Introduction

Renewed interest in total ankle arthroplasty (TAA) has resulted from the introduction of two-component and three-component TAA prosthetic designs that offer improved anatomic and biomechanical features over previous designs to ensure longevity of the implants. However, TAA is a challenging surgical procedure, and the long-term survival rate remains inferior compared with that of total hip or total knee arthroplasty. Therefore, analysis of the factors that could lead to malfunction and failure of TAA is important. This chapter reports on the effects of malalignment on TAA function.

The Normal Ankle Joint

The ankle joint is a highly constrained articulation, and the congruency of the bones provides primary stability for inversion and eversion under weight-bearing conditions. In addition, an intact periarticular ligamentous complex provides a large amount of stability in the sagittal (AP translation) and transverse (rotation) planes. Range of motion (ROM) at the ankle joint averages 20° of dorsiflexion (range, 13° to 33°) and 40° of plantar flexion (range, 23° to 56°) with small amounts of internal rotation (2°) and external rotation (7°). In addition, movement at the ankle joint is linked to tibial and subtalar motion. The cartilage layer of the ankle joint covers a small absolute surface area. The thin and stiff articular cartilage is less able to adapt to articular surface incongruity and increased stresses compared with the thicker articular cartilage of the knee and hip joints. Physiologic ankle forces for walking approach 150% of body weight and can surpass 300% of body weight when normal activities such as descending stairs are performed.

The Arthritic Ankle Joint

Any damage to the articular cartilage and subchondral bone, such as pilon fractures, creates articular surface incongruities and impairs joint stability. Eventually, the high contact stresses exceed the capacity of the joint to repair itself or adapt. It is not the case that most arthritic ankle joints undergo progressive deformation. Some patients have progressive degeneration of the ankle joint but no apparent articular surface damage, altered anatomy, or instability, whereas others have articular surface damage, altered anatomy, or instability but do not exhibit progressive degeneration of the ankle joint.

Requirements for and the Trade-off Inherent in TAA

A perfect TAA should restore the physiologic spectrum and magnitude of motion. It should provide resistance to injury in inversion and eversion and prevent talar component subsidence while maintaining enough intact bone to allow easy implant exchange in case of failure. That is, TAA should be as anatomic as possible to mimic physiologic kinetics and kinematics of the ankle joint. Despite those requirements, TAA should be performed with instrumentation that allows accurate and easy positioning of prosthetic components with regard to the anatomy of the hindfoot and lower limb. In addition, fixation should be strong enough to provide stability within the bone-prosthesis interface. Current TAA prostheses have a calcium hydroxyapatite and/or porous coating to promote stable fixation.
Nevertheless, TAA presents a dilemma in the trade-off between mobility and congruency. Unconstrained and semiconstrained designs allow mobility at the cost of congruent contact. As a result, increased contact stresses with potentially high wear rates are found. In contrast, a highly congruent design offers low contact stresses due to large contact areas but could overload the bone-prosthesis interfaces because of high constraint forces. Contemporary three-component designs allow for complete congruence and minimal constraint over the entire ROM but bear the risk of subluxation, dislocation, or both.

**Effects of Malalignment on TAA**

Unsophisticated implant design, poor positioning of the arthroplasty, malalignment of the hindfoot, and joint instability all can result in global and often complex malalignment about the ankle that leads to abnormal force transmissions and induces high joint contact pressures. In these situations, painful syndromes are likely to develop. In addition, edge loading of the polyethylene component results in increased wear, osteolytic reactions, and possible breakage. Failure of TAA is a gradual process and rarely happens instantly.

Causes of failure can be attributed to incorrect indications, incorrect soft-tissue balancing, incorrect positioning of components, and implantation in ankles with hindfoot malalignment and ankle instability. Factors and effects that could initiate malfunction and premature failure are discussed herein.

**Implant-Related Factors**

**DESIGN**

The design of a TAA prosthesis plays an important role in the mode of failure. As previously mentioned, a congruent but less kinematically constrained TAA prosthesis seems to offer better biomechanical properties with low contact pressures compared with a semiconstrained and incongruent TAA prosthesis. Therefore, the former design may exert less stress on the polyethylene inlay. TAA prostheses with a more cylindrical shape of the talus do not take into account the different radius of curvature of the medial and lateral talus. Rotational stress is therefore exerted on the implant during motion while the collateral ligaments of the ankle joint are overloaded, with resultant pain, as discussed in the section on medial pain syndrome. Anatomic and conically designed talar components reduce this negative effect because they better mimic talar anatomy.

