TOTAL ANKLE ARTHROPLASTY

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INTRODUCTION

Although primary degenerative disease of the ankle is virtually unknown, rheumatoid arthritis, post-traumatic degenerative disease, and osteochondritis dissecans affect the ankle with some frequency. When conservative treatment fails, the traditional surgical approach for the severely debilitated ankle has been arthrodesis. Arthrodesis is not without its disadvantages, however. Some of the problems encountered with ankle arthrodesis include continued pain, pseudoarthrosis, and lengthy cast immobilization.

In light of some of the reported disadvantages associated with ankle arthrodesis, along with the success achieved with component arthroplasty in other joints, efforts were focused on the development of an ankle joint prosthesis. Surgeons have been attempting to perfect an ankle implant since Dr. Morton Murdoc's trials in England in 1970 using an inverted total hip prosthesis. Between 1970 and 1990, trials were conducted on more than 9 designs produced by a wide-range of orthopedic hip and knee manufactures. All were working toward the same basic objectives of elimination of disabling joint pain, restoration of adequate motion, and increasing patient function. However, 50% failure rates were reported after implantation periods of 6 to 24 months. It was difficult to design an ankle that would duplicate hip and knee implant longevity.

Despite the failure of so many designs, three surgeons continued their work in an effort to perfect an ankle implant that could withstand the force of 5 times the body weight sustained by the ankle joint with each gait cycle. Frank Alvine, MD, in South Dakota began his work in 1979 and implanted his first Alvine Agility™ prosthesis in 1984. Hakron Koefod, MD began his work in the mid 1970s and implanted his prosthesis, the Scandanavian Total Ankle Replacement, (STAR™) in 1981 in Copenhagen. Frederick Buechel, MD and

Michael Pappas, Ph.D. began their ankle prosthesis design work in the early 1970s in New Jersey. They were noted for their previous development of the Low Contact Stress Total Knee (the New Jersey Knee), which utilized a moveable "meniscus" bearing of ultra high molecular weight polyethylene within the knee implant. They applied the moveable bearing idea to their New Jersey Ankle (later known as the Buechel-Pappas™ Total Ankle), and began implanting the three-piece ankle implant in the late 1970s. Over the last 20 years, approximately 2000 ankles have been implanted worldwide using these three prostheses.

EVOLUTION OF TOTAL ANKLE PROSTHESES

Morrey et al. described certain guidelines that were necessary for the ankle joint prostheses to function successfully. These guidelines are as follows:

* The materials used should provide low-friction motion and sufficient strength to withstand loads in excess of 5 times the body weight.
* The articular surfaces should not be subject to excessive wear.
* The design should give stability, yet allow sufficient motion for daily activity (a minimum of 25 degrees sagittal plane motion
* A minimum amount of bone and soft tissue should be resected so that salvage is feasible in the event of implant failure.
* The components should allow maximal surface area contact between bone and the prosthesis since contact area is inversely proportional to contact stress.

The first generation of ankle prostheses was based on a two-component system. These prosthetic designs can be further categorized into two types,

the design of a hip prosthesis. The stainless steel-polyethylene combination possesses a coefficient of friction of approximately 0.06, a low value that translates into reduced motion-energy requirements and diminished loosening forces at the prosthesis-bone interface. Interestingly, the shape of the polyethylene influences its wear characteristics. The wear of convex polyethylene has been found to be approximately 2.5 times greater than that of concave polyethylene. Since the talar component is usually convex and the tibial component concave, the use of polyethylene was generally limited to the talar component in the two-component designs.

