Total Ankle Replacement Using HINTEGRA, an Unconstrained, Three-Component System
Surgical Technique and Pitfalls

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KEY POINTS

- Total ankle replacement (TAR) has become a valuable treatment option in patients with end-stage ankle osteoarthritis (OA).
- One popular 3-component system, the HINTEGRA TAR, is an unconstrained system that provides inversion-eversion stability.
- Both primary (degenerative) and posttraumatic OA are important indicators for TAR, but the ankle joint is rarely affected by primary OA.

INDICATIONS FOR TOTAL ANKLE REPLACEMENT

Both primary (degenerative) and posttraumatic osteoarthritis (OA) are important indicators for total ankle replacement (TAR), but the ankle joint is rarely affected by primary OA. Clinical and epidemiologic studies revealed that previous trauma is the most common origin of ankle OA (**Fig. 1**).[1–19] Although rotational ankle fractures with consecutive cartilage damage were identified as the most common reason for

Fig. 1. (*A*) Anteroposterior and lateral radiographs of a 24-year-old man with displaced lower leg fracture sustained from a fall down stairs. (*B*) Weight-bearing radiographs show complete fracture healing after open reduction and internal fixation 10 months postoperatively. (*C*) Hardware was removed 23 months postoperatively. Despite the anatomic reduction and uneventful healing of the fracture, significant degenerative changes of the tibiotalar joint are visible. (*D*) All conservative treatment attempts were unsuccessful, and therefore 32 months after the accident, TAR using HINTEGRA was performed.

posttraumatic ankle OA,[19] repetitive ligament injuries may play a crucial role in joint degeneration (ligamentous posttraumatic ankle OA).[20] Other common indications for TAR are systemic (rheumatoid) arthritis[21–23] and secondary OA. Secondary OA has been found to be associated with underlying diseases such as hemophilia,[24] hereditary hemochromatosis,[25] gout,[26] postinfectious arthritis, and avascular talar necrosis.

Patients with bilateral ankle OA are good candidates for TAR because bilateral ankle fusion may not be optimal in this patient cohort, given its detrimental influence on gait and functional results.[27–29]

TAR has additional indications, like the salvage of failed primary procedures. Regarding the salvage of failed primary TAR, 1 critical issue is the quality and amount of remaining bone stock to ensure long-term stability of revision components.[30] If the residual bone stock is not sufficient, ankle fusion should be performed.[31–35] Another

special indication for TAR is the salvage of nonunion or malunion of previous ankle fusion.[36–38] Taking down an ankle fusion, and its conversion to TAR, is a technically demanding procedure, which should be performed only if bone stock is sufficient and soft tissue conditions are appropriate.[39] If performed by an experienced foot and ankle surgeon, this procedure shows promising midterm results with low intraoperative and postoperative complication rates.[38]

CONTRAINDICATIONS FOR TAR

The absolute contraindications for TAR are the following[8,40,41]: acute or chronic infections, avascular necrosis of more than one-third of the talus, neuromuscular disorders, neuroarthropathy (Charcot arthropathy of the midfoot or hindfoot), and diabetic syndrome with polyneuropathy. Patients with unmanageable instability or malalignment, which cannot be sufficiently addressed by additional procedures (eg, corrective osteotomies[42]), should not be considered for TAR. High demand for physical activities (eg, contact sports, jumping) is also a contraindication. Suspected or documented metal allergy/intolerance is rare; however, these patients should be excluded preoperatively.

The relative contraindications for TAR are the following[8,40,41]: severe osteoporosis, immunosuppressive therapy, and diabetic syndrome without polyneuropathy. Patients with increased demands for physical activities (eg, jogging, tennis, downhill skiing) should be informed about possible prosthesis failure because of increased wear and potential for a higher rate of aseptic loosening.[43,44]

IDEAL CANDIDATE FOR TAR

Based on our clinical experience, the ideal candidate for TAR

- is middle-aged or older
- is reasonably mobile
- has no significant comorbidities
- has low demands for physical activities (eg, hiking, swimming, biking, golfing)
- is not obese/overweight (normal or low body mass index, calculated as weight in kilograms divided by the square of height in meters; however, obesity is not a contraindication for TAR[45])
- has good bone stock
- has well-aligned and stable hindfoot
- has good soft tissue condition (eg, no previous surgeries of the foot/ankle)
- has no neurovascular impairment of the lower extremity

PREOPERATIVE PLANNING
Clinical Examination

First, all previous medical (surgery) reports and imaging data are collected and carefully analyzed. Second, careful assessment of the patient's history is performed, with specific address of the following aspects: pain, limitations in daily activities, sports activities, and current and previous treatments. Patients with any contraindications are excluded. If necessary, a consultation in neurology or internal medicine is performed before planning of surgery.

