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CURRENT CONCEPTS

Total ankle replacement
Design evolution and results

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The ankle joint has unique anatomical, biomechanical and cartilaginous structural characteristics that allow the joint to withstand the very high mechanical stresses and strains over years. Any minor changes to any of these features predispose the joint to osteoarthritis. Total ankle replacement (TAR) is evolving as an alternative to ankle arthrodesis for the treatment of end-stage ankle osteoarthritis. Initial implant designs from the early 1970s had unacceptably high failure and complication rates. As a result many orthopaedic surgeons have restricted the use of TAR in favour of ankle arthrodesis. Long term follow-up studies following ankle arthrodesis show risks of developing adjacent joint osteoarthritis. Therefore research towards a successful ankle replacement continues. Newer designs and longer-term outcome studies have renewed the interest in ankle joint replacement. We present an overview of the evolution, results and current concepts of total ankle replacement.

Keywords : ankle ; replacement ; arthroplasty ; prosthesis ; arthritis.

INTRODUCTION

Following the successful development of total hip and knee arthroplasty, total ankle replacement (TAR) was designed as an alternative to ankle arthrodesis in advanced ankle osteoarthritis (OA). Historically ankle arthrodesis was considered the gold standard for treatment of end-stage OA of the ankle joint. It has been found to reproducibly provide pain relief and return to activities of daily living (*49-52,69*). The procedure is well tolerated especially in relatively young and healthy patients with isolated ankle joint OA. Long-term follow-up studies of successful ankle arthrodesis however reveal further increase in disability due to degenerative changes in the ipsilateral hind- and midfoot in 44% to 100% of the patients (*6,12,20,49,71*). Elderly patients with diffuse degenerative joint disease do not easily tolerate the increased demands that are placed on other joints following ankle arthrodesis. They often require walking aids and permanent shoe modifications and may have decreased functional ability. Other established problems with ankle arthrodesis include non-union, pseudarthrosis, malunion, wound breakdown, infection. Functional limitations include limping, difficulty in walking on uneven surfaces, climbing stairs and

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running (6,13,19,53). Although ankle arthrodesis does help to relieve pain and improve activities of daily living, it should now be considered as a salvage procedure (71).

The development of ipsilateral hindfoot osteoarthritis and other complications have raised the interest in ankle replacement as an alternative. Total ankle replacement can preserve tibiotalar motion available at the time of surgery, thus reduce the demands on adjacent joints of the hind- and midfoot and allow better functional gait with reduction of limp (13,16,58). This paper presents an overview of the evolution, results and current concepts of total ankle replacements.

ANKLE ANATOMY AND BIOMECHANICS

Anatomy

The ankle joint is a highly congruent joint which is composed of three articulations : the tibiotalar, talofibular and tibiofibular joints. The body of the talus is held within the mortise formed by the distal tibia and fibula. Superiorly the talus articulates with the tibial plafond and its medial and lateral facets articulate with the malleoli. The talus is cone-shaped, with a smaller medial and larger lateral radius of curvature. When viewed from the top the articular portion of the talus appears shaped like a wedge that narrows from anterior to posterior. Soft tissue structures including collateral and syndesmotic ligaments, muscle-tendon units and the joint capsule help further stabilize the bony configuration of the ankle.

Biomechanics

Initially the ankle joint was thought to function as a simple hinge with a transverse axis at a right angle to the sagittal plane. Evidence now shows that ankle motion occurs in three planes : the sagittal, coronal, and transverse plane, resulting in mainly plantar and dorsiflexion, but also inversion and eversion, internal and external rotation. Due to the conical shape of the talus, with a smaller medial and larger lateral radius, motions in the ankle joint are coupled. Plantar flexion of the ankle results in inversion, whereas dorsiflexion results in eversion of the foot. Furthermore, plantar flexion causes external rotation of the leg and dorsiflexion causes internal rotation of the leg, when the foot is fixed on the ground (4,9,32,47,48,59). The wedge shape of the talus with a larger anterior mediolateral width and smaller posterior width locks the talus in the mortise in dorsiflexion and the available space between the talus and the medial and lateral malleoli allows rotatory movement in plantar flexion. As the talus moves from dorsiflexion to plantar flexion it has a continuously changing axis of rotation relative to the mortise (59).

