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Special Article

Total ankle arthroplasty in younger patients: Current concepts, contemporary evidence, and decision-making considerations

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Abstract

This article reviews the current evidence on total ankle arthroplasty (TAA) in patients younger than 55 years, including recent clinical outcomes and technical considerations, through a comparative analysis that underscores the areas of greatest controversy in its application. It is highlighted that, although in this group of patients there are higher rates of revision and re-operation, compared to older patients, the current evidence of TAA with state-of-the-art implants shows an acceptable survival in the medium term even in cohorts with young patients, indicating that, although age may be a risk modifier, it is not in itself an absolute contraindication. Rigorous patient selection and precise alignment are determinants, while prosthetic design and proper deformity correction significantly influence outcomes.

Level of Evidence V; Narrative Review, Expert Opinion.

Keywords: Total ankle arthroplasty; Ankle replacement; Young patient; Implant survivorship; Complications; Biomechanics.

Introduction

Ankle arthrosis (AA) is a disabling disease whose management was initially limited to tibiotalar arthrodesis, with disadvantages including functional loss of the ankle, morbidity of neighboring joints, and complications inherent to the procedure. For its part, the TAA has evolved significantly in the last two decades. First- and second-generation prostheses were reserved for patients with low functional demand and advanced age, whereas they are proposed more frequently for younger, more active individuals.

Overall prosthetic survival has shown encouraging results, with cumulative rates of 85%-90% at 10 years in the general population. However, direct extrapolation to patients under 55 should be made with caution, given their higher activity levels and longer prosthetic life expectancy. This article critically reviews contemporary evidence on TTA in adults under 55, integrating recent clinical outcomes, comparative analyses, and technical considerations, with an emphasis on controversy.

Theoretical framework

Anatomy

The articular surface of the distal tibia has a longitudinal convexity that coincides with a concavity in the surface of the talus. The center of coincident convexity and concavity divides the tibiotalar joint into the medial and lateral compartments, which are important when assessing ankle weight-bearing and degenerative changes. The bony and ligamentous anatomy of the ankle joint confers a high degree of stability and congruence, protecting the articular cartilage from shearing forces[1].

Study performed at the Santa Ana Medical Center, Bogotá, Colombia.

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A stable ankle is the result of a static interaction (bones, ligaments, retinaculum) and dynamic (muscles, tendons) anatomical structures. The movement course within the ankle joint is predominantly from plantar flexion to dorsiflexion. Additionally, it performs internal and external rotation movements. Under weight-bearing conditions, the congruence of bone structures provides 100% of the stability for eversion and inversion, but only 30% of the rotational stability, while the ligament component participates by controlling the remaining 70% and all of the anterior-posterior tibiotalar displacement(2).

The total area of the tibiotalar joint is approximately 350mm^2 and is subject to an axial force of ~ 500 N, compared to the hip and knee, which, with joint areas of 1,100mm^2 and 1,120mm^2 respectively, are subject to the same amount of force, thus indicating that the pressure on the ankle joint cartilage can be up to three times that of other joints of the lower limbs(3,4).

The articular cartilage of the ankle has an approximate thickness of 1-1.62 mm, much smaller compared to that of the knee, which is approximately 1.69-2.5 mm. It also has unique characteristics, including more cross-linked glycosaminoglycans and fewer collagenase and interleukin (IL)-1 receptors (IL-1R) than other types of articular cartilage, providing high stiffness and tensile strength(3).

Ankle osteoarthritis

Osteoarthritis involves progressive thinning of the hyaline cartilage layer, increasing mechanical stress within the cartilage matrix and reducing the tissue available to withstand joint loads. This results in a spiraling cycle of degeneration, whereby aberrant mechanical feedback drives a chronic and pathological remodeling process that accelerates the progression of AA(2). Figure 1 shows the terminal arthrosis of the left ankle in a 44-year-old female patient is presented as a sequel to an astragalus fracture, Hawkins III.

Globally, various classification schemes for ankle osteoarthritis are frequently used in medical practice to guide diagnosis(3). Tables 1 to 3 present the most widely used and are generally based on a description of four stages according to the evolution of joint involvement.

Epidemiology of ankle osteoarthritis in younger patients

Approximately 15% of the global adult population is affected by joint pain and disabilities resulting from osteoarthritis, and approximately 1% has ankle osteoarthritis(4). Ankle arthrosis has a prevalence of 47.7 cases per 100,000 inhabitants, with a representation of the annual consultation of 50,000 cases with symptomatic osteoarthritis in the United States, generating a social impact that compares to that of end-stage renal disease or congestive heart failure(5,6).