The routine physical examination includes careful inspection of the foot and ankle while walking and standing, with special attention given to obvious deformities and the skin and soft tissue condition. Hindfoot stability is assessed manually with the patient sitting. Ankle alignment is assessed with the patient standing.

Ankle range of motion is determined with a goniometer placed along the lateral border of the leg and foot.[3,46] All goniometer measurements are performed in the weight-bearing position, comparable with the method described by Lindsjö and colleagues.[47]

Radiographic Evaluation

Radiographic evaluation of affected ankles is performed using weight-bearing radiographs, including anteroposterior views of the foot and ankle and a lateral view of the foot. Only weight-bearing radiographs should be used for evaluation of foot and ankle alignment because nonweight-bearing radiographs are often misleading.[48–50] Furthermore, the standing position standardizes the radiograph technique, allowing more reliable comparison between preoperative and postoperative radiographs. The supramalleolar ankle alignment (**Fig. 2**) should be assessed in coronal and sagittal planes by measurement of the medial distal tibial angle and anterior distal tibial angle (**Fig. 3**), respectively.[51,52] The medial distal tibial angle has been measured to be 92.4 ± 3.1° (range 88–100°) in a radiographic study[51] and 93.3 ± 3.2° (range 88–100°) in a cadaver study.[51,53] The measurement of the medial distal tibial angle depends on radiograph technique; it is not the same on whole leg images and mortise views of the ankle.[54] The anterior distal tibial angle has been measured to be 83.0 ± 3.6° (range 76–97°).[52] The Saltzman view should be used to assess the inframalleolar alignment.[55] In patients with degenerative changes of the adjacent joints, single-photon emission computed tomography (SPECT) may help to evaluate the morphologic changes and their biological activities.[56,57] We do not recommend the routine use of magnetic resonance imaging (MRI) in patients with ankle OA. However, MRI may be helpful to assess injuries or morphologic changes of ligament structures and tendons, and to evaluate the localization and degree of avascular necrosis of talus or tibia.[58]
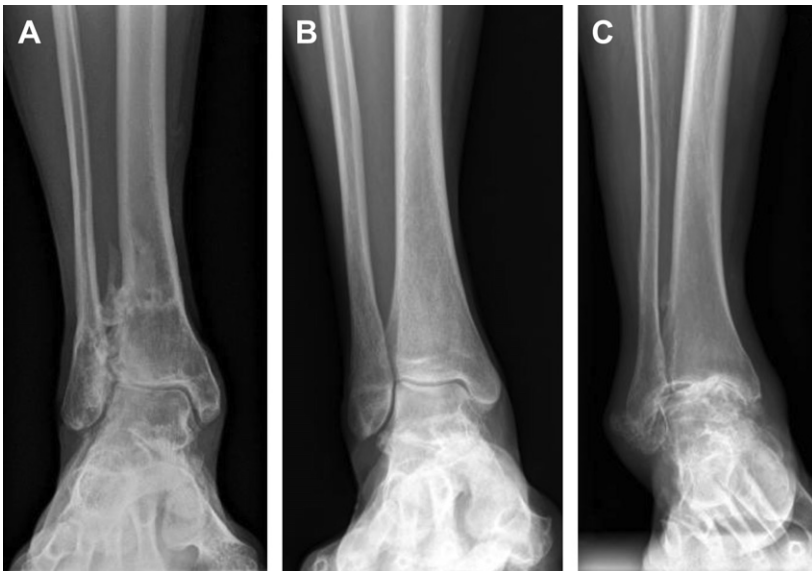