Plantarflexion and dorsiflexion constitute the greatest amount of motion in the healthy ankle, with plantar flexion ranging from 23° to 56° and dorsiflexion from 13° to 33°. During the normal gait cycle the ankle moves between 10° dorsiflexion and 10° to 15° plantar flexion (59). Average sagittal plane motion measures 24°, climbing stairs requires 37°, and descending requires 56°. In the arthritic ankle, dorsiflexion is typically restricted, limiting daily activities like walking stairs (66). The total contact surface area (CSA) of the loaded ankle joint is much smaller than that of the knee or hip, and therefore it has to withstand more load per mm^2 (7,36,38,70). More than 75% of the load is distributed through the superior articular surface of the talus and the force per unit area is greatest over the anterior and lateral portions of the talar dome. The remaining load is distributed through the medial and lateral facets (38). The complex anatomic and biomechanical properties of the ankle joint including the small weight-bearing surface and the high forces it needs to withstand, makes designing a total ankle prosthesis very challenging.

OSTEOARTHRITIS

Ankle osteoarthritis is a progressive degenerative disease of cartilage leading to pain, reduced range of motion, loss of quality of life and general disability (fig 1) (3). Unlike the hip and knee, the ankle joint is rarely affected by primary osteoarthritis (10,60,70). In over 70% of ankle osteoarthritis the aetiology is due to abnormalities in ankle formation or post-traumatic, most commonly associated with

Fig. 1. — AP and Lateral view of an ankle with end stage osteoarthritis.

ankle fractures and/or recurrent ankle instability. This can be from a single injury or cumulative effects of multiple sprains (*27,58*). Other causes of ankle degenerative joint disease include inflammatory arthropathies like rheumatoid disease, psoriatic arthritis or gout, haemochromatosis, infe tion, osteochondritis dissecans, neuropathic arthropathy (Charcot), tumours or neurological conditions (*70,72,77*).

Articular cartilage

The ankle joint has to endure contact stresses of up to five times body weight during walking due to the small articular contact surface area (CSA) (*38, 66,71*). Sheperd and Seedhom compared cartilage thickness in ankles, knees and hips and found that ankle cartilage is the thinnest, ranging from 1 to 1.7 mm. They also found that this thinner cartilage has a higher compressive modulus (*60*).

Simon *et al* showed that the most congruent joints have the thinnest cartilage to better equalize the contact stresses (*62*). Under load, the talus moves to a position of maximum congruency within the ankle mortise and ankle congruency is affected by fractures and integrity of the medial supporting structures (*54*). Problems such as a malunited ankle fracture cause reduction in the CSA with secondary alteration of contact stresses, which then potentially leads to degeneration of the articular cartilage and eventual ankle arthritis (*70*).

Mechanical properties of cartilage

Kempson studied the effect of ageing on cartilage and observed that, contrary to femoral head cartilage, the tensile strength of the talar cartilage decreased only slightly with age (*37*). Normally the compressive deformation of cartilage is restricted to the more superficial layers of articular cartilage during loading. The superficial layer in the talus makes up a greater proportion of the cartilage thickness and this may protect the talus against developing osteoarthritis (*33*). These particular characteristics protect the ankle from osteoarthritis, but also create a vulnerability to posttraumatic arthritis. This then suggests that the majority of degenerative arthritis in a previously normal ankle joint is of posttraumatic origin, and occurs in a younger age group (*70*).

INDICATIONS AND CONTRA-INDICATIONS OF ANKLE REPLACEMENT

Proper patient selection is critical to obtain favourable results in any joint arthroplasty, including total ankle replacement. Wood *et al* stated that : "the *ideal patient is the middle aged or elderly patient with an anatomically aligned ankle and heel, whose ankle has a well-preserved range of motion that includes at least 5 degrees of dorsiflexion"* (*79*).