The first generation of total ankle prosthetic components were typically cemented into place utilizing polymethylmethacrylate. Unfortunately, polymethylmethacrylate becomes brittle over time and may eventually crack under shear and tensile forces. Component loosening associated with cemented implants is well documented and remains the number one complication of total joint arthroplasty. Currently, there exist four published studies comparing the success of cementless versus cemented ankle prostheses. All four articles agreed that cementless implants demonstrated less component loosening and thus a higher survival rate. More specifically, Takakura et al. cited an 85% survival rate over 14 years for cementless implants compared to a 75% rate found in cemented implants over the same 14 year time interval. More encouragingly, Buechel and Pappas found a 94.75% survival rate over a 10 year period utilizing a cementless, meniscal-bearing design.

Cementless implants utilize a porous surface capable of inducing a living ingrowth of tissue and bone. The concept of a porous ingrowth system was originally investigated in the field of plastic surgery in the 1960s. The use of biologic fixation in ankle implants offers the advantage of continual bone remodeling for long-term component adherence. Concerns with porous-coated prostheses include long-term changes in medullary canal dimensions, metallic ion release to adjacent tissues, and the ease of retrieval in the event of failure.

INDICATIONS AND CONTRAINDICATIONS

The indications for total ankle arthroplasty have been heavily debated. Total ankle arthroplasty in general, is indicated when conservative treatment fails, in the event of failed ankle arthrodesis, and when ankle joint destruction is secondary to rheumatoid arthritis, post-traumatic degenerative joint disease, and in some cases of avascular necrosis of the talus. Although rarely undertaken, total ankle joint replacement is possible in some previously fused ankles. Currently, fusion take-downs are possible only with the Buechel-Pappas™ ankle implant. In addition, the distal fibula must be intact. There is general agreement that ankle arthroplasty is indicated in rheumatoid arthritis. The poor results of ankle arthrodesis in rheumatoid patients coupled with the low functional demands make total ankle replacement a possible alternative.

Total ankle arthroplasty in cases of degenerative joint disease is not advocated in the first generation two-component prostheses. Stauffer reported that the heavy demands inflicted on the prosthesis by this particular group of patients disproportionately increased the risk of failure, and therefore it should be avoided. Since a number of clinical studies have demonstrated a direct relationship between success rates and patient age, ankle arthroplasty has been limited to patients over the age of 60 with degenerative joint disease. In contrast, degenerative joint disease is considered an unequivocal indication for total ankle replacement with the three-component, meniscal-bearing prosthesis. In a study involving the STAR™ total ankle prosthesis, Kofoed and Sturup observed no difference in implant survival rates between rheumatoid arthritis patients and those with degenerative joint disease.

Two other possible indications include avascular necrosis of the talus and failed ankle fusion. As in fusion take-downs, only the Buechel-Pappas™ prosthesis may be used in AVN patients. This is because the Buechel-Pappas™ ankle has a specific thick talar component for the AVN talus. Because of the bone deficit associated with these two conditions, it is customarily felt that ankle replacement is not feasible. However, based on accommodations built into Buechel-Pappas™ prostheses, an ankle implant may be possible in the event of significant bone loss with this specific design. Absolute contraindications to ankle arthroplasty include active infection, unaddressed ligament instability, neuropathy, vascular insufficiency, and neuromuscular disease with spasticity or paralysis.

CURRENTLY USED DESIGNS

The Alvin Agility™ Ankle Prosthesis

The Alvin Agility™ ankle prosthesis (DePuy, Warsaw, Indiana) is a two-component semi-constrained implant. (Fig. 1) The hallmark of this design involves simultaneous arthrodesis of the tibiofibular syndesmosis in order to increase stability of the components as well as allowing transfer of weight to the fibula. The tibial component is composed of titanium with a polyethylene element secured inferiorly to articulate with the talar component. The cobaltchromium talar component is designed with the anterior portion wider than the posterior, theoretically making the ankle more stable in dorsiflexion.