Fig. 2. Weight-bearing anteroposterior ankle radiographs showing (*A*) valgus alignment, (*B*) normal alignment, and (*C*) varus alignment in the coronal plane.
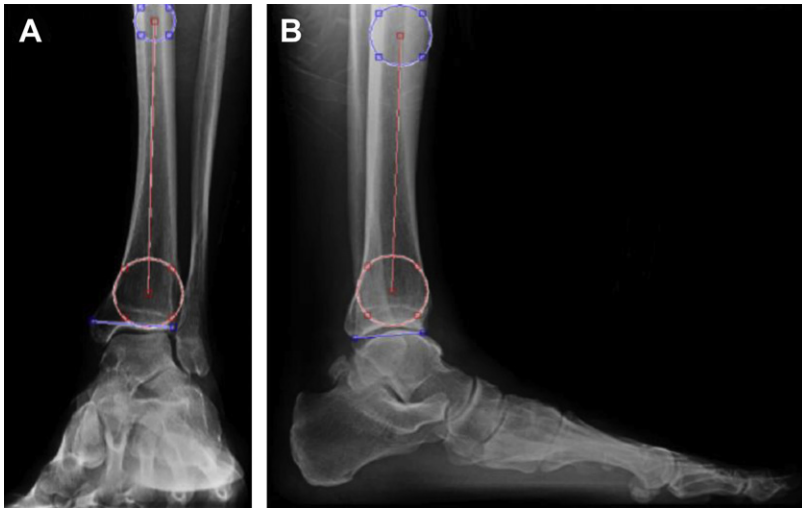
Fig. 3. Weight-bearing (*A*) anteroposterior and (*B*) lateral views of the ankle of a 51-year-old man showing the measurement of the medial distal tibial angle[54] (in this case 87°) and the measurement of anterior distal tibial angle[52] (in this case 84°).

HINTEGRA TOTAL ANKLE PROSTHESIS

The HINTEGRA total ankle prosthesis was designed and developed in 2000 by Dr B. Hintermann (Basel, Switzerland), Dr G. Dereymaeker (Pellenberg, Belgium), Dr R. Viladot (Barcelona, Spain), and Dr P. Diebold (Maxeville, France).[59] The HINTEGRA prosthesis is an unconstrained, 3-component system that provides high inversion/eversion stability.[3,40,59] Since its introduction in 2000, there have been 3 prosthesis generations (**Fig. 4**): (1) first-generation with single hydroxyapatite coating (May 2000–April 2001); (2) second-generation with 200 μm porous cobalt-chromium

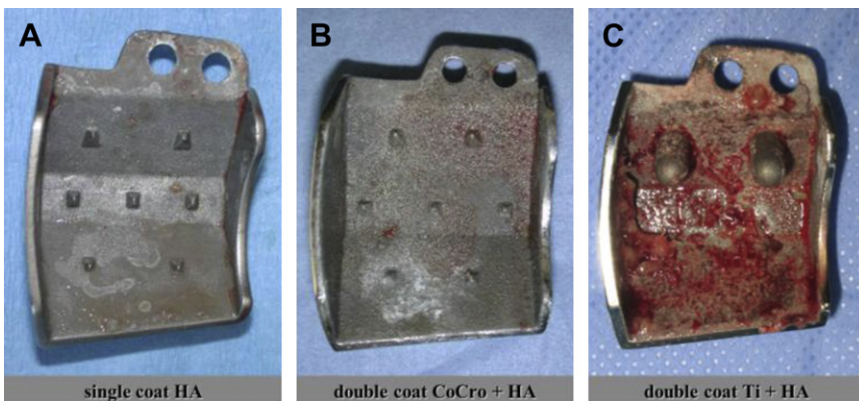single coat HA   double coat CoCro + HA   double coat Ti + HA

Fig. 4. Inferior view of 3 talar components explanted as a result of aseptic loosening: (*A*) first-generation with single hydroxyapatite coating; (*B*) second-generation with 200 μm porous cobalt-chromium with double hydroxyapatite coating; (*C*) third-generation with 200 μm titanium with double hydroxyapatite coating.

with double hydroxyapatite coating (May 2001–May 2003); and (3) third-generation with 200 μm titanium with double hydroxyapatite coating (since May 2003).

In the current (third) generation, the tibial component consists of a flat, 4-mm-thick loading plate, with 6 pyramidal peaks against the tibia (**Fig. 5**). It has an anterior shield for appropriate contact with anterior border of the distal tibia, including 2 oval holes for screw fixation (in most cases, screw fixation is not required). The anatomically sized surfaces ensure optimal bone-prosthesis contact and require only minimal bone resection of 2 to 3 mm. The talar component is anatomically shaped, with a conical form, with a smaller radius medially than laterally (**Fig. 6**A, B). It has 2 2.5-mm rims on the medial and lateral sides, which ensure stable position of the polyethylene insert. Two pegs (see **Fig. 6**A) facilitate the insertion of the talar component and provide additional stability.

