pain for 5 years. Kofoed[25] did not consider young age to be a contraindication; however, the patient must be made aware of the implant's inability to tolerate high-impact forces associated with running and jumping. The age of the patient is associated with the level of physical demand. Younger patients usually have higher physical demands. The older patient tends to have a lower physical demand, which means less force and impact across the implant and the less chance of failure.

Absolute contraindications also exist when converting an ankle fusion into an ankle arthroplasty, which include the presence of clubfoot, Charcot neuroarthropathy, poor circulation, and large scars on the medial aspect of the ankle along with severe compromise of the soft tissue structures. Relative contraindications include an absent distal fibula, valgus deformity, severe dorsal soft tissue contractures secondary to prolonged immobilization, and leg shortening greater than 3 cm (**Fig. 1**A, B).[13]

BIOMECHANICS

Because of the biomechanics involved at the level of the ankle, one cannot compare an ankle replacement with a replacement of the hip or knee. The ankle needs to be able to withstand 500% of the patient's body weight during the normal gait cycle on

Fig. 1. (*A*) and (*B*) Demonstrating a patient who is an ideal candidate for TAR. The patient is affected by posttraumatic arthritis and is elderly and thin, and his activities consist of light physical demand with no significant deformity.

a much smaller surface area. The slightest variation in the surface alignment of the ankle joint can lead to implant failure. Joint incongruity can cause polyethylene wear and osteolysis.[31] Lee and colleagues[32] performed a study to examine the patient's static and dynamic postural imbalance 1 year after TAR. In the motor impairment arm of the study, patients with TAR demonstrated a decrease in motor control. In the sensory impairment arm of the study, there was no difference in proprioception between patients with TAR and the control group. However, there was a significant degree of dynamic postural imbalance with the patients with TAR. These patients were found to rely more on hip function to keep their balance. The authors surmised that this may be related to the decrease in muscle strength at the leg and ankle along with the decrease in reflexes at the ankle. Morgan and colleagues[33] described the results of a gait analysis study conducted by Piviou and colleagues on patients with TAR, which showed a better overall gait analysis regarding pattern, timing, and distribution of ground reaction force compared with patients with an ankle arthrodesis.

DESIGNS

Lord and Marotte introduced the first TAR in the early 1970s.[3,34] The implant had a ball-and-socket–type design based on the hip replacement. Of the 25 patients who underwent the TAR procedure, 18 patients failed. Because of this unacceptably high failure rate, they recommended fusing the ankle joint than trying to replace it.[3] Later, first-generation implants were constrained or unconstrained, cemented, 2-component systems consisting of a polyethylene concave tibial component and a metal convex talar component.[2,3,24] These implants acted like a hinge joint, allowing motion in only 1 plane. The constrained version generated force on the cement-bone interface, which led to loosening of the implant,[1,4,17,18] whereas the early unconstrained designs, which allowed the most movement, relied on the collateral ankle ligaments for support. This unconstrained version was prone to displacement because of the inherent instability.[1,35] Other common complications of the first-generation implants were subsidence and osteolysis.[17,35]

The survival rate at less than 5 years for the first-generation implants was 80% to 85%; however, long-term outcomes proved to be very poor. The revision rate was upward of 40%.[3,17] Factors contributing to the high failure rate include the nonanatomic or malconstrained designs, the use of cement, the need for aggressive bone resection, poor patient selection, and poor surgical technique.[4,9] Van Den Heuvel and colleagues[3] thought that the high rate of failure could be attributed to the use of cement in the constrained designs. Because of the poor outcomes, first-generation designs were quickly abandoned and are no longer in use.[12,36]

Examples of first-generation designs are the Conaxial ankle replacement and the Mayo TAR.[3,5]

The high failure rate of the first-generation implants led to the development of the second-generation implants.[37] Technical improvements included a less-constrained design to decrease the amount of shear and torsion, the need for less bone resection, and uncemented designs. The tibial and talar components were given stems and pegs to assist with stability and load distribution by allowing bony ingrowth than relying on cement.[3,4,7] With new implant designs, a new set of complications arose, including failure of the polyethylene insert, instability, impingement, and component dislocation.[4]

The second-generation implants are uncemented, 2-component, polyethylene-on-metal designs that can be divided into 1 of 2 types. The first type is a 2-component, fixed-bearing implant in which the polyethylene insert is fixed to the tibial component.

This gives the implant 1 point of articulation between the talar and the tibial components. This type of fixed or semiconstrained design is used in the United States at present. The second type of second-generation implant is the 3-component, mobile-bearing implant. This type has a polyethylene insert that is not fixed to either the tibial or the talar component. It is free to move between the 2 components, thus giving the implant 2 points of articulation. This freely moving meniscus greatly reduces the amount of shearing on any 1 surface. Also, the lack of constraints on the insert reduces the amount of wear on the insert.[1–3,17,35] The Scandanavian total ankle replacement (STAR) is at present the only Food and Drug Administration–approved mobile-bearing implant used in the United States.

The STAR implant was designed by Dr Hakon Kofoed in 1978 and first came into use in the early 1980s. The original design was a 2-component, cemented, unconstrained, fixed-bearing implant. Because of the high rate of loosening associated with this design, many modifications took place. The STAR ankle implant is now a 3-component, uncemented, mobile-bearing device that requires minimal bone resection. The newer design decreases the rotational stress at the bone-implant interface and is the most commonly used ankle replacement system in Europe.[3,4,35,37]

The Buechel-Pappas ankle implant was introduced in the United States in 1981. At present it is an uncemented, 3-component, mobile-bearing device. The talar component has a fin-type fixation design that reduces the amount of subsidence.[3,37] This implant is not available in the United States at present.