Some TAA designs use metaphyseal stem fixation within the distal tibia. These designs could provoke stress shielding and resultant local osteolysis because of aberrant force transmission, although this suggestion has not yet been proved (Figure 1). In the author’s experience, a flat tibial component that fully covers the tibial plafond seems to perform better and cause fewer osteolytic reactions.

**MATERIAL PROPERTIES**

Polyethylene wear has been identified as an important factor in the development of osteolysis and subsequent aseptic loosening of TAA prostheses. Polyethylene wear depends on geometry, strength (ultrastructural), and alignment of components. Osteolysis has been recognized as more than a simple biologic reaction against submicron-sized wear particles; rather, it is a more complex phenomenon attributable to biologic and biomechanical stimulation. The incidence of osteolysis has been shown to correlate with the concentration of polyethylene wear particles. The average particulate threshold for polyethylene-induced osteolysis has been identified as 10 billion particles per gram of tissue. In addition to polyethylene wear, there is a risk that the metallic components could break, resulting in major dysfunction and failure of the TAA prosthesis, if present (Figure 2).

**INSTRUMENTATION**

Correct alignment and implantation of TAA prostheses strongly depends on precise instrumentation. In general, placement of the tibial component in
Effects of Total Ankle Arthroplasty Malalignment

The coronal plane is done perpendicular to the mechanical (anatomic) axis of the tibia and with a small amount of posterior slope in the sagittal plane. Current designs align the talar component on the basis of the position of the tibial component. However, rotational alignment of TAA is difficult to control, and the clinical significance of rotational malalignment remains unknown. Two-component TAA designs (with a fixed polyethylene inlay on the tibial component) are more susceptible to rotational malalignment with consecutive rotational stresses. Three-component designs have a flat interface between the tibia and polyethylene, allowing the polyethylene to rotate freely in the transverse plane. This freedom of rotation of the polyethylene in the transverse plane allows the talus to find its natural position dictated by the residual bony mortise as well as the medial and lateral collateral ligaments.

Anatomic Factors
Anatomic deformities and malalignments can be caused by hereditary or environmental factors.

Supramalleolar malalignment can be present in the coronal, sagittal, and transverse planes. Multiplanar deformities may occur and are more difficult to manage than single-plane deformities. Coronal deformities include varus and valgus malalignment. Sagittal malalignment encompasses recurvatum or procurvatum deformities. Torsional malalignments result from excess external and internal rotation.

Malalignment at the ankle joint itself is frequently found in patients with chronic ankle instability, malunited ankle fractures, or erosive end-stage arthritis. It frequently results from ligamentous insufficiency with plastic deformation of the malleoli. A typical deformity includes intra-articular varus malalignment with overload of the medial compartment and resultant erosion of the medial distal tibia. Less frequently an intra-articular valgus malalignment can be seen, such as after pilon fractures involving the lateral plafond, with attenuation of the medial deltoid ligament complex, which then becomes incompetent.

Inframalleolar malalignment includes varus and valgus hindfoot deformities that can exist in the absence of ankle deformity. Examples are cavovarus foot and flatfoot or malunited hindfoot fusions.

Surgical Errors
Any surgical procedure has potential to cause iatrogenic malalignment.

TAA Prosthesis Implanted Too Far Proximally
If the prosthesis is implanted too proximally, the joint line moves proximally. As a result, the triceps surae loses mechanical advantage, leading to limited plantar flexion. Because of the proximal shift of the talar component and its center of rotation, painful medial and lateral malleolar impingement may occur. The farther proximal the tibial cut is made, the greater the risk of placement of the tibial component on weak cancellous bone that will not resist subsidence. In the case of a proximally implanted tibial component with a too-thick polyethylene meniscus, the ligaments will be too taut and the ROM will be impaired.

TAA Prosthesis Implanted Too Far Distally
If the prosthesis is implanted too distally, the joint line moves distally and may result in four effects. First, distal implantation of the TAA moves the joint line in the plantar direction. Consequently, the gastrocnemius-soleus complex becomes taut, resulting in loss of ankle dorsiflexion. Second, distal implantation due to excessive talar resection can critically weaken the bone, resulting in fracture when the talar component is inserted. Third, if the talar component is placed into cancellous bone without proper support of the cortical shell, postoperative subsidence...
is a risk. Fourth, because of loosening of ligament tension, the TAA can become unstable.