The polyethylene insert (ultrahigh molecular weight) has a flat surface on the tibial side and a concave surface that perfectly matches the talar prosthesis surface (**Fig. 7**). It has a minimum thickness of 5 mm and is available in different sizes. The insert position aligns well with the longitudinal tibial axis and remains stable over time.[60]

SURGICAL TECHNIQUE
Anesthesia and Patient Positioning

General or regional anesthesia can be used for TAR. The patient is placed in a supine position with the feet on the edge of the table (**Fig. 8**). The ipsilateral back of the patient is lifted until a strictly upward position of the whole lower extremity is obtained. A pneumatic tourniquet is applied on the ipsilateral thigh. In most cases, a pressure of 320 mm Hg is sufficient, and total tourniquet time of 2 hours should not be exceeded. If significant deformity is to be corrected, the unaffected lower extremity should also be draped.

Surgical Approach

A standard anterior ankle approach is used for TAR (**Fig. 9**A, B).[3,8] An anterior longitudinal incision (10–14 cm) is made to expose the retinaculum, which is thickening of the deep fascia above the ankle, running from tibia to fibula.[61,62] After the anterior tibial tendon is identified, sharp dissection of the retinaculum is performed along the lateral border of the anterior tibial tendon (see **Fig. 9**C). This dissection allows exposure of the anterior aspect of the distal tibia. During preparation of the soft tissue
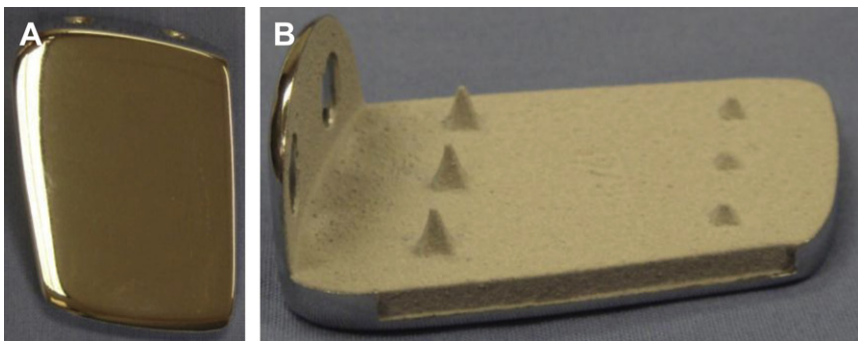

Fig. 5. (*A*) Inferior and (*B*) lateral-superior view of the tibial component of HINTEGRA total ankle prosthesis. The tibial component is anatomically shaped, with 6 pyramidal peaks on the flat surface, double-coated with hydroxyapatite.
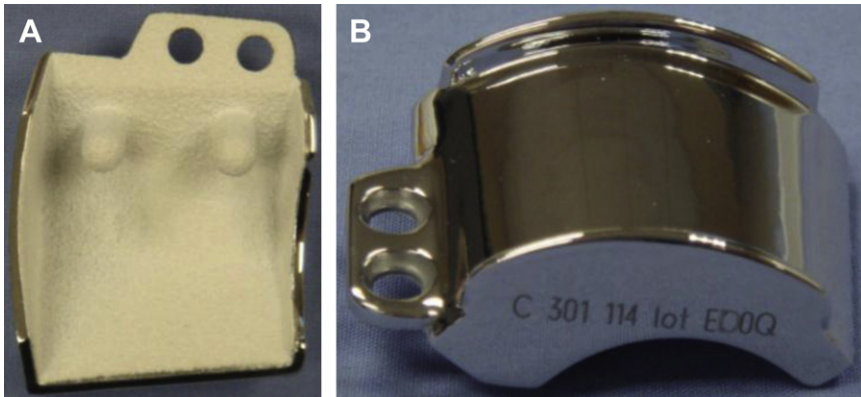
Fig. 6. (*A*) Inferior and (*B*) lateral-superior view of the talar component of HINTEGRA total ankle prosthesis. The talar component is conical, with 2 pegs on the inferior surface, and double-coated with hydroxyapatite.

mantle, special attention is paid to the tibialis anterior vascular bundle, which is localized behind the extensor hallucis longus or between the extensor hallucis longus and the extensor digitorum longus.[63] After the ankle joint is sufficiently exposed, capsulotomy and capsulectomy are performed (**Fig. 10**A). A self-retaining retractor is applied to control the soft tissue mantle; skin hooks should not be used so as not to disturb wound healing. Osteophytes on the tibia (especially on the anterolateral aspect) and on the talar neck should be removed; however, the bone cortex should not be destroyed (see **Fig. 10**B, C).