In 75%/80% of AA cases, there is a history of a traumatic event (Figure 2); of these, 62% are related to fractures around the ankle and 16% to chronic ligament instability, especially that involving the lateral ligament complex of the ankle; 13% of cases have their origin in secondary causes such as inflammatory arthropathies, hemochromatosis, hemophilia, or osteonecrosis; and only 9% of patients have primary osteoarthritis, which differs from what is evident in the hip and knee(3,4,7).

Consistently, in 2005, Saltzman et al.(6) reported that the origin of ankle osteoarthritis is 70% post-traumatic, 12% rheumatoid disease, and 7% idiopathic (primary osteoarthritis). In addition, they explained that AA is due to an alteration in the relationship between the load exerted on the articular surfaces in the presence of joint incongruity and the instability resulting from soft tissue injuries, with a predictable progression in three stages: stage I: increased contact stress with joint damage, stage II: chondrocyte response to alteration and rupture of the extracellular matrix and stage III: failure of the chondrocyte response.

Figure 1. Anteroposterior, lateral and mortise views showing end-stage osteoarthritis of the left ankle.

Table 1. Takakura classification

Stage	Radiographic signs of osteoarthritis
Stage 1	No joint space narrowing, but early sclerosis and osteophyte formation.
Stage 2	Medial joint space narrowing.
Stage 3	Obliteration of the joint space with medial subchondral bone contact.
Stage 4	Obliteration of the entire joint space with complete bone-on-bone contact.

Table 2. Ankle osteoarthritis classification system (as suggested by Giannini et al.)

Stage	Radiographic signs of osteoarthritis
Stage 0	Normal joint space or subchondral sclerosis.
Stage 1	Presence of osteophytes without joint space narrowing.
Stage 2	Joint space narrowing with or without osteophytes.
Stage 3	Subtotal or complete disappearance or deformity of the joint space.

Table 3. COFAS classification system for end-stage ankle osteoarthritis (as suggested by Krause et al.)

Type	Description
Type 1	Isolated ankle arthritis.
Type 2	Ankle arthritis with intra-articular varus or valgus deformity, tight heel cord, or both.
Type 3	Ankle arthritis with hindfoot deformity, tibial malunion, midfoot abduction or adduction, midfoot supination, plantarflexed first ray, etc.
Type 4	Type 1 to 3 findings plus involvement of subtalar, calcaneocuboid, or talonavicular osteoarthritis.

Figure 2. Radiological image of the left ankle in a 29-year-old female patient with a Hawkins III talus fracture. (A) Anteroposterior, lateral, and mortise views of the fracture (B) Anteroposterior and mortise views of the ankle, and anteroposterior view of the foot, comparative.

On the other hand, Soyoung Lee et al. (8), in 2022, in their study conducted in South Korea, found that women with sprains and obese individuals had a 40% higher risk of developing ankle osteoarthritis. Additionally, they reported that age greater than 65 years and exercise were not significant risk factors for the diagnosis of AA in patients with compromised status.

A recent epidemiological study evaluating nearly 200,000 patients with ankle sprain demonstrated a significant association with later development of osteoarthritis, underscoring the cumulative burden of micro instability and chondral damage[8]. The predominantly post-traumatic etiology tends to affect a younger patient population, between 18 and 44 years of age, than those with other degenerative joint diseases in the lower limbs[4,7]. This explains why a relevant proportion of definitive surgical candidates are in the fifth decade of life. Contemporary analysis of therapeutic algorithms for AA recognizes that isolated chronological age is no longer an absolute criterion for ruling out TAA[7].

Paradigm shift: from arthrodesis to TAA

Historically, AA has been considered the gold standard for younger patients, as it offers predictable results and a lower rate of long-term reintervention compared with TAA. However, long-term follow-up demonstrated that arthrodesis alters hindfoot kinematics and increases mechanical loads in adjacent joints, particularly in the subtalar and midtarsal joints. This results in progressive secondary degeneration and eventual need for additional procedures[9].

On the other hand, the evolution of prosthetic design, anatomical designs, resurfacing technique (minimal bone sacrifice), biocompatible surfaces, osseointegration by porous coatings, fixed inserts, and use of biomaterials with lower friction torque, innovations in surgical technique that enable more precise prosthetic implantation, and patient-specific prosthetic design have improved clinical results and reduced the rate of early catastrophic failures reported in first- and second-generation prostheses.