Figure 1. The Alvin Agility™ Ankle Prosthesis

Both components are biologically fixated utilizing a porous coating of hydroxyapatite. The tibial component is coated along the entire superior portion in addition to both medial and lateral sides. This large surface area for bone ingrowth allows fixation of the tibial component with the medial and lateral malleoli. The talar component is coated only on its inferior surface. The semiconstrained nature of the design allows mediallateral translation of the talar component within the polyethylene element of the tibial component as well as some axial rotation. The prosthesis allows a theoretical 60 degrees of sagittal plane motion. The Alvin Agility™ ankle prosthesis is available in 3 sizes and comes in specified left and right implants.

In a study of 100 consecutive Alvin Agility™

ankle replacements, the clinical results of the prosthesis were found to be encouraging. The follow-up time ranged from 2 to 12 years with an average of 4.8 years. Clinical results were evaluated on the basis of patient satisfaction, pain relief, and functional improvement. Pain relief was used as the main criterion of success. Of the 82 patients available for follow-up, 79% were extremely satisfied with the procedure, 13% were satisfied, 4% were indifferent, and 4% were unhappy. Ninety-five percent of the patients stated that they would have the procedure performed again, and 96% stated they would recommend it to a friend. Pain relief was experienced by 98% of the patients. Eighty-three percent of the patients reported not needing any pain medication for the ankle during the follow-up period while 17% regularly required pain medication. Interestingly, the patients who had the procedure performed for posttraumatic osteoarthritis reported significantly more pain following the procedure when compared to patients with primary osteoarthritis or rheumatoid arthritis.

Functional improvement was reported in 73% of the patients. The sagittal plane range of motion following the procedure averaged 36 degrees. Fifty percent of the patients were noted to have an equinus deformity. Forty-five percent of the patients reported difficulty with stair climbing, however, only 27% attributed this to the ankle while 73% blamed other problems.

Radiographic analysis of the prosthesis was performed in 98 of the ankles. Sixty-two percent had a successful fusion of the syndesmosis, while 29% had a delayed union, and 9% had a non-union. Ballooning lysis at the interface between the bone and the tibial component was significantly higher in those ankles with a delayed union or nonunion. Similarly, tibial component migration was more prevalent in ankles with a delayed union or nonunion. Therefore, it was concluded that successful fusion was related to tibial component stability. Pain relief, on the other hand, was not linked to successful fusion of the syndesmosis, but instead affected by the position of the tibial component. Tibial components placed in greater than 4 degrees of valgus were significantly more painful.

Complications included tibial component fracture, talar component loosening or malposition, persistent pain, superficial wound infections, and decreased sensation along the superficial peroneal nerve. Revisions were performed in instances of
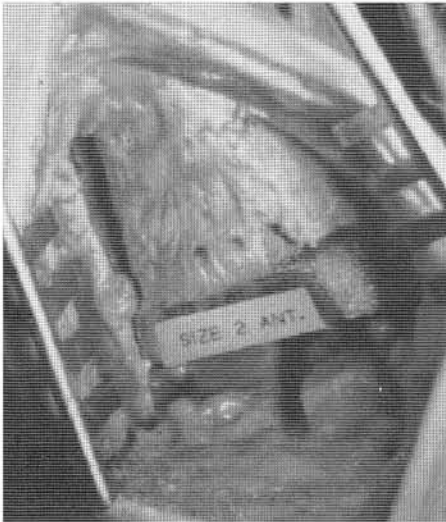
Figure 2. Intraoperative view of implant placement.

Figure 3. A 66-year-old female patient at 1 year postoperative.

Figure 4. The Buechel-Pappas™ Total Ankle Prosthesis.

component fracture, loosening, or malposition. Persistent pain necessitated removal of the implant. Superficial wound infections resolved with antibiotic therapy, while diminished sensation did not cause a functional problem.

Operative Technique. The patient is positioned supine with a thigh tourniquet. An external fixator is applied to the medial aspect of the ankle to aid in joint distraction and to facilitate joint alignment. Following inflation of the thigh tourniquet, an incision is placed on the anterior aspect of the ankle joint, between the tibialis anterior and extensor hallucis longus tendons. The incision is carried down to the ankle joint capsule, which is then incised longitudinally. The tibia is exposed subperiosteally distally, as well as medially and laterally. The external fixator is used to distract the joint and any varus or valgus malalignment is then corrected.