The Agility ankle implant was introduced in 1984 by Frank Alvine, MD. This was the first and most popular implant of its generation in early 2000s in the United States and is a fixed-bearing, semiconstrained design. This ankle implant, unlike any other, requires a fusion of the syndesmosis to allow load sharing through the fibula. The fusion improves overall stability and provides support to the tibial component. This implant also requires the use of an external fixator for distraction during surgery.[3,8,36–38]

The idea of soft tissue balancing led to the development of the third-generation designs. These implants place more emphasis on stability by relying on the collateral ligaments. Most of these designs are noncemented, 3-component, mobile-bearing implants that require minimal bone resection. The polyethylene insert is not fixed to either component.[2,3,33,34,36]

Initially, these implants had a flat tibial component and a convex talar component. This design created a lot of instability in the ankle, which ultimately led to implant failure. The latest versions copy the natural movements of the ankle joint, thus decreasing the amount of strain on the ligaments. These designs have a talar component that mimics the natural anatomic shape of the talus and a tibial component that is convex and spherical than flat. This is found to be compatible with the ankle ligaments.[11,23,34]

The metal tibial and talar components are made of either cobalt-chromium or a combination of cobalt-chromium and titanium. Hydroxyapatite is used as a coating to facilitate bone fixation in the implants used in Europe. The implants used in the United States and Canada have a titanium porous coating.[3,39] Compared with the second-generation implants, the third-generation implants have a second interface between the tibial component and the polyethylene insert, which allows for better adaptation to changes in position, thus decreasing the degree of abnormal loading on the ligaments and the degree of wear on the insert.[11]

There are approximately 23 different types of third-generation implants in use worldwide at present. One example is the BOX ankle, described by Giannini and colleagues.[23] This implant has tibial and talar component shapes that are

nonanatomic, and the polyethylene insert is fully conforming. This version can only be used in patients with stable ankle ligaments because the implant allows the ligaments to remain isometric during passive motion (**Figs. 2–4**).[23,37]

PREOPERATIVE DEFORMITIES

When ankle deformities, most importantly a varus or valgus deformity, are present preoperatively, they must be corrected before or in conjunction with the insertion of a TAR to ensure a successful outcome. Because of the location of the foot to the ankle and the role the foot plays in balance and alignment, a stable plantigrade foot will have a positive effect on the success rate of the TAR.[8,21]

The ipsilateral lower limb of the affected ankle needs to be thoroughly examined. Any bony deformity above, at, or below the level of the ankle joint can adversely affect the alignment of the ankle and the function of the TAR.[1,17,21] Failure to correct any preoperative deformity leads to premature failure of the implant because of edge loading, bearing subluxation, and polyethylene wear.[22]

Many surgeons agree that the presence of either a varus or a valgus deformity makes the TAR procedure much more challenging and the outcome less successful.[8,21] If a preoperative varus or valgus deformity is not corrected, this increases the risk of implant failure because of instability, implant tilting, bearing subluxation, or bearing dislocation.[29] There is a wide disparity, and many varying opinions are in the literature of the correctable upper limits of frontal-plane deformities. Patients with a varus or valgus deformity of more than 10° are at a greater risk of developing instability and bearing subluxation. In addition, a study by Haskell and Mann revealed a 10 times greater risk of developing edge loading in an incongruent joint.[1] Hobson and colleagues[15] demonstrated that when the proper steps are taken to surgically correct the varus or valgus deformity at the time of the TAR, patients with a preoperative deformity of up to 30° are not at an increased risk of developing postoperative complications and implant failure. The authors conceded that still the most common type of failure especially in patients with more than 20° of deformity is instability. For any deformity greater than 30°, a fusion is recommended. Coetzee[21] recommended an arthrodesis in those ankles with greater than 20° of deformity. Fifty percent of the patients who had a TAR performed in an ankle with more than 20° of preoperative varus deformity went on to failure within 3 years. Wood and colleagues[28] recommended a fusion when the varus or valgus deformity is more than 20°. Anders and

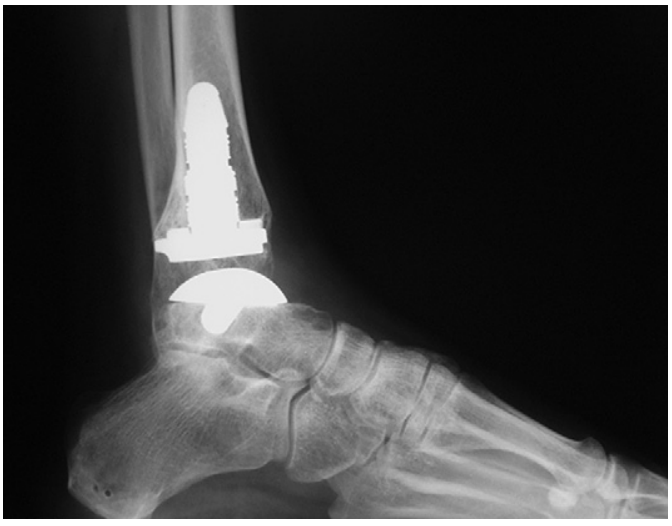

Fig. 2. A postoperative lateral radiograph of an in-bone ankle arthroplasty.

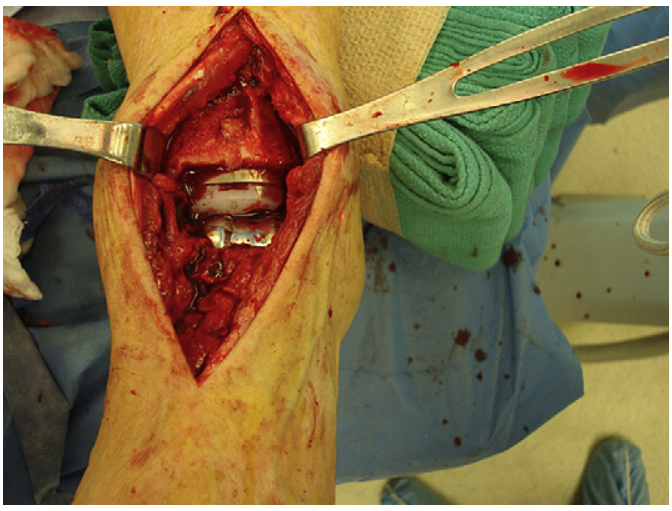

Fig. 3. An intraoperative view demonstrating an operative view of a Salto Tolaris ankle implant after insertion into the distal tibial-talar joint.

colleagues[19] also advised doing an ankle fusion over a TAR in patients with a severe varus or valgus deformity.