Currently, TAA offers the advantage of preserving mobility, allowing a more physiological gait pattern, and protecting adjacent joints. These are especially relevant factors in patients with long functional life expectancy.

Ankle prosthesis

In 1962, an ankle joint “hemiarthroplasty” was performed on a 31-year-old male patient using a custom talar dome-covering implant made of Vitallium (a biocompatible cobalt-chromium-molybdenum alloy). The procedure was performed by Carrol Larson, who applied the concept of "cup arthroplasty" of the hip to the ankle, popularized at the time by his mentor, Smith-Petersen. Larson implanted a talar dome replacement prosthesis using a lateral approach[9].

For its part, the first TAA was practiced by Lord and Marrotte in 1970. Its prosthesis could be described as an "inverted hip", with a long-stemmed metal component implanted in the tibia, which articulates with an acetabular cup cemented in the calcaneus, after having completely extracted the talus[9,10].

First-generation prostheses did not fully account for the anatomy and biomechanics of the ankle, thereby imposing excessive or insufficient restrictions. These were two-part systems with a concave articular surface of polyethylene and a convex surface of metal with chromium-cobalt alloys. In most cases, the polyethylene component was adapted to the tibial component, while the talar component was made of metal. In all cases, the technique was supplemented using bone cement. These prostheses showed promising initial results but had high failure rates after two years, so the technique was abandoned for almost a decade[10,11].

In the case of second-generation prostheses, new implants were designed with special attention to replicating normal ankle anatomy, joint kinematics, ligament stability, and mechanical alignment, using semi-constrained devices and avoiding the use of cement[10].

In the early 1990s, designs more closely replicated the natural anatomy of the ankle, showing better clinical outcomes, improving implant designs, featuring mobile inserts, and less constriction, resulting in gradual improvement, with survival rates of approximately 80% at 10 years[9,10].

The three-component prosthesis consists of two metal components: one in the talus and one in the tibia, separated by a "mobile meniscus" of ultra-high molecular weight polyethylene, which provides a movement with low contact effort, while allowing inversion and eversion[9].

The third- and fourth-generation prostheses focus on customized components and better anatomical adaptation; additionally, fourth-generation prostheses aim to perform a smaller bone resection.

The Infinity® Ankle Prosthesis (Stryker) is a state-of-the-art bicomponent ankle prosthesis widely used in the United States; it is characterized by minimal bone resections (Figure 3), small tibial fixation pegs and talar (PEG) that avoid the use of long stems, uncemented technique, and an anatomical component of the talus that reproduces the geometry of the native talus[12] (Figure 4). For its part, a study by Shaferry et al. with a 6.5-year (5-8 years) follow-up demonstrated a 93.8% survival rate for the Infinity® prosthesis[13].

The Inbone® ankle prosthesis (Stryker) has been used since 2005, with a survival rate of 90.3% at 5 years[14]. It is a modular intramedullary tibial stem device that allows the addition of components to increase its length, a logging component, and a polyethylene insert in a saddle distribution.

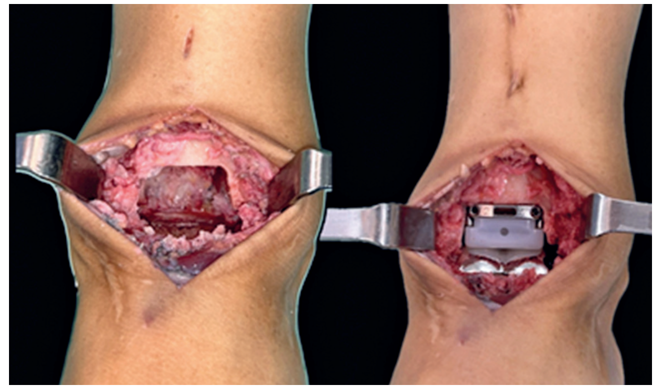

Figure 3. Infinity® prosthesis implantation.

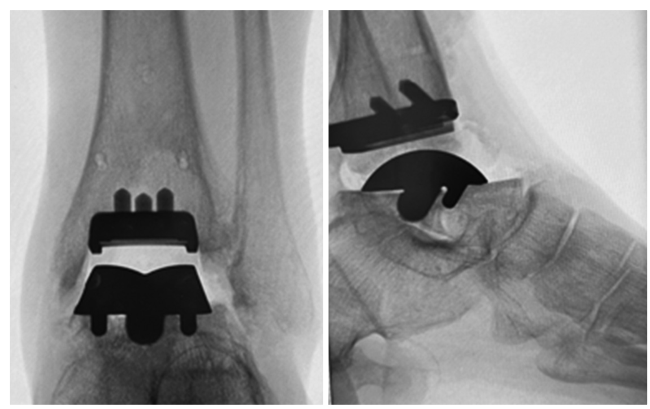

Figure 4. Post-operative radiological image of total ankle arthroplasty, Infinity® prosthesis.