Age

The age range of candidates for TAR has not been clearly defined. We know that survival of the implant is related to the loading history placed upon it (*56*). As ankle arthritis is mostly of traumatic origin, the patients tend to be younger and more active compared to those who develop arthritis of hip and knee. These patients will want to resume more vigorous activities after TAR, which then reduces the long-term survival of the implant. Therefore in these patients the prosthesis may fail early (*11,17,79*).

Alignment

Early failure is also associated with pre-operative varus or valgus malalignment. Several studies recommend that a deformity of more than 15° should be considered unsuitable for TAR (*17,28,29,80*). Other authors have shown that more deformity is acceptable but point out the importance of carrying out concurrent realignment procedures. Hobson *et al* compared two groups : 91 ankles with a hindfoot deformity up to 11° and 32 ankles with a hindfoot deformity of 11° to 30°. They found no difference in TAR survival rates. They also recommended that attention should be paid to correction of any misalignment by a combination of soft-tissue and bony procedures prior to total ankle replacement surgery, to prevent failures due to instability (*33*).

Range of motion

Ankle replacement might not be the best solution for an arthritic ankle with a severely reduced range of motion. TAR does not increase movement, but preserves the range of motion present preoperatively (*13,79,81*). In ankles with severely reduced range of motion, arthrodesis might be the best option as complications are more frequent in ankle replacements and the clinical outcome will be similar (*63*).

Wood *et al* also pointed out the importance of dorsiflexion to at least a neutral position as they found that an ankle fused in an anatomical position gives a better gait than a replacement that will not dorsiflex (*79*).

Indications

TAR is indicated in severe ankle joint OA, inflammatory arthritis, primary osteoarthrosis, or other conditions which affect the ankle such as haemochromatosis or recurrent haemarthrosis due to haemophilia (*11,18*).

Contra-indications

The contra-indications can be either absolute or relative.

Absolute contra-indications include active or recent infection, neuropathic arthropathy, avascular necrosis of the talus affecting more than 50% of the body, poor quality soft tissue envelope, lower limb neurological dysfunction, severe irreducible malalignment and chronic ankle instability. The relative contraindications include young age and/or high physical demands, a history of successfully treated local osteomyelitis, previous open ankle fracture / dislocation, segmental bone loss or severe osteoporosis (*11,24,32*). Diabetes mellitus, obesity, malnutrition, and long-term steroid use have been associated with an increased risk of infection (*26*).

DESIGNS AND RESULTS

First generation designs

The first attempted ankle joint replacement was performed in the early 70's by Lord and Marotte, with a ball and socket type implant based on total hip replacement designs. They carried out 25 replacements and found that only 7 cases could be considered as satisfactory and therefore concluded that arthrodesis was the better procedure (*45,46*).

Subsequent designs were either constrained or non-constrained. They predominantly consisted of two components, a polyethylene concave articular surface on the tibia and a metal convex surface on the talus. All first generation implants were cemented (*75*).

The first reports on TAR around early to mid 1970s showed good to fair results in 80% to 85% of patients at a mean follow-up of less than 5 years (*44, 53,65,67,78*). Subsequent long-term reviews, longer than 5 years, showed extremely poor results.

Unger *et al* reviewed 23 ankle replacements after an average of 5.6 years and found 93% loosening (*74*). Kitaoka *et al* reported on 204 Mayo TAR's performed between 1974 and 1984. Overall implant survival rate was 79% at 5 years, 65% at 10 years and 61% at 15 years, with a revision rate of 41% for persistent pain (*39*). Even worse results were reported for the constrained group of implants. Wynn and Wilde found that 60% of the Conaxial (Beck-Steffee) ankle replacement had loosening after 5 years and 90% after 10 years (*82*). Bolton-Maggs *et al* showed high complication rates and poor clinical results from 62 ankle replacements performed between 1974 and 1981, and recommended that arthrodesis remain the treatment of choice, regardless of the underlying pathology (*5*). The main complications reported were severe osteolysis, component loosening, impingement, infection and soft-tissue breakdown (5,39,44,45,46,53,67,78,82).