**TAA PROsthesis Implanted Too Far Medially**

Implantation of the TAA prosthesis too far medially can happen when the tibial cut is performed too far medially. The medial distal tibia is thereby weakened, enhancing the risk of possible malleolar fracture. In addition, the lateral ligaments become taut and could cause pain.

**TAA PROsthesis Implanted Too Far Laterally**

Placing the TAA prosthesis too far laterally could cause fibular impingement associated with chronic pain and subsequent development of osteolysis. The overhang of the anterolateral tibial component causes the anterolateral distal tibia to become eccentrically stressed and potentially subside, causing secondary valgus displacement of the TAA prosthesis.

**TAA PROsthesis Implanted Too Far Anteriorly**

If the TAA prosthesis is implanted too far anteriorly, the center of rotation is moved anteriorly and the triceps is tensioned. In addition, unequal tension of the collateral ligaments can result in loss of dorsiflexion. Because of eccentric overload, the anterior distal tibia may be weakened, resulting in secondary anterior subsidence of the tibial component. As a result, the talar component is forced out of the joint in an anterior direction.

The talar component itself can also be implanted too anteriorly. In this case, the supporting bone at the neck-body junction may be insufficient and can lead to subsidence of the talar component.

**Figure 3** AP radiograph demonstrates rigid varus ankle deformity in a patient who underwent total ankle arthroplasty but sustained an injury to his right ankle 2 days after the procedure. As a result, the version exceeded 5° and the polyethylene inlay dislocated completely.

**Figure 4** AP radiograph of a left ankle in which the tibial component of the total ankle arthroplasty prosthesis was inserted too far medially, resulting in fracture of the medial malleolus. Note callus formation at the medial malleolus. In addition, the medial corner of the distal tibial plafond weakened substantially, resulting in varus malalignment of the prosthesis. Leading to ankle instability. Stress fracture of the medial malleolus also may occur (Figure 4).

**Valgus Malalignment of Components**

As a result of valgus malalignment of the components, the lateral compartment becomes overloaded, resulting in edge loading of the polyethylene inlay and increased risk of asymmetric wear. The high tensile forces exerted through the medial ligament complex may result in pain and medial ankle instability along with possible dysfunction of the posterior tibial tendon.

**Forgotten Debris and Damage to Components**

Before TAA is performed, all surfaces should be irrigated and cleaned of debris. Forgotten debris within the joint can damage the metallic and polyethylene surfaces and cause wear, metallosis, and failure of the TAA. This process
can also be initiated and/or accelerated by scratching the surface of the components with instruments.

**Medial Pain Syndrome After TAA**

When a TAA prosthesis begins to malfunction, patients often report painful disturbances about the ankle joint. Approximately 60% of patients report pain after TAA, which typically resolves over time (usually in 1 to 2 years). However, some patients have chronic pain in the medial ankle region. This pain is called medial pain syndrome. Medial pain syndrome after TAA has been classified into four types (Figure 5).

**TYPE I: CONTRACTURE OF THE MEDIAL LIGAMENTS**

Type I medial pain syndrome is caused by contracture of the deltoid ligamentous complex. Long-standing varus deformity of the talus often is associated with chronic lateral ankle instability and muscular imbalance. The deformity is maintained by an excessive pull of the tibialis posterior muscle relative to that of the peroneus brevis muscle. The medial collateral ligament apparatus contracts. If the contracture is not directly corrected, the surgeon may attempt to overcome the problem by inserting a larger polyethylene component. As a consequence, the deltoid complex pulls the talus more medially, causing pain.

**TYPE II: VALGUS DEFORMITY**

Type II medial pain syndrome occurs with an inframalleolar valgus deformity and is frequently seen after malunited subtalar or triple arthrodesis. Although the ankle joint is well aligned, the calcaneus is positioned in valgus. The eccentric pull of the Achilles tendon increases the valgus thrust, and as a consequence the talus impinges medially against the medial malleolus. Placement of the talar component in a position that is too medial exacerbates the situation and should be avoided.

**TYPE III: VARUS DEFORMITY**

Type III medial pain syndrome is associated with a varus deformity of the hindfoot. As a result of the varus deformity, the medial tibial plafond and the medial malleolus become overloaded. A varus knee, supramalleolar varus deformity, or intra-articular varus deformity can be responsible for this type of medial pain syndrome.

