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Evolution of Total Ankle Arthroplasty

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Abstract: Despite significant advances in joint replacement surgery for the hip, knee, and shoulder, end-stage ankle arthritis remains a challenging problem. Orthopaedic surgeons can offer few options to patients with ankle arthritis that is refractory to nonoperative care. Traditionally, surgical treatment has been limited to tibio-talar arthrodesis, the results of which are predictable but often unsatisfactory. Total ankle arthroplasty (TAA) was developed as an alternative to fusions, but the results of early designs were discouraging. Wrought with complications such as wound breakdown and early prosthetic loosening, TAA was largely abandoned in favor of tibio-talar arthrodesis. More recently, improved TAA designs have demonstrated good intermediate-term results and have renewed interest in this alternative to ankle fusions for carefully selected patients.

Historical Perspective

Ankle fusions have traditionally been the treatment of choice for end-stage ankle pathology refractory to nonoperative treatment. Initially performed over 100 years ago, tibio-talar arthrodesis have been successfully performed to alleviate pain, correct deformity, and restore stability. However, ankle fusions are fraught with complications, including wound-healing problems, infections, malunions, nonunions, and excessive limb shortening. Complication rates as high as 34–60% have been reported [1–3], although results have improved with modern AO techniques. Postoperatively, many patients have significant gait abnormalities and require ambulatory aids and/or orthotics. The elimination of ankle motion increases the stress on adjacent joints, which in turn hastens the subsequent development of arthritis in the knee, subtalar, and midtarsal joints [4]. Pathology in adjacent joints may necessitate additional fusions, resulting in profound functional limitations for the patient. The drawbacks of tibio-talar arthrodesis, coupled with the success of hip and knee arthroplasty, have prompted the development of total ankle arthroplasty (TAA) as an alternative treatment for end-stage ankle arthritis.

Buchholz has been credited with performing the first TAA in Hamburg in the early 1970s [5]. Soon thereafter, several other TAA designs were developed at various institutions throughout Europe and the United States. Two basic design philosophies emerged: constrained and unconstrained devices. Constrained prostheses offer the advantage of greater stability but with reduced motion. In addition, constrained devices result in increased stresses at the bone-cement-implant interfaces, which in turn often leads to early loosening and failure. Examples of constrained implants included the St. Georg/Buchholz, Imperial College London Hospital (ICLH), Conaxial, and Mayo designs. Unconstrained systems provide improved range of motion in multiple planes at the expense of stability. Unconstrained devices also minimize the forces seen at the bone-cement-implant interface. Examples of unconstrained designs included the Waugh/Irvine, Smith, and Newton prostheses. Whether constrained or unconstrained, TAA were generally implanted with cement fixation during the 1970s.

The results of early unconstrained TAA designs were dismal. Evanski and Waugh [6] published their initial results on 28 unconstrained TAA (24 Irvine and four Smith ankles) with an average follow-up of only nine months. Seven cases (25%) had complications and two others (7%) failed. Dini and Bassett [7] evaluated 21 Smith ankles at two years and had 11 patients (52%) with fair to poor results. Reviewing his first 50 patients with an average follow-up of three years, Newton [8] reported a 50% failure rate.

Although somewhat better, the results of constrained first-generation TAA systems were also discouraging. Bolton-Maggs et al. [9] reviewed 62 ICLH implants at an average of 5.5 years. Thirteen cases (21%) failed and required attempted arthrodesis and only 13 TAA (21%) had a satisfactory outcome. Wynn and Wilde's [10] review of 36 Conaxial ankles at 10 years revealed a 28% failure rate and a 60% complication rate. Radiographs revealed loosening in 90%. Despite more promising early results with the Mayo ankle, Kitaoka and Patzer [11] reported a 36% (57 of 160 TAA) failure rate at nine years.

In the 1980s, several institutions started using cementless TAA designs with improved results. Disappointed by the results of their cemented, constrained New Jersey ankle, Buechel et al. [12] developed the uncemented New Jersey Low Contact Stress (LCS) ankle. Reviewing 23 uncemented LCS devices at an average follow-up of three years, they found that 20 (87%) of the replacements resulted in no or only mild pain.

Takakura et al. [13] compared their original cemented stainless steel-on-polyethylene design to a cementless ceramic-on-polyethylene implant. They performed 30 cemented metal ankles, nine cemented ceramic ankles, and 30

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uncemented ceramic ankles. At an average of 8.1 years of follow-up, six of 39 (15%) cemented prostheses, including one ceramic and five metal devices, failed. On the other hand, none of the 30 cementless ceramic implants (0%) failed at an average follow-up of 4.1 years. They concluded that uncemented systems should be used when osteoporosis is not significant.