The use of bone cement in this first generation of ankle replacements was a major contributing cause of failure. Larger bone resections were required to fit these implants with cement, which then exposed weaker surfaces of the talus and tibia to compressive loads, as bone strength rapidly decreases below the subchondral plate (35,64). This contributed to component subsidence with early loosening. Poor soft tissue handling and the lack of appropriate surgical instrumentation resulted in wound dehiscence, infection and inaccurate positioning of the implants. Results with the first generation ankle replacements were so disappointing that several publications advised against the use of total ankle replacements (39,53,78,82).

Second generation

Following the disappointing results from first generation ankle replacements, the search for a successful TAR continued. The second generation of TAR's were developed with some major improvements including porous bead/hydroxyapatite coating for cementless fixation, minimal bone resection techniques, attempted replication of normal ankle anatomy by restoring mechanical alignment and joint kinematics. The designs can be divided into two groups : two-component fixed bearing and three-component mobile bearing. The fixed-bearing ankle replacements have only one articulation between the tibial and talar component, with the polyethylene insert attached to the tibial component. Mobile-bearing replacements use a moving polyethylene bearing as a meniscus between the tibial and talar components resulting in two separate articular surfaces. The moving meniscus reduces shear forces by having minimum constraints. It also maximises congruency between the articular surfaces, thus minimising polyethylene wear. Three second-generation designs have dominated the market : the Scandinavian Total Ankle Replacement (STAR, Waldemar Link, Hamburg, Germany), the Buechel-Pappas Total Ankle Replacement (Endotec, South Orange, NJ) and the Agility Total Ankle System (Depuy, Warsaw, IN) (10,14,18,32,76).

Scandinavian Total Ankle Replacement (STAR)

In the early 80`s the first version of the Scandinavian Total Ankle Replacement (STAR), a cemented, two-component, fixed bearing design, became available in Europe (figs 2 & 3). The STAR has been further developed to a cemented three-component mobile bearing implant in 1986, and to the current cementless, three-component ankle replacement from 1990. It has become the most popular ankle replacement in Europe.

Results and complications

Kofoed reviewed 58 patients operated between 1986 till 1995. Cement fixation was used in 33 patients between 1986 and 1989 and the subsequent 25 patients had cementless fixation (1990-1995). Survivorship analyses for 12 years based on life tables showed 70% survival rates for the cemented group and 95.4% for the uncemented group (42). A prospective study of 68 ankle replacements with a mean follow-up of 3.7 years by Valderrabano *et al* showed excellent or good results in 67 patients : 35 (54%) patients were pain free. The American Orthopaedic Foot and Ankle score (AOFAS) improved from 24.7 to 84.3 points. Fourteen ankles (21%) required additional operations. No ankles were converted to arthrodesis (75). Wood *et al* presented the results of 200 TAR's with a mean follow-up of 88 months. Their five year survival rate was 93.3% and the ten year survival 80.3%. Five ankles had delayed wound healing (81). Anderson *et al* studied a series of 51 ankles : 12 had to be revised, including 5 conversions to arthrodesis. The 5 year survival rate was 70% (2). Complications reported with the STAR included 29 intraoperative fractures in 468 ankles (5.3%) in 5 studies, wound problems in 36 of 615 ankles (5.9%) and deep infection in 0.4% found in 8 studies. Radiographic loosening occurred in 34 of 376 ankles (9%) in six studies with 3.8 years mean follow-up (22,23).

Fig. 2. — The STAR total ankle replacement

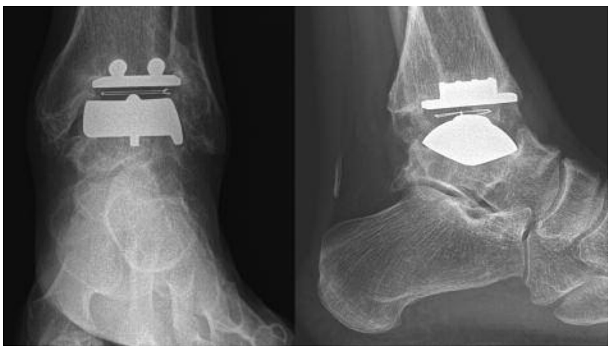

Fig. 3. — AP and Lateral view of an ankle with a STAR prosthesis.