A separate second incision is placed anterolaterally to approach the syndesmosis. The anterior tibiofibular ligament is reflected, the syndesmosis distracted, and its soft tissues removed. An alignment jig is secured to the tibia to facilitate removal of bone from the distal tibia and talar dome. All cartilaginous surfaces are removed from the ankle joint, including the lateral malleolus. The tibial and talar components are then placed in the proper position. (Fig. 2) Bone obtained from the resected articular surfaces is placed in the syndesmosis and the syndesmosis stabilized with lag screws. Overall, approximately 10mm of the distal tibia, approximately 50% of the medial malleolus, approximately

50% of the lateral malleolus, and the dome of the talus are removed. The external fixator is removed, the skin closed, and dressings applied. This is followed by application of a short-leg posterior splint with the foot in neutral position The patient remains non-weightbearing in the splint for 6 weeks. (Fig. 3)

Buechel-Pappas™ Total Ankle Prosthesis

The Buechel-Pappas™ prosthesis (Endotec, South Orange, NJ) consists of titanium alloy tibial and talar components with an ultra high molecular weight "meniscal" element interposed between them. (Fig. 4) The tibial component possesses a 7 degree anteriorly inclined short fixation stem superiorly and a flat loading plate inferiorly. The talar component incorporates a convex superior surface with a central trochlear groove and two anchoring fins

inferiorly for fixation to the talus. The meniscal element articulates congruently with both components via a flat surface superiorly and an inferior surface that perfectly matches the curved trochlear surface with its central groove. Both the tibial and talar components are biologically fixated by means of titanium nitride coated porous beads. The prosthesis is available in 6 sizes.

Operative Technique. The patient is positioned supine with a sandbag under the buttock of the affected side. Following exsanguination of the limb, a thigh tourniquet is inflated. A linear incision is made on the anterior aspect of the ankle between the tendons of the tibialis anterior and extensor hallucis longus. The incision is deepened down through the subcutaneous tissue with care being taken to protect the superficial peroneal nerve. The superior and inferior extensor retinaculum are identified and incised and the incision carried down to the bone of the tibia and talus. The periosteum from the tibia and talus is reflected, and the ankle joint exposed.

The level of tibial pathology is determined by visual inspection and the Tibial Marking Osteotome is placed parallel to the articular surface and centered on the tibia. The Tibial Marking Osteotome is impacted to mark out and begin the cut on the distal tibia. The Tibial Resection Guide with its 7 degree inclined cutting surface is placed on the previously marked tibial cut and pinned into place. A power saw is used to complete the transverse cut parallel to the articular surface, with care being taken not to undercut the medial malleolus or injure the posterior neurovascular bundle. The vertical cuts are completed with a smaller saw blade or osteotome. Posterior bony fragments are removed with curettes or a pituitary rongeur.

The Tibial Window Osteotome is used to fashion an anterior cortical window in the distal tibia for introduction of the Tibial Component Fixturing Stem. The Base Plate of the Tibial Window Osteotome is placed over the previous tibial resection surface and centered over the talus. The osteotome is impacted to outline the cortical window. A power saw is used to complete the cuts down to the center of the tibial shaft in the lateral plane. The cortical window is removed and placed in a blood-soaked sponge for later reinsertion. A curette is used to deepen the central channel in the tibial canal to a 1 inch depth.

The Tibial Trial is inserted and should sit with the Base Plate flush against the tibial cut and the stem should be snug in the central channel. The

talar cuts are then performed beginning with the talar sulcus. A 10 mm spherical burr is used to fashion an anterior-to-posterior central sulcus in the talus. The Talar Sulcus Rasp ensures adequate depth and width to allow the undersurface of the talar component to fit adequately.