Recently, Shock and colleagues[40] demonstrated a stepwise approach for consistent correction for coronal-plane deformities.

Regarding valgus deformities, Coetzee and DeOrio[8] stated that mild to moderate cases can usually be corrected with a medial calcaneal osteotomy and a repair of

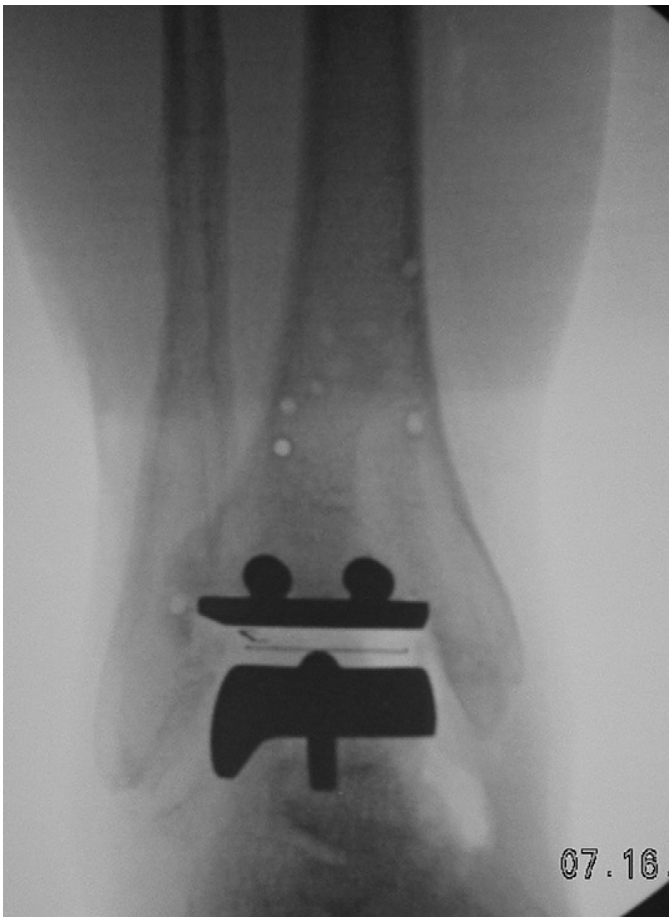

Fig. 4. An intraoperative anteroposterior view after insertion of a STAR implant.

the medial soft tissue structures including the deltoid ligament. In more severe cases, a double-stranded allograft is needed to reconstruct the deltoid ligament. In patients with rheumatoid arthritis, a valgus ankle is reported as the most common deformity, found in as much as 29% of patients who have had rheumatoid arthritis for more than 5 years (**Fig. 5**).[1,25]

A varus deformity can be caused by lateral instability, bony erosion, or a combination of both. Correction of a varus deformity should take place in a proximal-to-distal direction, making the TAR the last procedure performed.[21] A stepwise approach has been developed by Alvine to classify the degree of varus deformity and how it should be surgically managed. Stage 1 is a mild deformity because of medial bone erosion. The varus deformity can be eliminated with the tibial bone cuts. Once the tibial component is in place, the surgeon should test for medial and lateral instability and make any needed repairs. The instability can usually be corrected with a lateral ligament repair. A simple Broström repair, however, does not provide enough strength to maintain stability. Stage 2 deformities have a combination of bony erosion of the medial malleolus and contracture of the medial soft tissue structures. Large osteophytes are also noted in the lateral gutter of the ankle joint. Multiple corrective procedures need to be performed before the TAR to eliminate the varus deformity, restore motion by removing the osteophytes, and restore stability. If the medial soft tissue structures are tight, a release of the deep deltoid ligament or a distal sliding osteotomy of the medial malleolus is performed. If a varus deformity is still present in the hindfoot even after the ankle joint has been mobilized and realigned, then a lateral closing wedge calcaneal osteotomy needs to be performed. Stage 3 deformities are characterized by severe instability along with secondary deformities. These patients require not only an ankle arthrodesis but also a fusion of the subtalar joint because of the degree of arthritis present. TARs are not advised at this stage.[8,21]

Kim and colleagues[29] developed algorithms for moderate to severe ankle varus deformities to assist in proper surgical correction. The first step is to identify the varus deformity as either congruent or incongruent, which is determined by the degree of talar tilt. A talar tilt of less than 10° is considered congruent, whereas that of more than 10° is incongruent. In congruent deformities, the ankle mortise is usually tilted along with the talus. To correct this, the tibia is cut to neutralize the mortise along

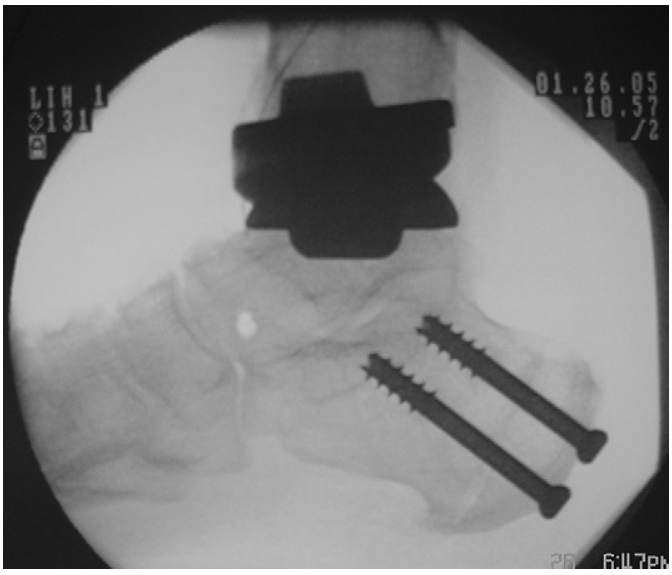

Fig. 5. An interoperative lateral radiograph demonstrating an Agility ankle implant. The patient had a preoperative calcaneal varus deformity; thus, a lateral slide calcaneal osteotomy was performed.

with a medial soft tissue release. Incongruent deformities are because of contracture of the medial soft tissue structures. In these cases, the ankle mortise is properly aligned. Balancing the lateral soft tissue structures results in a neutral ankle.