For implantation, a support is used to firmly fix the limb and to allow orthogonal cuts in the sagittal and coronal planes, with alignment achieved during insertion using fluoroscopy. Its design allows its use for both primary replacements in cases of severe deformities, tibial bone loss, or distal tibial infarction, and revision surgeries[15]. In the Inbone II® version, greater modularity of the tibial component was added, two anterior PEGs were introduced into the talar component, and a central groove-shaped talar design was implemented. Gagne et al., in their study in 2021, demonstrated a survival rate of 98% at 5 years[16].

Ankle prosthesis in younger patients

The number of TAAs in younger patients is increasing, and their indications have expanded over time due to improved design and growing evidence of their use. It must be considered that multiple variables, including patient characteristics, influence their outcome[17].

Historically, it has been proposed that the ideal patient for a TAA is a physically undemanding patient, not obese, older, with non-traumatic primary ankle osteoarthritis in the terminal stage or multiple joint arthritis with minimal deformity, good bone reserve, without neurovascular deterioration of the leg and with more than two-thirds of the normal range of motion of the ankle.

Regarding the indication for TAA in younger patients, great caution has been taken, given that implant longevity may be affected by functional requirements and long-term expectations, which are directly proportional to life expectancy. In addition, younger patients tend to be more active, which can lead to faster wear of the implant. Additionally, special attention should be paid to patients with inflammatory joint disease, since they are younger at the time of implantation but are often less active because multiple joints are affected[17].

In 1999, Kofoed and Lundberg-Jensen published the results of 100 uncemented STAR prostheses, 30 of which were implanted in patients under 50 years, with a survival of 75% at 6.8 years, and 70 in patients over 50 years, with a survival of 81% at six years, indicating the absence of a statistically significant difference between the two groups[18].

In 2013, Rodríguez-Pinto et al.[19,20], evaluated ankle prostheses in 31 patients under 50 years versus 72 patients over 50 years, at a 40-month follow-up, finding a significant increase in AOFAS scores, postoperative gains in mobility ranges, and a tendency toward fewer minor complications in the group of patients under 50 years.

In 2015, in a cohort of 395 patients divided into 3 age groups (< 55, 55-70, and > 70 years), they found that patients younger than 55 years had greater improvements in AOFAS vitality and function scores than those older than 70 years. They found no differences in pain, physical performance outcomes, or incidence of wound complications or need for reoperation or revision[21].

In a 2020 meta-analysis, 10 articles were evaluated, including 1963 implants that met the inclusion criteria. They found that overall implant survival was 86.5%. Using a median age of 62.65 years, they reported a survival rate of 95.5% in studies above the median and 90.3% in studies below it, although this association was not statistically significant[22].

In 2022, Cottom et al.[23] reported a series of 112 cases of ankle prostheses divided into three age subgroups: Group 1: < 55 years, Group 2: 55-70 years, and Group 3: > 70 years, showing improvement in the AOFAS score and the Foot Function Index (FFI); no statistically significant difference was found regarding complications.

However, post-traumatic ankle osteoarthritis usually presents at a much younger age, and although TAA has traditionally been recommended for older and less physically demanding patients, it has been shown that patient satisfaction remains high, even in younger populations with higher functional demand and probably higher postoperative expectations[17,23].

Biomechanics and specific considerations of the younger patient

The survival and behavior of a prosthesis in younger patients represents a biomechanical challenge different from that of older patients, considering the level of physical activity with greater intensities and a greater number of load cycles over time (cumulative load), a greater expectation of prosthetic survival, and deformities frequently associated with a post-traumatic etiology.

However, from a biological and functional perspective, the improved baseline musculoskeletal status of this age population could contribute to more efficient rehabilitation and potentially to greater functional durability of the implant. This considering that in general the younger patient presents better bone quality, better muscle condition, greater functional reserve, more effective gait patterns, less proprioceptive and balance commitment, which translates into a better ability to restore joint kinematics after TAA, obtaining a better response in relation to parameters such as cadence, step length and gait speed and reflecting a relevant functional recovery, with symmetry in gait and joint mechanics.