Promising intermediate-term results have also been obtained with Link's cementless Scandinavian Total Ankle Replacement (STAR). Of 31 uncemented STAR followed for 3.5 years, only one revision (3%) for malalignment has been performed. This compares favorably to the cemented STAR, which demonstrated a 70% survivorship at 10 years [14]. The fact that all published results on the STAR have been presented by the designer is a source of concern. Currently, trials for the cementless STAR are in progress in the United States on a very limited basis. Proponents of the STAR prosthesis emphasize the minimal bone cuts required for implantation of the device, which allows for the maintenance of leg length if a salvage arthrodesis is required.

The outcomes of early TAA designs were largely disappointing but served to elucidate some of the etiologies for those failures. Constrained implants had higher loosening and failure rates, which can probably be attributed to the greater stresses seen at the bone-cement-implant interface. Experience has also shown that cementless prostheses have better results than cemented devices. Addressing these factors has led to the development of a second-generation system using an uncemented, semiconstrained device, the Agility Ankle (Depuy, Inc., Warsaw, IN). The Agility has demonstrated promising intermediate-term results [15,16] and is currently the prosthesis used at our institution. It is available only to surgeons who have completed an approved fellowship and/or course and is not available to the general public.

The Agility is a two-component system consisting of a cobalt-chromium talus and a one-piece titanium-backed polyethylene tibia. Both the tibial and talar components are porous coated for cementless press-fit fixation. The device is semiconstrained, allowing for rotation and medial/lateral translation. Because the talar component is wider anteriorly than posteriorly, the implant becomes more rigid with the ankle in neutral or in dorsiflexion. A unique feature of the Agility is the addition of a syndesmotic fusion to allow load transfer from the tibial component to both bones of the leg. The porous coating of the tibial base extends to both the medial and lateral surfaces, allowing for ingrowth with the cut surfaces of the medial and lateral malleoli, respectively. In addition, 20 degrees of external rotation is incorporated into both components, so that the device's axis of rotation approximates the intermalleolar axis.

Indications

TAA should only be considered after an appropriate course of conservative care. Nonoperative modalities include medication, activity modification, weight loss, physical therapy, orthotics, and bracing. Indications for TAA include both inflammatory and noninflammatory arthritis. Initially, TAA was primarily reserved for rheumatoids and other low-demand patients. More recently, with the advent of improved prosthetic designs and surgical techniques, the indications have been broadened to include more active patients, such as those with post-traumatic osteoarthritis.

Surgical Technique

The preoperative evaluation should include a thorough history and physical examination, with a detailed neurovascular assessment. Any signs or symptoms of vascular insufficiency warrant further workup. In addition, standard weight-bearing radiographs of the ankle and foot should be obtained. Malalignment, bone quality, and involvement of joints other than the ankle should all be assessed. Hindfoot malalignment and/or arthritis would warrant a concurrent hindfoot fusion, such as a triple arthrodesis, with the TAA.

Described below is the operative technique for the Agility Ankle, the prosthesis used at our institution. The patient is placed supine on the operating room table, with a sandbag under the ipsilateral hip to enhance access to the fibula. The entire leg distal to and including the knee is scrubbed and prepped. The drapes should seal off a sterile field from just below the knee to the dorsum of the foot.

Under fluoroscopic guidance, an ankle distracter, such as the EBI external fixator (Parsippany, NJ), is placed. Two distal and two proximal pins are used. The distal pins are placed so as to permit correction of any varus or valgus deformity. The first pin is placed medially in the talar neck, angled parallel to the ankle joint in the coronal plane. The second pin is placed parallel to the first pin, through a guide, into the posterior calcaneus. Next, the two proximal pins are placed from medial to lateral in the tibia, perpendicular to the shaft. After completing the external fixator construct, the ankle is distracted approximately 1 cm into a neutral position. The ankle should not be maximally distracted.

Next, an anterior approach to the ankle is used. Dissection is performed in the interval between the anterior tibial and extensor hallucis longus tendons, with care to identify and protect both the anterior neurovascular bundle and the superficial peroneal nerve. The capsule is incised longitudinally and reflected subperiosteally in both the medial and lateral directions (Fig. 1). Both the medial and lateral malleoli must be adequately visualized for the bony cuts. A second incision should be made laterally over the distal fibula. After adequate exposure, the anterior tibiofibular ligament is excised and the syndesmosis is mobilized with an osteotome. Caution should be taken to avoid fracture of the lateral malleolus.