The Buechel-Pappas Total Ankle Replacement

In 1981 the Buechel-Pappas Total Ankle Replacement was introduced in the USA. It is an uncemented mobile bearing design (fig 4). The talar component has since been modified and now has a deeper sulcus and an additional talar fixation fin, in order to reduce the rate of talar component subsidence (*14,18,75*).

Results and complications

Buechel and Pappas presented two consecutive series of patients. In a series of 40 patients with the shallow sulcus design and a mean follow-up of

Fig. 4. — The Buechel-Pappas total ankle prosthesis

12 years, the clinical results were 70% good to excellent with a 20 year overall survivorship of 74.2%. Reports on the deep sulcus design showed 88% good to excellent results in a series of 75 ankles and 12 year overall survivorship of 92% (*8*). Doets' independent review of 93 Buechel-Pappas ankle replacements with a mean follow-up of 8 years showed a mean overall survival rate of 84%. The series included 19 LCS implants with a 60% survivorship at 10 years and 74 deep sulcus designs with 90% survivorship at 12 years (*17*).

Complications with wound healing were reported in 9.7%, deep infections in 3% and intra-operative fractures were found in 9.2% of cases across four studies (*22,23*).

The Agility Total Ankle System

The Agility Total Ankle System was first used in 1984. It is a fixed-bearing, semi-constrained design. It resurfaces the superior, medial and lateral articular surface and requires an arthrodesis of the syndesmosis for load shearing through the fibula (fig 5). It was approved for use in the USA by the

Fig. 5. — The Agility total ankle prosthesis

FDA in 1992 and is the most used ankle replacement in the USA. The Agility too has undergone changes in design and currently the Phase IV implant is in use (*18,40,54,78*).

Results and complications

Pyevich *et al* studied the intermediate-term results of the first 100 Agility ankle replacements performed by the inventor, F.G. Alvine. They found 85 surviving implants at an average of 4.8 years. The average age was 63 years at time of operation. Eighty-three percent of patients had little or no pain, 93% were satisfied (*55*). Knecht did a longer-term study on the first 100 Agility ankle replacements and a further 32 that had been performed by F.G. Alvin. The mean follow-up period was 9 years, average age of patients at time of surgery was 61 years. More than 90% of the patients clinically followed had decreased pain and were satisfied. An 11% revision rate was reported, and 76% showed peri-implant radiolucency without clinical implications ; 41% of patients had a delayed union of the syndesmosis of more than 6 months (*40*).

Less than 25% of their patients followed radiographically had progressive hindfoot arthritis, which is substantially better than reports of 50% and more following ankle arthrodesis (*1,6,19,49,68*).

Spirt *et al* reviewed the complication and reoperation rates in 306 consecutive Agility TARs at a mean follow-up of 33 months. Eighty-five ankles in 85 patients (28%) underwent 127 reoperations, most commonly for debridement of heterotopic bone (34%), correction of axial malalignment (24%), and component replacement (18%).

Five-year survivorship free of reoperation was 54%, survivorship free of failure was 80% for all patients, and 89% in patients greater than 54 years of age. Younger age was found to have a negative effect on the rates of re-operation and failure rates (*64*).

Kopp *et al* retrospectively reviewed the results of Agility TAR in 41 consecutive patients (43 ankles) with an average follow-up of 44.5 months. The AOFAS-scores improved from 33.6 points to 83.3. Overall, 37 of 38 patients clinically reviewed were satisfied and would have the same procedure under similar circumstances. Radiographic follow-up revealed periprosthetic lucency, lysis, and component migration/subsidence. These did not appear to adversely affect the intermediate-term clinical outcomes. They concluded that the long-term consequences of such radiographic findings are of concern, and surgeons and patients choosing this procedure need to be cautious (table I) (*43*).

Complications reported on the Agility Total Ankle System included wound complications in 32 of 503 implants (6.4%) and deep infection in 8 of 503 replacements (1.6%) across five studies. Two studies showed an intra-operative malleolar fractures in 15 of 93 ankles (16.1%) and repeat surgery rates of 135 in 429 cases (31.5%) in two studies (*22,23*).