**TYPE IV: VARUS-VALGUS DEFORMITY**

Type IV is the most complex medial pain syndrome and results from both varus and valgus deformity. The tibial component is placed in varus, whereas the hindfoot is in valgus.

**Impaired ROM**

Studies have shown that with small (6- and 8-mm) polyethylene components, anterior malpositioning of the talar component reduces plantar flexion. With polyethylene components measuring 10 mm or larger, anterior displacement results in the reduction of both plantar flexion and dorsiflexion. The use of a polyethylene component that is too thick increases the strain on the ligaments, negatively affecting biomechanics and thereby impairing ROM. One study revealed that a slightly anterior
position of the talar component with respect to the tibial component resulted in greater ROM.

**Anticipating and Managing Malalignment**

The goal of surgical realignment is to achieve a well-balanced hindfoot. Appropriate balance maximizes the chances for optimal function of the TAA. In general, any deformity should be corrected at its apex. Proper identification of malalignment is mandatory and requires specific preoperative imaging techniques. Detailed algorithms of corrective surgery are beyond the scope of this chapter, but some principles of deformity correction are discussed.

A thorough knowledge of the normal angular values is essential when planning TAA. The medial distal tibiotalar angle averages 92° in the coronal plane. In the sagittal plane, the anterior distal tibiotalar angle averages 80°. Long-leg radiographs are recommended to assess weight-bearing axes and to help anticipate any deformity that should be corrected. In addition, weight-bearing AP, mortise, and lateral views of the ankle should be obtained for surgical planning. Hindfoot alignment or long axial views of the ankle can be used to identify the apex of deformity and the site of correction.

An ankle is defined as congruent when the difference between the talar and tibial alignments is less than 10° (Figure 6, A). Otherwise, it is defined as incongruent (Figure 6, B). Patients with an incongruent joint preoperatively are 10 times more likely to have progressive edge loading than are those with congruent joints.

Supramalleolar deformity up to 10° to 15° can be corrected at the ankle level by adjusting the cutting jig. However, greater deformities need additional surgical procedures to achieve adequate balancing of the ankle joint. When attempting to correct a malaligned hindfoot, the surgeon must determine whether a single- or two-stage procedure is most prudent. Single-stage procedures combine corrective procedures (such as osteotomies and lateral ankle ligament reconstructions) and TAA implantation in one anesthetic administration. Single-stage procedures can increase the risk of perioperative complications such as wound breakdown and nonunion, depending on the tissue integrity. If a risk of increased complications is present, a two-stage procedure (surgical realignment followed by TAA implantation) may provide a safer solution.

Osteotomies are an efficient tool to align the osseous architecture about the ankle. Osteotomies can be done on the tibia, fibula, or calcaneus. Supramalleolar tibial osteotomies can be done in a uniplanar or multiplanar fashion (to correct coronal, sagittal, and transverse malalignment). An osteotomy of the medial malleolus helps adjust deltoid ligament tension and can be very effective. Fibular osteotomies can be used to lengthen, shorten, or derotate the bone. The author of this chapter uses an oblique fibular osteotomy and strong plate fixation to maintain correction. Varus deformities of the calcaneus can be addressed with a lateralizing osteotomy, whereas valgus deformities are corrected with a medializing osteotomy. Greater varus deformities of the ankle may be corrected with a Z-shaped osteotomy. This type of osteotomy allows triplanar correction. In addition, lateral ligament reconstructions and tendon transfers (peroneus longus to peroneus brevis) can help restore and/or support lateral ankle stability. In some patients, malalignment is associated with subtalar and/or Chopart joint arthrosis. In these patients, selected fusions may be needed to realign the hindfoot and create a stable socket for TAA.
Summary

Malalignment of TAA or the surrounding tissues is multifactorial and, if neglected, can be detrimental for function and can impair longevity of the prosthesis. To prevent premature failure of TAA, the surgeon must assess any deformity that could lead to abnormal biomechanics and make sure that the TAA prosthesis is properly implanted. Current TAA prosthetic designs offer improved materials and behavior and can be placed physiologically with the use of sophisticated instrumentation. Additional surgical procedures, such as osteotomies, tendon transfers, tenodeses, ligament reconstructions, and fusions, should be part of the surgeon’s armamentarium to prevent and solve problems associated with malalignment.

Bibliography


Degenerative Conditions of the Ankle