An extramedullary alignment jig is placed parallel to the tibial shaft. The appropriately sized cutting block is attached to the alignment jig and centered over the ankle joint with fluoroscopic guidance (Fig. 2). The cutting block should be placed so that an equal amount of distal tibia and talar dome, as well as an equal amount of the medial and lateral malleoli, will be resected. No more than one third of each malleolus should be resected. Proper alignment is achieved when all the cutting block captures are fully visualized by fluoroscopy (Fig. 3).

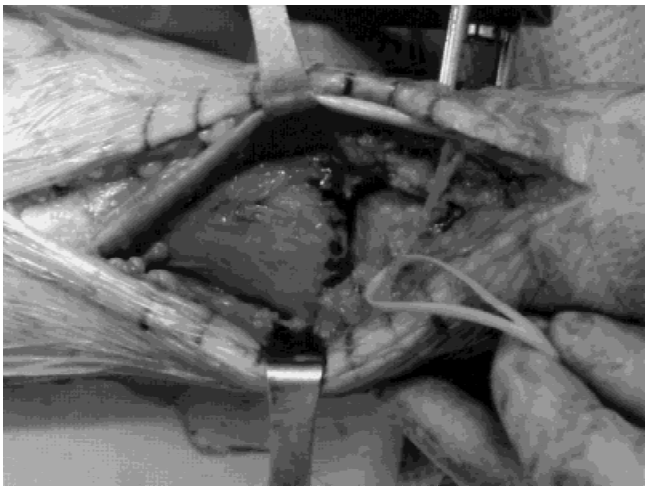

Fig. 1. Medial and lateral subperiosteal dissection of the ankle.

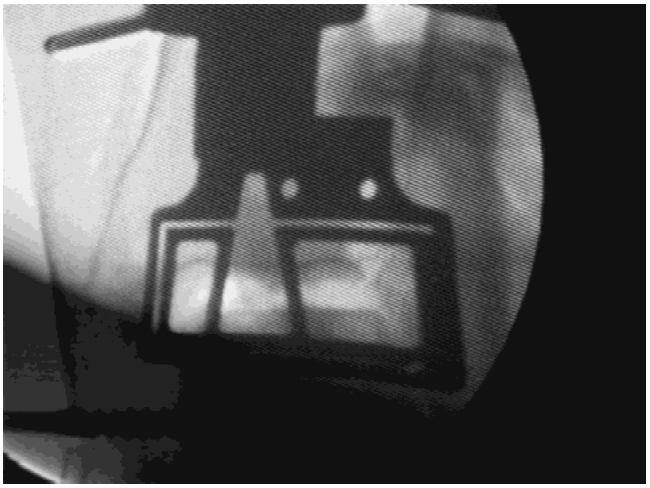

Fig. 3. Fluoroscopic confirmation of proper alignment.

Bone resection is made with an oscillating saw, being careful to cut perpendicular to the jig to avoid any medial or lateral swinging (Fig. 4). This swinging of the saw blade can cause medial or lateral malleolar fractures, a common complication with inadequate exposure. If a fracture is created, the malleolus should be internally fixed with standard AO technique (Fig. 5). After completion of the cuts, including the cut for the tibial component fin, the alignment jig and cutting block are removed. Then, the cutting jig for the talar component fin is placed parallel to the talar body, and not the neck. The handle of the jig should be aligned with the second toe, which provides approximately 20 degrees of external rotation. Once properly placed, the talar fin tract is cut with a reciprocating saw.

The tibial trial can be inserted by gently spreading the syndesmosis with an osteotome. The tibial fin should be inserted straight anterior to posterior, but the body of the tibial component should be in approximately 20 degrees of external rotation. The talar trial can be inserted by providing some additional distraction and/or placing the ankle in more equinus. After placement of both trials, soft tissue balancing should be obtained. Range of motion should also be assessed and a percutaneous heel cord lengthening should be performed if the ankle cannot be brought out to 10 degrees of dorsiflexion. Once satisfied with the trial components, the final prosthesis is then inserted. After insertion of both components, the ankle distracter, but not its pins, should be removed to allow for formal anteroposterior, lateral, and mortise radiographs to confirm proper seating of the prosthesis. Again, adequate range of motion should be confirmed.