When converting an ankle arthrodesis into an ankle arthroplasty, Hintermann and colleagues[27] recommended examining the surrounding joints for arthritic changes. If arthritis is present, fusion of the adjacent joints should take place before the takedown of the ankle fusion. Other preoperative abnormalities, if present, that need to be surgically addressed before a TAR include medial and lateral ligament insufficiency, an equinus deformity, and malalignment of the calcaneus.

COMPLICATIONS

According to Steck and Anderson,[17] complications from a TAR procedure occur because of 1 of 3 reasons: poor patient selection, inexperience on behalf of the surgeon, or surgical error. The TAR has a steep learning curve, and the success of the implant depends on the level of the surgeon's experience. Also one must keep in mind that every new implant has its own learning curve. Lee and colleagues[41] explained that the rate of complication decreases as the surgeon's experience with the implant increases. The authors described a study of 50 patients who underwent TAR using the Hintegra device (Life Sciences Plainsboro, NJ, USA). The first 25 patients had a higher incidence of complications compared with the last 25 patients. The chance of a successful outcome also increases as the surgeon's experience increases.[10,17,19,41,42]

Performing a TAR on the proper patient also aids in decreasing the risk of postoperative complications and in increasing the chance of a successful outcome. Therefore, patients should meet strict criteria through strict inclusion guidelines and a thorough perioperative workup. Proper surgical technique and choosing the proper implant also play an important role in achieving a successful outcome and in decreasing the rate of complications.[3,4] Certain conditions, however, are prone to a higher complication rate because of the pathologic condition of the arthritis. Bai and colleagues[43] found the rate of complication to be higher in patients with posttraumatic arthritis compared with those with primary osteoarthritis.

Glazebrook and colleagues[12] thought that the rate of a complication is not an accurate measure of its severity; therefore, they divided the complications of a TAR into 3 groups based on its effect on the outcome, that is, its rate of failure. The 3 groups are low-, medium-, and high-grade complications. Low-grade complications have minimal risk of causing TAR failure, and examples include intraoperative fractures and superficial wound issues. Medium-grade complications cause failure of the implant less than 50% of the time and include technical error, subsidence, and postoperative fractures. High-grade complications cause failure of the implant more than 50% of the time and include deep infection and aseptic loosening.

Wound complications can be categorized as either major or minor. Minor wounds tend to be superficial, require local care only, and pose no threat to the implant. Necrosis of the skin edges is considered a minor wound complication. A major wound is an infection of the deep soft tissue layers that poses a threat to the implant. To decrease the incidence of wound complications, the surgeon should limit the amount of dissection, take care when using retraction, and limit the degree of plantar flexion at the ankle postoperatively, that is, keep the ankle in a neutral position.[17,27] Deep infections need to be handled promptly. The necrotic tissue needs debridement, and cultures need to be taken for proper intravenous antibiotic coverage. Deep infections can lead to septic loosening of the implant, which results in its removal and the

insertion of an antibiotic cement spacer. Any type of revision is held off until the infection is completely eradicated. Infection rates range from 0.5% to 3.5% and are higher among an ankle arthroplasty than a knee or hip arthroplasty.[11,19,36]

Subluxation of the polyethylene insert, also known as edge loading, decreases the amount of contact between the insert and the metal components. This causes polyethylene wear particles to buildup, leading to osteolysis. The wear particles stimulate a macrophage-mediated cystic response in the bone. The inflammation mediators, specifically interleukin 1 and 2, tumor necrosis factor, and prostaglandin, inhibit osteoblasts and stimulate osteoclastic activity. Osteolysis is seen on a radiograph as lucent areas in the talus, tibia, and/or the fibula. Mechanical lysis is also known as ballooning lysis and presents early in the postoperative course. This type of lysis is because of remodeling of the tibia and stress shielding and is not a threat to the implant. Expansile lysis occurs late in the postoperative course and is progressive to the point in which bone grafting is needed to counteract any weakness in the bone. This type of lysis is usually because of an abnormal wear.[17,20,44,45] Besse and colleagues[20] evaluated the rate of osteolysis when using the ankle evolutive system (AES). They observed a higher rate of osteolysis, which led to a higher rate of subsidence. Because of this finding, the authors have discontinued using this system. Koivu and colleagues[44] found the risk of osteolysis to be more than 3 times higher in patients with the AES implant because of the dual-coating, titanium-hydroxyapatite coating than in those with implants that have only the hydroxyapatite coating. Because of the concerns regarding the high rate of osteolysis when using the AES implant, the manufacturer has withdrawn the implant from use.[33]

Subsidence of the prosthetic components requires revision of the implant, which can be because of poor bone quality, overly aggressive bone resection, improper implantation of the device, use of a device that is too small, and sepsis.[1,17]

Loosening of the implant is caused by a failure of bony ingrowth on the implant or an interruption of bony ingrowth, also known as aseptic loosening. Patients complain of pain and have a dark halo around the implant. The halo is because of the lack of bony ingrowth.[17] Loosening of the talar component may be because of malalignment, poor bone quality, noncompliance, and malrotation of the talus. Talar malrotation can lead to an increase in polyethylene wear and an increase in rotational torque.[31]