Third generation

Currently there are about twenty ankle replacements available on the marketplace worldwide (*14*). The latest generation all consist of three components : the tibial and talar components are made of cobalt-chromium and have a titanium porous coating for cementless fixation, some of them also with hydroxyapatite ; they articulate with a polyethylene mobile bearing (*10,14,18,32,76*).

These third generation designs include the Hintegra® (Integra, France) (figs 6, 7), Ankle Evolution System (AES) (Biomet Europe,

Table I. — Survivorship analysis and failure rates of second generation TAR's

Author	Prosthesis	Number of ankles	Mean follow-up in years	Survivorship analysis	Failures
Kofoed *(42)*	STAR	58	9.4 (> 2)	70% at 12 y (cemented) 95.4% at 12 y (uncemented)	9/33 (27%) (cemented) 1/25 (4%) (uncemented)
Valderrabano *et al.* *(75)*	STAR	68	3.7 (2.4-6.2)		9/68 (13%)
Wood *et al* *(81)*	STAR	200	7.3 (5-13)	80% at 10 y	24/200 (12%)
Anderson *et al.* *(2)*	STAR	51	4.3 (3-8)	70% at 5 y	12/51 (23%)
Buechel-Pappas *(8)*	Buechel-Pappas	75 (deep sulcus)	5 (2-12)	92% at 12 y	6/75 (8%)
Doets *et al.* *(17)*	Buechel-Pappas	93 (LCS and deep sulcus)	7.2 (0.4-16.3)	84% at 8 y	15/93 (16%)
Pyevich *et al.* *(55)*	Agility	100	4.8 (2.8-12.3)	80% at 5 y	6/86 (7%)
Knecht *et al.* *(40)*	Agility	132	9 (7-16)	63% at 14 y	14/132 (11%)
Spirt *et al.* *(64)*	Agility	306	2.8 (0.3-6.3)	80% at 5 y	9/306 (3%)
Kopp *et al.* *(43)*	Agility	40	2.8 (2.2-5.3)		2/40 (5%)

Belgium), Bologna-Oxford (BOX) (Finsbury, Leatherhead, UK) Salto™ (Tornier, Grenoble, France) and Mobility (Depuy, Leeds, UK) *(14)*. Lessons were learned from previous generations of ankle replacements and more emphasis has been placed on soft tissue balancing, use of ligaments for stability, correction of deformity and salvage options for failed replacements *(10,14)*. Hintermann *et al* reported the short-term results of the HINTEGRA ankle replacement in a consecutive series of 116 patients (122 ankles). Eight ankles had to be revised : four because of loosening of at least one component, one because of dislocation of the meniscus, and three for other reasons. After an average of 18.9 months (range, 1-3 years), 84% of patients were satisfied, and the clinical results were rated as good or excellent in 82% of cases. The AOFOS scores improved from 40 points to 85 at follow-up (table II) *(31)*.

In 2007 independent authors have reported on outcomes from the joint arthroplasty registers from Sweden, Norway and New Zealand in particular on replacement survival rates. Henricson *et al* reported on 531 three-component TARs from the Swedish register implanted between April 1993 and June 2006. This included 5 different types of third-generation TARs. The STAR was the most common prosthesis with 318 implants followed by the Buechel-Pappas with 92 replacements. They found 101 ankles (19%) had been revised by June 2006. The overall survival rates were 78% (95% CI : 74-82) at 5 years and 62% (95% CI : 52-72) at 10 years. The survival rates became significantly higher as the surgeon gained more experience after the first 30 cases. Lower age at time of surgery implied increased risk of revision whereas diagnosis or gender did not. There was no significant difference in survival rates between cemented and uncemented prostheses (table II) *(30)*. Fevang *et al* reported on 257 TARs performed in Norway between 1994 and 2005 ; 212 were uncemented STAR prostheses and 32 were cemented TPR prostheses (a 2-component fixed bearing design). Revision surgery was carried out in 27 cases. The overall survival rates were 89% at 5 years and 76% at 10 years. There was no significant influence of age, sex, type of prosthesis, diagnosis or year of operation on the risk of revision (table II) *(20)*.