Functional demands: Patient, under 55 years of age, usually maintains a demanding occupational activity and participates in recreational sports. Repeated exposure to high cyclic loads may accelerate polyethylene wear and micromotion-related loosening. In addition, young patients have a higher expectation of returning to impact activities, which requires a clear preoperative discussion of realistic limitations.

Prosthetic load and survival: Mechanically, TAA survival depends on proper coronal alignment, ligament balance, bone quality, and homogeneous load distribution. In younger patients with post-traumatic residual deformity, the risk of eccentric overload increases if the correction is not anatomical.

Ligamental alignment and balance: Neutral or slightly valgus alignment is critical. Residual varus greater than 5° is associated with increased risk of tibial loosening. In younger patients with significant structural deformity, TAA should be combined with corrective osteotomies and ligament reconstruction when necessary.

Clinical outcomes and prosthetic survival

Contemporary discussion of TAA in younger patients should be supported by evidence specific to this age group. A comprehensive meta-analysis published in 2020 on global prosthetic survival demonstrated cumulative survival rates close to 85%-90% at 10 years in the general population[22]. However, this analysis predominantly included older patients, limiting direct extrapolation to those under 55 years.

When younger patients are specifically analyzed, the evidence becomes even more nuanced. A 2020 study on total ankle replacement in young patients reported significant functional improvement but also a higher rate of reoperation compared with older cohorts; in the meantime, they will avoid progressive degeneration of adjacent joints[24]. This finding suggests that while the clinical benefit is real, the cost in terms of reinterventions is not negligible.

More specifically, a 2021 study that evaluated survival, complications, and revision rates in patients younger than 55 years included 51 patients, with a mean age of 49.4 years, a mean weight of 93kg, and a mean follow-up of 31.2 months. There were seven major complications (13%) that required a return to the operating room. These included two surgical wound dehiscences, two talar component subsidences, two deep joint infections, and one flexor hallucis longus tendon injury. Overall implant survival was 94%, and only three patients required explantation. There were eight minor complications (15%) that resolved with conservative treatment. Nonetheless, medium-term survival rates remained clinically acceptable, reinforcing the need for interpretation and contextualization rather than absolute conclusions[25].

More recently, an intermediate follow-up study in patients ≤ 50 years published in 2024, with a follow-up of 8.8 years in 58 patients, showed that functional results can be satisfactory in the medium term; 11 patients presented complications related to arthroplasty, and only one patient required revision of the metal components of the prosthesis, which evidenced a survival of the implant of 98% at 8.8 years[26]. This reinforces the concept that TAA in younger patients is not synonymous with early failure, but does imply a higher cumulative likelihood of reoperation.

A 2024 systematic review by Kipp et al.[27] failed to demonstrate statistically significant differences between younger (≤ 50 years) and older patients in terms of reoperation rate (RR 1.24; $p = 0.412$), complications (RR 1.01; $p = 0.955$), and implant survival (RR 1.04; $p = 0.155$). From a clinical perspective, this work questions the traditional paradigm that restricted TAA to older patients with low functional demand, supporting a cautious expansion of indications towards younger patients.

Current indications and contraindications

- **Deformity:** Severe deformity is not an absolute contraindication, but it increases the technical complexity and risk of reintervention.
- **Instability:** Concomitant ligament correction is critical to avoid early failure.
- **Avascular necrosis:** Careful selection is essential, particularly in advanced talar collapse.
- **Obesity and occupational activity:** Recent evidence suggests that greater physical activity may be associated with higher complication rates.

Surgical technique

For proper implantation, it must be considered that weight-bearing radiographs are mandatory, an evaluation of the hindfoot must be conducted, during implantation, it is essential to perform the complete correction of the deformity in both varus and valgus, oversizing of the components must be avoided, and a meticulous ligament balance must be performed.

Future direction

- Navigation
- Custom implants
- Improvements in biomaterials

Conclusion

Total ankle arthroplasty in patients younger than 55 years should not be discounted on the basis of chronological age. Contemporary evidence increasingly demonstrates improved medium-term prosthesis survival and functionally significant improvements for patients. However, these patients are at consistently higher risk of revision and complications. The key is not the age itself, but the biomechanical environment, proper deformity correction, accurate implant selection, and realistic targeting of expectations by the surgeon. In expert hands, TAA is a carefully selected, valid strategy for preserving mobility in younger patients.

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