Fractures of the medial and lateral malleolus can show up either early or late in the postoperative course and are the result of surgical error. Early fractures are often the result of surgeon error by commission. Late fractures are usually the result of a surgeon's negligence, resulting in an improperly balanced ankle.[20] The medial malleolus is commonly fractured. One or 2 Kirschner wires can be driven into the medial malleolus before making the horizontal cuts, which prevents overzealous cuts, thus decreasing the risk of fracture. This same technique can also be used to prevent fractures on the lateral malleolus (**Figs. 6** and **7**).[27,29]

Malalignment can be prevented with careful preoperative planning and the use of fluoroscopy throughout the procedure. When present, malalignment will cause an increase in the amount of force generated between the metal component and the bone, which in turn leads to osteolysis because of the buildup of polyethylene wear particles.[27,29]

Sensory deficits and nerve damage occur if any 1 of the nerves that cross the ankle joint is lacerated during surgery. Traction injuries can also occur because of nerve exposure. The superficial peroneal nerve and its branches are at greatest risk for injury because of its close proximity to the anterior incision. Careful dissection is needed to prevent injury to this nerve and any other nerve that is in or near the area of dissection.[17,27,36]

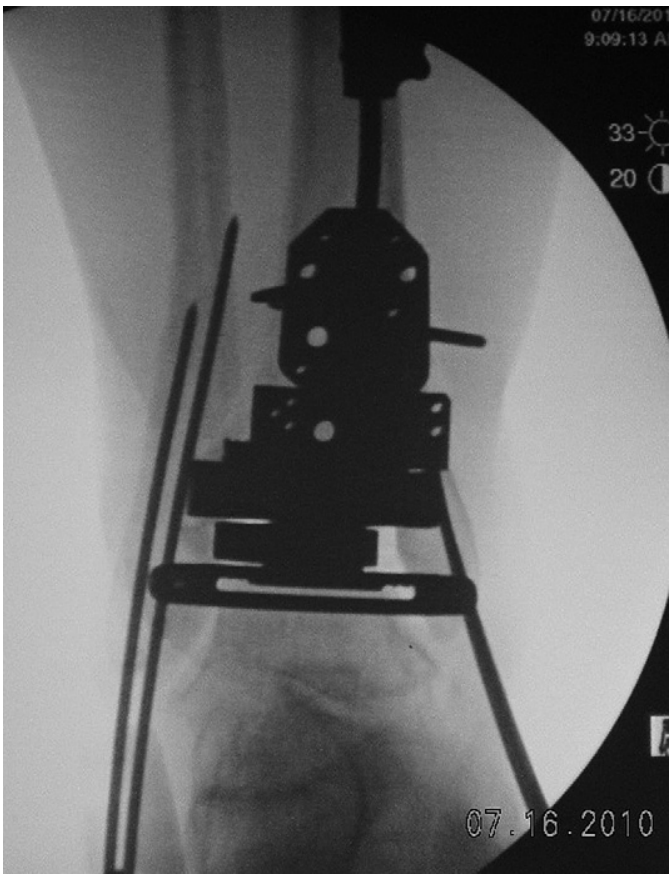

Fig. 6. An intraoperative view demonstrating the use of 2 Kirschner wires on each of the medial and lateral malleolus to avoid fracturing the malleolus before making the tibial bone cuts.

A complication that is unique to the Agility implant is nonunion of the syndesmosis. A nonunion can increase the risk of malalignment of the tibial component, subsidence, and osteolysis. If the nonunion persists for more than 6 months, revision is needed.[7,8]

Kim and colleagues[46] found that patients who had a TAR performed simultaneously with a hindfoot fusion were at a greater risk for instability and dislocation, whereas those who had the TAR and the hindfoot procedures done as a 2-stage process were at a greater risk of developing complications with the soft tissue, such as scarring and bony impingement. In another study, Kim and colleagues[46] noticed an increase in the degree of osteolysis in patients who had a TAR in association with a hindfoot fusion compared with that in those who did not have a hindfoot fusion. This may have an adverse effect on the long-term success of the TAR.

Other complications that can occur with a TAR procedure are deep vein thrombosis, damage to the flexor hallucis longus tendon, and damage to the proprioceptors, which will lead to problems with postural balance (**Fig. 8**A–C).[1,27,32]

CLINICAL OUTCOMES AND SURVIVAL RATES

Barg and colleagues[42] thought that because of the favorable mid- and long-term results, a TAR is recommended in patients with rheumatoid arthritis and posttraumatic arthritis. In patients with hemophilic arthritis, the results are promising enough that they recommend a TAR over an arthrodesis. In a study of patients with hemophilia who had a TAR, all patients experienced a significant decrease in pain. Fifty percent of these patients went on to become completely pain free.

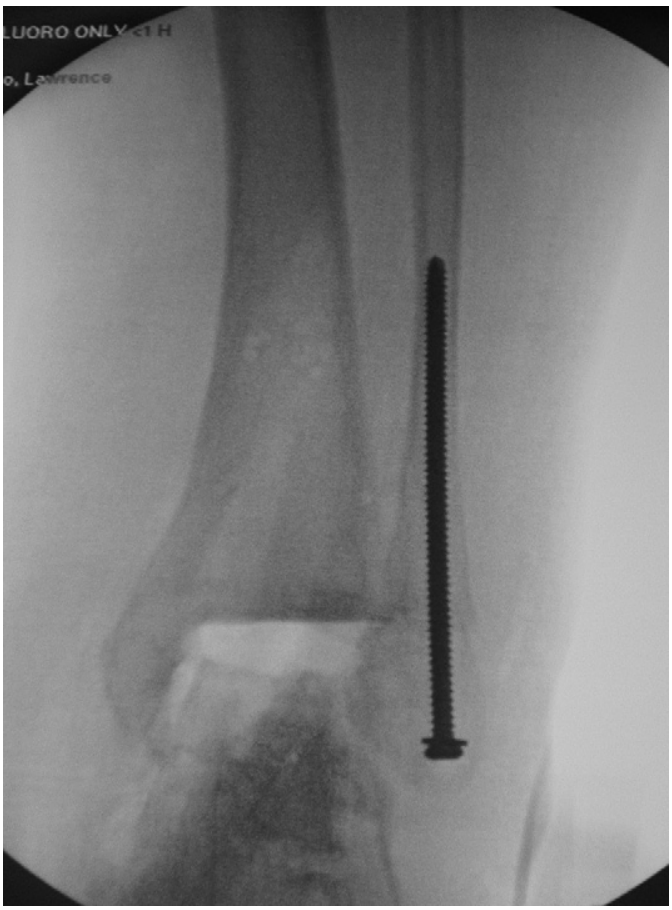

Fig. 7. An interoperative view using a 4-mm cortical screw for repair of a fibula fracture.