In a review of 202 total ankle replacements with a follow-up of 6 years in the New Zealand joint registry by Hosman *et al*, the overall cumulative 5 year survival was 86%. Fourteen revisions were recorded due to component loosening. In addition they found a higher failure rate in TARs which had longer operative times. The replacements used were the Agility total ankle system, the STAR, the

Table II. — Survivorship analysis and failure rates of third generation TAR's

Author	Prosthesis	Number of ankles	Mean follow-up in years	Survivorship analysis	Failures
Hintermann *et al.* (*31*)	Hintegra	122	1.57 (1-3)		8 (7%)
Henricson *et al.* (*30*)	STAR, BP, AES, Hintegra, Mobility	531		78% at 5 y 62% at 10 y	101 (19%)
Fevang *et al.* (*20*)	TPR, STAR, AES, Hintegra	257	4 (0.01-12)	89% at 5 y 76% at 10 y	27 (11%)
Hosman *et al.* (*34*)	Agility, STAR, Mobility, Ramses	202	2.3 (0.6-6.3)	86% at 5 y	14 (7%)

Fig 6. — The Hintegra total ankle prosthesis

Fig 7. — AP and Lateral view of an ankle with a Hintegra prosthesis.

Mobility and the Ramses (table II) (*34*). Stengel *et al* did a systematic meta- analysis of studies on three-component total ankle prostheses and found a weighted 5-year prosthesis survival rate of 90.6%. Weighted complication rates ranged from 1.6% (deep infections) to 14.7% (impingement). Revision surgery had to be performed in 12.5% ; secondary arthrodesis was necessary in 6.3%. They concluded that ankle arthroplasty improves pain and joint mobility in end-stage ankle arthritis, but that it's performance compared to ankle arthrodesis needs further study in a properly designed randomized trial (*68*).

DISCUSSION

The ankle joint has been the latest joint in the lower limb to be replaced. As a result there have not been many studies on TARs. Contrary to hip and knee joints, primary OA is rare in ankle joints as the majority of cases are secondary, usually due to trauma, and occur at a younger age. This makes the population requiring TAR surgery different from THR or TKR and as a result the number of ankle replacements performed annually is much lower.

Ankle replacements were originally designed as an alternative to ankle arthrodesis. In an observational study comparing reoperation rates following ankle replacement and ankle arthrodesis

Soohoo *et al* found a rate of 23% at five years for TAR and 11% for arthrodesis. The patients treated with ankle arthrodesis had a higher rate of subtalar fusion at five years (2.8%) compared to TAR (0.7%). The authors confirmed that compared to ankle arthrodesis, ankle replacement was associated with a higher rate of complications, but noted a decreased risk for patients requiring subtalar joint fusion (*63*). In a systematic review of the literature looking at the intermediate and long-term outcomes of TAR versus ankle arthrodesis, Haddad *et al* found 5- and 10 year survival rates of 78% and 77% respectively after TAR. Revision surgery was required in 7% of patients following TAR, in 9% following ankle arthrodesis . The authors concluded that although the evidence was limited, the intermediate results suggest the two procedures are comparable (*25*). In a prospective controlled multi-centered trial of STAR TAR versus ankle arthrodesis, Salzmann *et al* concluded that by 24 months, ankles treated with a STAR ankle replacement had better function and equivalent pain relief as ankles treated with fusion, but longer-term follow-up is required to better evaluate the durability and functional longevity of TAR (*57*). The majority of studies on TARs have limited mean follow-up times and are usually relatively small series. Comparisons between different series of TARs are difficult because of variability in implant design, length of follow-up, heterogeneous study population and the lack of standardised outcome measures.

Although there are no long-term results with a mean follow-up of 10 to 15 years from independent researchers available, short- to mid-term results have been promising with survival rates of up to 90% (68). These results have improved greatly comparing to those of first and early second generation designs of TARs. Improvements in the success and survival rates are to be expected as further developments of implant design, instrumentation, operation techniques and surgeon training and experience continue.

In carefully selected patients total ankle replacement is a promising alternative to ankle arthrodesis, when performed by experienced surgeons familiar with the anatomy and biomechanics of the ankle joint.

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