At this point, attention is directed to the syndesmotic fusion. The syndesmosis is decorticated and packed with morcellized autograft from the tibial and/or talar bone cuts. Two syndesmotic screws are then inserted in standard fashion. Closure of the anterior and lateral wounds should be meticulous, with careful handling of the skin edges. Proper soft tissue handling should minimize the incidence of wound-healing complications. Most soft tissue complications can be successfully treated with just local wound care.

After the ankle distracter pins are removed, the patient is placed in a well-padded splint immediately postoperatively and then transferred into a cast upon discharge. The patient is immobilized in this nonweight-bearing short leg cast for

Fig. 2. Alignment jig centered over the tibiotalar joint.

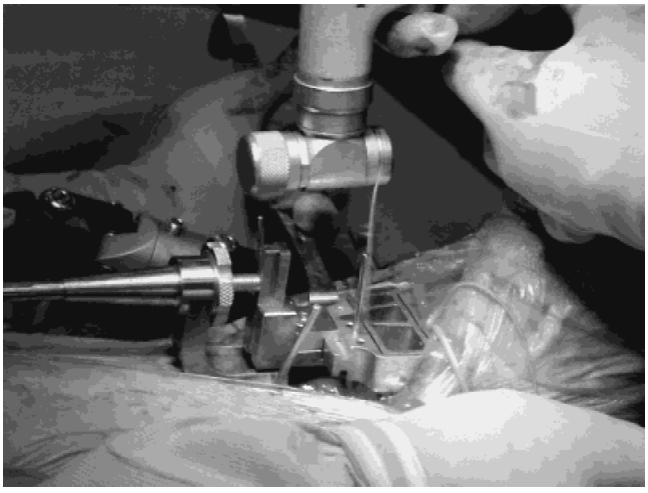

Fig. 4. Resection of bone surfaces.

at least six weeks to allow for syndesmotic fusion and porous ingrowth of the components. If an Achilles tendon lengthening was performed, the patient should be casted in dorsiflexion. After six weeks, the patient is started with range of motion exercises and progressively mobilized.

Results

The Agility Ankle has demonstrated promising intermediate-term results. Pyevich et al. [15] published the results of the first 100 Agility TAA performed in 95 patients by Dr. Frank Alvine between 1984 and 1993. The patients ranged in age from 27 to 81 years, with an average age of 63 years. Independent examiners performed the follow-up examination and radiographic evaluation at an average of five years postoperatively. Eighty-six ankles in 83 patients were available for review; the other 12 patients were deceased at the time of follow-up. Six prostheses (7%) required a revision or a resection. Seventy-nine ankles (92%) had satisfactory outcomes. They also noted that cases with delayed or nonunion of the syndesmosis appeared to result in less predictable outcomes.

Conti et al. [17] have also reported their experience with the Agility Ankle. They restricted their patients to those over 50 years of age. At five-year follow-up, 79 of the 86 cases (92%) had a satisfactory outcome. A radiographic review revealed that 12 tibial and seven talar components (22%) had migrated. Eight of the 12 tibial components that had migrated (67%) involved a syndesmotic delay or nonunion.

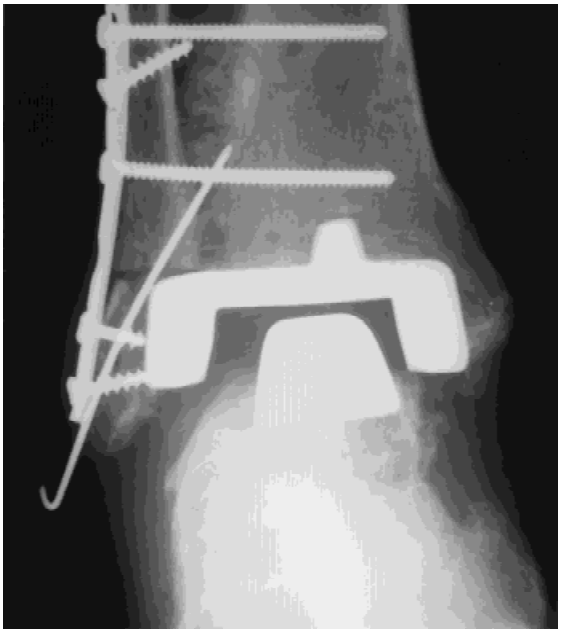

Fig. 5. Fixation of intraoperative lateral malleolus fracture.

Conclusion

Currently, several TAA systems are being investigated. Many of these newer prostheses have addressed the problems that have plagued older designs. However, until long-term follow-up data are gathered, TAA should be reserved for only the carefully selected patient in the setting of close clinical monitoring of a specially trained surgeon.

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