Once the sulcus is completed, the Talar Slot Burr is used to prepare the talar component fixation channels. The foot is plantarflexed to ensure the posterior cuts are even. The depth of the fixation channels is checked with the Talar Channel Depth Template. An alternative method is to use a reciprocating saw to fashion the channels. The Talar Component Trial is then used to assure a good fit. The anterior edge of the trial should be even with the anterior edge of the tibia and should lie in the same coronal plane.

All three trial components are then inserted to ensure adequate fit. The Tibial Trial Component is first inserted, followed by the Talar Trial Component. The Bearing Trial is then inserted. The bearing inserted should match the size of the talus and should be a maximum thickness as long as it does not restrict sagittal plane motion. Once the sizes have been determined, the Tibial Component is implanted first. Bone graft can be packed around the stem to ensure a snug fit. The tibial impactor is used to seat the stem firmly into the channel. The base plate must be flush with the tibial surface.

The Talar Component is then inserted. Again, bone graft can be used in the fixturing channels and the talar impactor seats the component onto the talus. The bearing is then inserted with the wider side faced anterior. Good distraction of the foot is necessary to be able to insert the bearing. After all components are in place, the tibial bone window is replaced into its original position after it is trimmed to the appropriate size. More graft may be used if the bone window does not wedge into the tibia. (Fig. 5) The wound is then closed in layers over a suction drain. Non-absorbable deep sutures are used to minimize wound healing problems and the patient is maintained in a non-weightbearing short leg cast for six weeks. (Fig. 6)

Scandinavian Total Ankle Replacement (STAR™)

The STAR™ (Link, Germany) is another three-component designed prosthesis. The tibial and talar components are made of a Chromium-Cobalt alloy. The tibial component has a double stem fixation system with a flat articulation surface. The talar
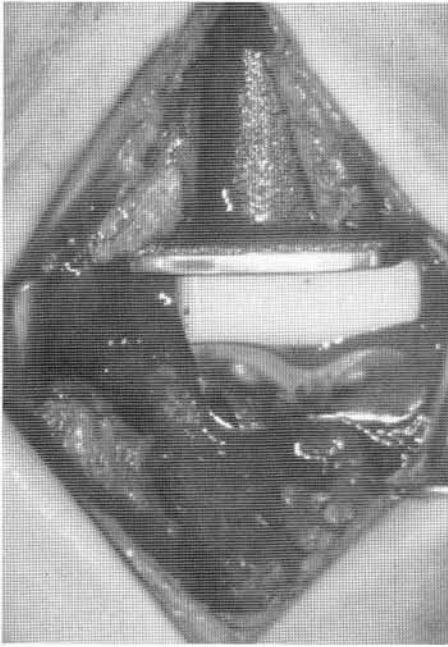
Figure 5. Intraoperative view of the completed Buechel-Pappas™ prosthesis.

Figure 6. Postoperative x-ray.

Figure 7. The Scandinavian Total Ankle Replacement (STAR™)
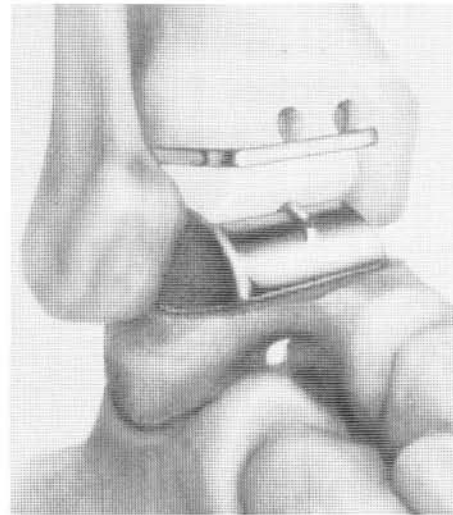
Figure 8. Diagram showing the placement of the implant.