Barg and colleagues[10] performed simultaneous bilateral TARs on patients and noted that they had a significant decrease in pain; however, the mean pain score was higher compared with that of the unilateral group.

When analyzing TAR survival rates, Gougoulias and colleagues[24] advised against taking in the data at face value. Much of the information reported may be from the inventors of the implant, which gives a higher survival rate simply because of the familiarity with the implant.

The failure rate for first-generation implants was as high as 36%. For second-generation implants, the midterm results fair better, with a 5-year survival rate of 78% to 93% and a 10-year survival rate of 76% to 80%.[35]

Anders and colleagues[19] showed that consisting of a mid-term analysis of 93 TAR procedures performed with the AES implant, the 5-year survival rate was 90%. Besse and colleagues[20] had a 96% survival rate at 40 months postoperatively using the AES system in 50 ankles. However, because of the high rate of cyst formation and the risk of mechanical failure, the authors refrained from using this device.

Coetzee and DeOrio[8] had a survival rate of 80% in 300 ankles using the Agility implant. They went on to explain that Wood and colleagues had a 5-year survival rate of 93% using the STAR in 200 ankles. Doets and colleagues[47] had a survival rate of 84% at 8 years postoperatively on 93 implants.[1] Patients with rheumatoid arthritis also have good survival rates with TAR procedures. DiDomenico and colleagues[1] pointed out that Fevang and colleagues had a survival rate of 89% in patients with rheumatoid arthritis with a TAR at the 5-year follow-up and 76% at the 10-year follow-up. San Giovanni and colleagues[48] performed 31 TARs on patients with rheumatoid arthritis using the Buechel-Pappas implant. The survival rate was 93% at the 8.3-year average follow-up.[1]

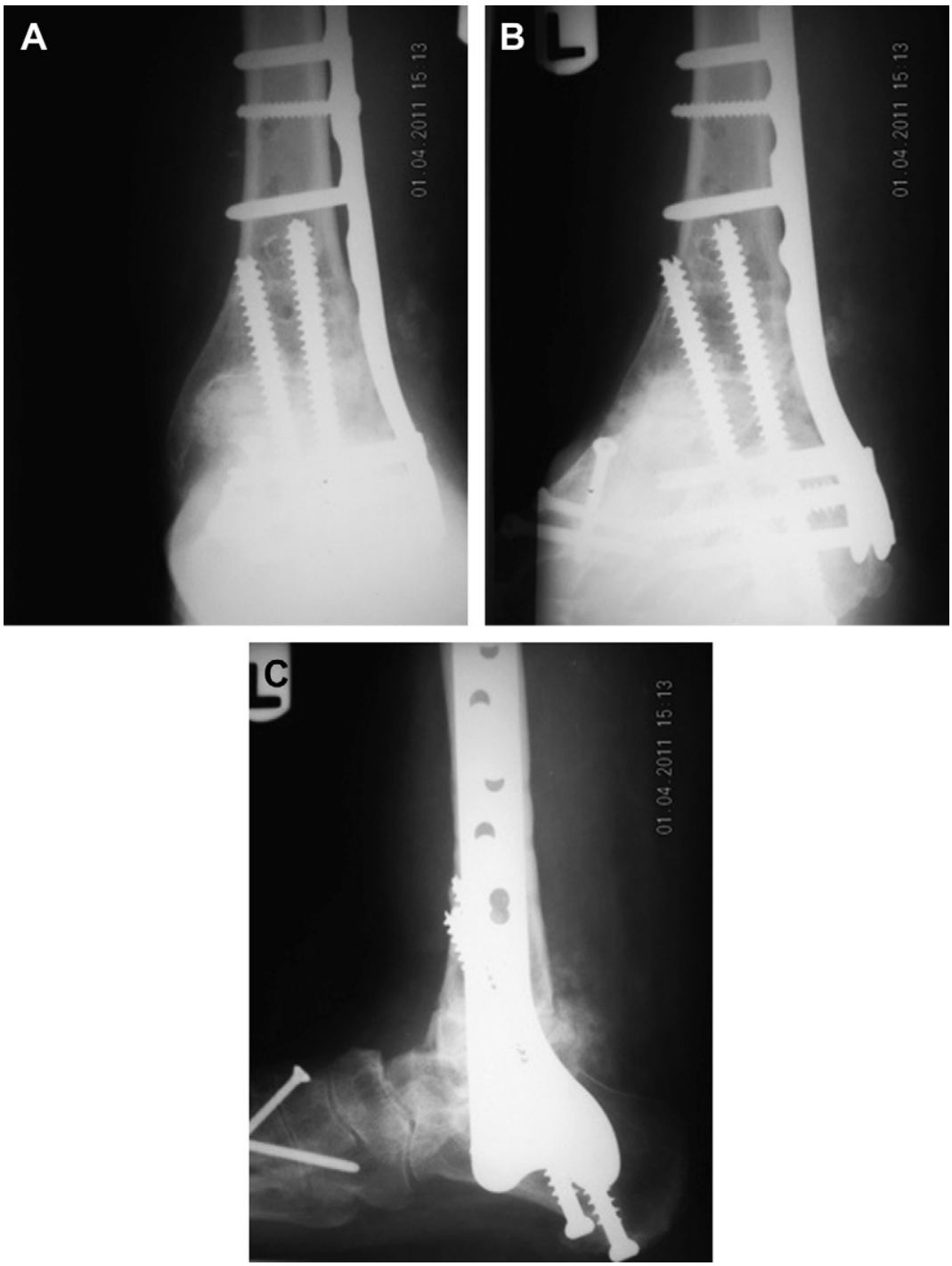

Fig. 8. Anteroposterior (*A*), lateral (*B*), and medial oblique (*C*) radiographic views of an ankle implant converted to an arthrodesis after trauma approximately 6 years after successful implant of an Agility implant. The trauma fractured the talus; therefore, this was converted to a tibal, talar, calcaneal arthrodesis using a femoral locking plate.