component has a cylindrical talar cap and single stem for fixation. The articulating surface of the talar cap has a central rib running anterior to posterior which guides the meniscus. The meniscus is made of high-density polyethylene and has a central groove on its undersurface that glides with the talar component. (Fig. 7)

Operative Technique. An anterior approach is utilized similar to the Buechel-Pappas technique. Once the tibia and talus are visualized, the tibia is first prepared. A tibial saw guide is used to resect the distal 5 mm of the tibia leaving the medial and lateral malleoli intact. With this same saw guide in place, a 4 mm sizer is added to resect the talar dome surface. The suitable talar saw guide is then anchored and the medial and lateral surfaces of the talus are resected. A second talar saw guide is used to resect the sagittal and frontal segments. Next a groove for the talar fixation stem is created with a 3 mm drill and a milling template.

The tibial cylindrical stem holes are then prepared with a tibial drill guide. Once the implant sites on the tibia and talus are complete the talus cap is first implanted. The tibial component is inserted and the meniscus size is determined and inserted. (Fig. 8) The two most important steps in the STAR™ procedure are: make certain that as you drill the two anchoring holes on the tibia, you "aim" the drill bit cephalad so that the drill will not
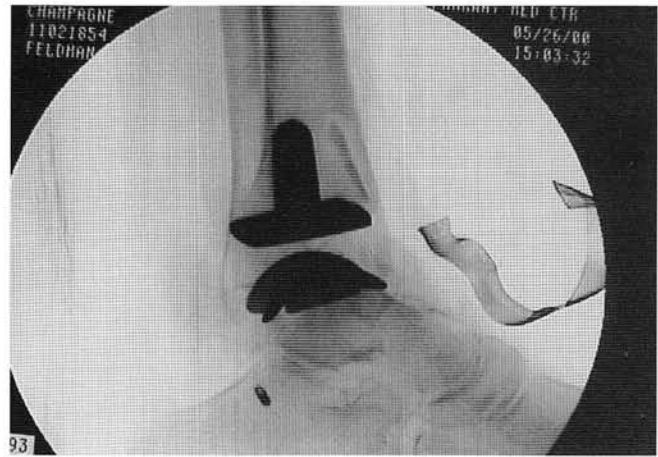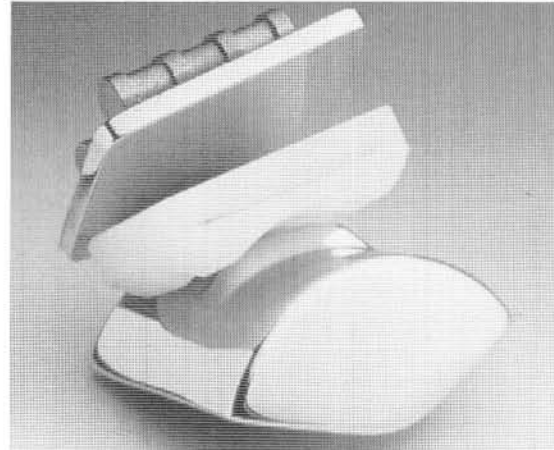
slide distally towards the plafond, and the talar component must be placed posterior enough on the talus to be aligned directly under the tibia, centered. Most STAR™ failures are because the tibial plate rods are not seated securely in the tibia due to the drill holes or the talar component is seated too far anterior. (Fig. 9)

CONCLUSION

Osteoarthritis and rheumatoid arthritis of the ankle are very painful and debilitating. Many patients suffer to the extent that they even request an amputation. To date, arthrodesis of the ankle has been the only viable alternative for treatment, and yet it is not without complications of its own. With the advent of the current generation of ankle implants, there is new potential and promise for the patient with a chronic, painful ankle joint. With appropriate training 0.surgeons can now offer the total ankle implant as a viable treatment option to these patients.

Figure 9. Postoperative view. Note the correct alignment of all three components.

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