EXPECTATIONS

For a successful outcome, the surgeon must use the proper indications, proper patient selection, a well-designed implant, the lifespan of the implant regarding the patient's age, and the proper instruments. The surgeon must also take into account the patient's current level of activity and his or her expected level of function postoperatively.[14,16,19]

Bonnin and colleagues[16] explained that the patient's postoperative level of satisfaction relies heavily on whether his or her preoperative expectations were met. It is of utmost importance that the patient has realistic expectations and goals regarding the overall outcome. The authors further explained that younger patients tend to have unreasonably high expectations regarding their postoperative functional capacity. This is usually because younger patients tend to be more active and more likely to be affected by posttraumatic arthritis. The surgeon must clearly explain to patients that they can expect to participate in light recreational activities and nonimpact sports postoperatively. On the other hand, high-impact activities and sports, including any activity involving running and jumping, are unrealistic.

Gougoulias and colleagues[24] stated that patients need to be made aware preoperatively that an increase in range of motion at the ankle joint is not one of the benefits of a TAR. Postoperative range of motion should never be compared with physiologic motion. The amount of motion a patient can expect to have depends on the amount of motion present preoperatively.[8,14] Coetzee and DeOrio[8] pointed out that one can expect no more than a 5° improvement in range of motion postoperatively. This is thought to be because of the degree of stiffness or laxity present in the surrounding soft tissue. In their study, Gougoulias and colleagues[24] had an improved postoperative range of motion between 0° and 14°. According to Lagaay and Schuberth,[14] only 20° to 25° of total motion is needed at the ankle joint to avoid limping. Their study with the Agility implant was approximately 23° of total range of motion. Other studies ranged between 18° and 36° postoperatively. The authors showed that patient satisfaction does not necessarily correlate with the degree of ankle motion. Although patients expected more motion postoperatively, the amount of pain relief achieved significantly outweighs what little motion is gained.

SUMMARY

With the advent of the TAR, a viable option over an arthrodesis is now available for those patients with end-stage ankle arthritis. When compared with an ankle arthroplasty, the ankle arthrodesis has poor long-term outcomes and short- and long-term complications are common. Haddad and colleagues[49] have even demonstrated that the rate of amputation is higher in patients with anarthrodesis than in those with an arthroplasty. Proper training, strict patient selection, and proper implant contribute to a successful outcome. As advances continue to be made in both implant design and surgical technique, the benefits of a TAR are proving to be greater than those of an arthrodesis.

REFERENCES

1. DiDomenico L, Treadwell J, Cain L. Total ankle arthroplasty in the rheumatoid patient. Clin Podiatr Med Surg 2010;27:295–311.
2. Goldberg A, Sharp R, Cooke P. Ankle replacement: current practice of foot & ankle surgeons in the United Kingdom. Foot Ankle Int 2009;30:950–4.
3. Van Den Heuvel A, Van Bouwel S, Dereymaeker G. Total ankle replacement design evolution and results. Acta Orthop Belg 2010;76:150–61.
4. Mendicino R, Catanzariti A, Shadrick D. The STAR total ankle replacement. Foot Ankle Quarterly 2010;21:157–66.
5. Gougoulias N, Khanna A, Maffulli N. History and evolution in total ankle arthroplasty. Br Med Bull 2009;89:111–51.

6. Saltzman C, Kadoko R, Suh J. Treatment of isolated ankle osteoarthritis with arthrodesis or the total ankle replacement: a comparison of early outcomes. Clin Orthop Surg 2010;2:1–7.
7. Total ankle replacement for degenerative ankle disease. Supplement to OR Manager 2010;26(4).
8. Coetzee J, DeOrio J. Total ankle replacement systems available in the United States. Instr Course Lect 2010;59:367–74.
9. Saltzman C, Mann R, Ahrens J, et al. Prospective controlled trial of STAR total ankle replacement versus ankle fusion: initial results. Foot Ankle Int 2009;30:579–96.
10. Barg A, Knupp M, Hintermann B. Simultaneous bilateral versus unilateral total ankle replacement. A patient-based comparison of pain relief, quality of life and functional outcome. J Bone Joint Surg Br 2010;92:1659–63.
11. Barg A, Elsner A, Chuckpaiwong B, et al. Insert position in three-component total ankle replacement. Foot Ankle Int 2010;31:754–9.
12. Glazebrook M, Arsenault K, Dunbar M. Evidence-based classification of complications in total ankle arthroplasty. Foot Ankle Int 2009;30:945–9.
13. Hintermann B, Barg A, Knupp M, et al. Conversion of painful ankle arthrodesis to total ankle arthroplasty. J Bone Joint Surg Am 2009;91:850–8.
14. Lagaay P, Schuberth J. Analysis of ankle range of motion and functional outcome following total ankle arthroplasty. J Foot Ankle Surg 2010;49:147–51.
15. Hobson S, Karantana A, Dhar S. Total ankle replacement in patients with significant pre-operative deformity of the hindfoot. J Bone Joint Surg Br 2009;91:481–6.
16. Bonnin M, Laurent J, Casillas M. Ankle function and sports activity after total ankle arthroplasty. Foot Ankle Int 2009;30:933–44.
17. Steck J, Anderson J. Total ankle arthroplasty: indications and avoiding complications. Clin Podiatr Med Surg 2009;26:303–24.
18. Van der Heide H, Schutte B, Louwerens J, et al. Total ankle prostheses in rheumatoid arthropathy. Outcome in 52 patients followed for 1-9 years. Acta Orthop 2009;80:440–4.
19. Anders H, Knutson K, Johan L, et al. The AES total ankle replacement. A mid-term analysis of 93 cases. Foot Ankle Surg 2010;16:61–4.
20. Besse J, Brito N, Lienhart C. Clinical evaluation and radiographic assessment of bone lysis of the AES total ankle replacement. Foot Ankle Int 2009;30:964–75.
21. Coetzee J. Surgical strategies: lateral ligament reconstruction as part of the management of varus ankle deformity with ankle replacement. Foot Ankle Int 2010;31:267–74.
22. Frigg A, Nigg B, Hinz L, et al. Clinical relevance of hindfoot alignment view in total ankle replacement. Foot Ankle Int 2010;31:871–9.
23. Giannini S, Romagnoli M, O'Connor J, et al. Total ankle replacement compatible with ligament function produces mobility, good clinical scores, and low complication rates. An early clinical assessment. Clin Orthop Relat Res 2010;468:2746–53.
24. Gougoulias N, Khanna A, Maffulli N. How successful are current ankle replacements? A systematic review of the literature. Clin Orthop Relat Res 2010;468:199–208.
25. Kofoed H. Concept and use of the Scandinavian total ankle replacement. Foot Ankle Spec 2009;2:89–94.
26. Margolis D, Allen-Taylor L, Hoffstad O, et al. Intermediate and long-term outcomes of total ankle arthroplasty and ankle arthrodesis. A systematic review of the literature. Diabet Med 2004;22:172–6.
27. Hintermann B, Barg A, Knupp M, et al. Conversion of painful ankle arthrodesis to total ankle arthroplastyh Surgical technique. J Bone Joint Surg Am 2010; 92(Suppl 1):55–66.

28. Wood P, Karski M, Watmough P. Total ankle replacementh The results of 100 mobility total ankle replacements. J Bone Joint Surg Br 2010;92:958–62.
29. Kim B, Choi W, Kim Y, et al. Total ankle replacement in moderate to severe varus deformity of the ankle. J Bone Joint Surg Br 2009;91:1183–90.
30. Spirt A, Assal M, Hansen S Jr. Complications and failure after total ankle arthroplasty. J Bone Joint Surg Am 2004;86:1172–8.
31. Fukuda T, Haddad S, Ren Y, et al. Impact of talar component rotation on contact pressure after total ankle arthroplasty: a cadaveric study. Foot Ankle Int 2010;31: 404–11.
32. Lee K, Park Y, Song E, et al. Static and dynamic postural balance after successful mobile-bearing total ankle arthroplasty. Arch Phys Med Rehabil 2010;91:519–22.
33. Morgan S, Brooke B, Harris N. Total ankle replacement by the Ankle Evolution System. Medium-term outcome. J Bone Joint Surg Br 2010;92:61–5.
34. Affatato S, Taddei P, Leardini A, et al. Wear behaviour in total ankle replacement: a comparison between an in vitro simulation and retrieved prostheses. Clin Biomech 2009;24:661–9.
35. Karantana A, Hobson S, Dhar S. The Scandinavian total ankle replacement. Survivorship at 5 and 8 years comparable to other series. Clin Orthop Relat Res 2010;468:951–7.
36. Chou L, Coughlin M, Hansen S Jr, et al. Osteoarthritis of the ankle: the role of arthroplasty. J Am Acad Orthop Surg 2008;16:249–59.
37. Cracchiolo A, DeOrio J. Design features of current total ankle replacements: implants and instrumentation. J Am Acad Orthop Surg 2008;16:530–40.
38. DeOrio J, Easley M. Total ankle arthroplasty. AAOS Instr Course Lect 2008;57: 383–413.
39. Younger A, Penner M, Wing K. Mobile-bearing total ankle arthroplasty. Foot Ankle Clin 2008;13:495–508.
40. Shock RP, Christensen JC, Schuberth JM. Total ankle replacement in the varus ankle. J Foot Ankle Surg 2011;50(1):5–10.
41. Lee K, Lee Y, Young K, et al. Perioperative complications of the MOBILITY total ankle system: comparison with the HINTEGRA total ankle system. J Orthop Sci 2010;15:317–22.
42. Barg A, Elsner A, Hefti D, et al. Haemophilic arthropathy of the ankle treated by total ankle replacement: a case series. Haemophilia 2010;16:647–55.
43. Bai L, Lee K, Song E. Total ankle arthroplasty outcome comparison for posttraumatic and primary osteoarthritis. Foot Ankle Int 2010;31:1048–56.
44. Koivu H, Kohonen I, Sipola E, et al. Severe periprosthetic osteolytic lesions after the Ankle Evolutive System total ankle replacement. J Bone Joint Surg Br 2009; 91:907–14.
45. Wood P, Sutton C, Mishra V, et al. A randomized, controlled trial of two mobile-bearing total ankle replacements. J Bone Joint Surg Br 2009;91:69–74.
46. Kim B, Knupp M, Zwicky L, et al. Total ankle replacement in association with hindfoot fusion. Outcome and complications. J Bone Joint Surg Br 2010;92:1540–7.
47. Doets HC, Brand R, Nelissen RG. Total ankle arthroplasty in inflammatory joint disease with use of two mobile bearing designs. J Bone Joint Surg Am 2006; 88(6):1272–84.
48. San Giovanni T, Keblish D, Thomas W, et al. Eight-year results of a minimally constrained total ankle arthroplasty. Foot Ankle Int 2006;27(6):418–26.
49. Haddad S, Coetzee C, Estok R, et al. Intermediate and long-term outcomes of total ankle arthroplasty and ankle arthrodesis. J Bone Joint Surg Am 2007;89: 1899–905.