Tibial Preparation

First, the tibial cutting block should be aligned using the following anatomic landmarks: the tibial tuberosity (or the anterior iliac crest in patients with significant lower leg deformities) as the proximal reference and the middle of the anterior border of the tibiotalar joint as the distal reference (**Fig. 11**). The natural slope of the tibial plafond,
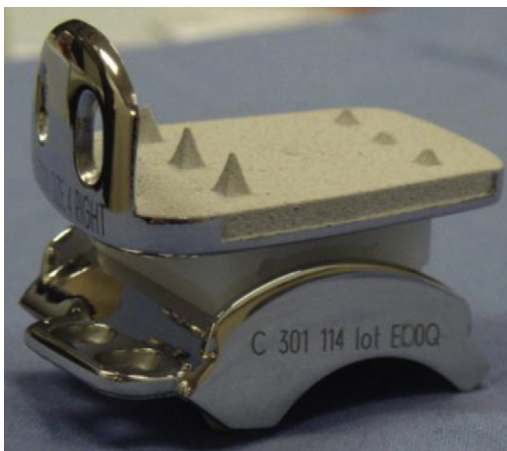

Fig. 7. The assembled 3-component HINTEGRA total ankle prosthesis.

Fig. 8. Patient in supine position with the feet on the edge of the table.

approximately 2° to 4°, should be considered. After final adjustments in sagittal and frontal planes are made, the proximal part of the tibial cutting block should be fixed by 2 pins. Then, resection height should be adjusted; usually no more than 2 to 3 mm of the tibial plafond should be resected. In ankles with varus deformity, more tibial resection should be performed, whereas in patients with valgus deformity or significant ligamental laxity, less bone resection is advised. Regarding rotational adjustment, the medial surface of the tibial resection block should be parallel to the medial surface of the talus. This position may help to avoid intraoperative malleolar
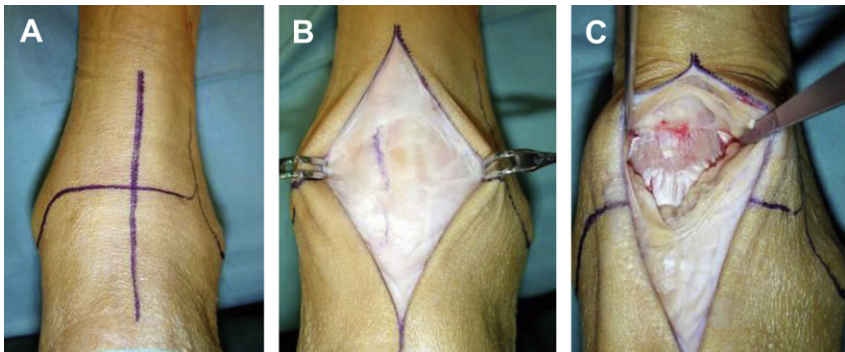

Fig. 9. Standard anterior ankle approach for TAR. (*A*) Landmarks for planning of approach: medial and lateral malleoli and tibiotalar joint line. (*B*) Anterior longitudinal incision up to 12 cm long for exposure of retinaculum (*C*), which is dissected along the lateral border of the anterior tibial tendon.
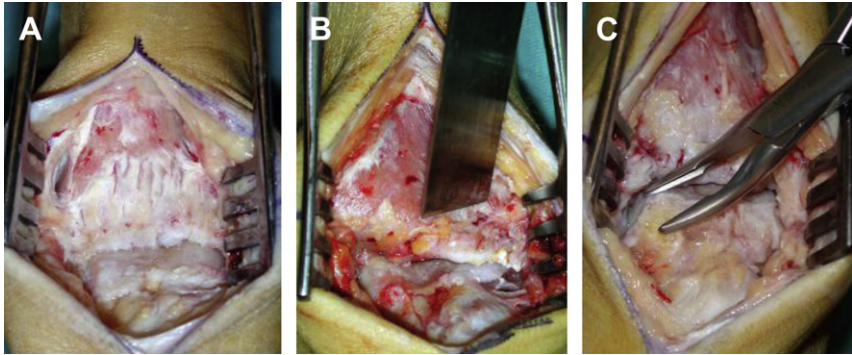
Fig. 10. (*A*) Ankle joint is exposed and capsulotomy/capsulectomy is performed and a self-retaining retractor is applied to protect the soft tissues. Osteophytes (*B*) on the tibia and (*C*) on the talar neck are removed.

fractures caused by the oscillating saw blade. After the position of the tibial resection block is adjusted and fixed, the tibial cutting guide is placed into the cutting block. The cut is performed through the cutting slot and attention is paid to avoid any injuries to the malleoli. Malleolar fractures have been reported as a common intraoperative complication, with a prevalence as high as 10%.[64–66] We suggest prophylactic pinning of the malleoli. After the tibial cut is performed, a reciprocating saw should be used to finalize the cuts, particularly for the vertical cut on the medial side. Careful

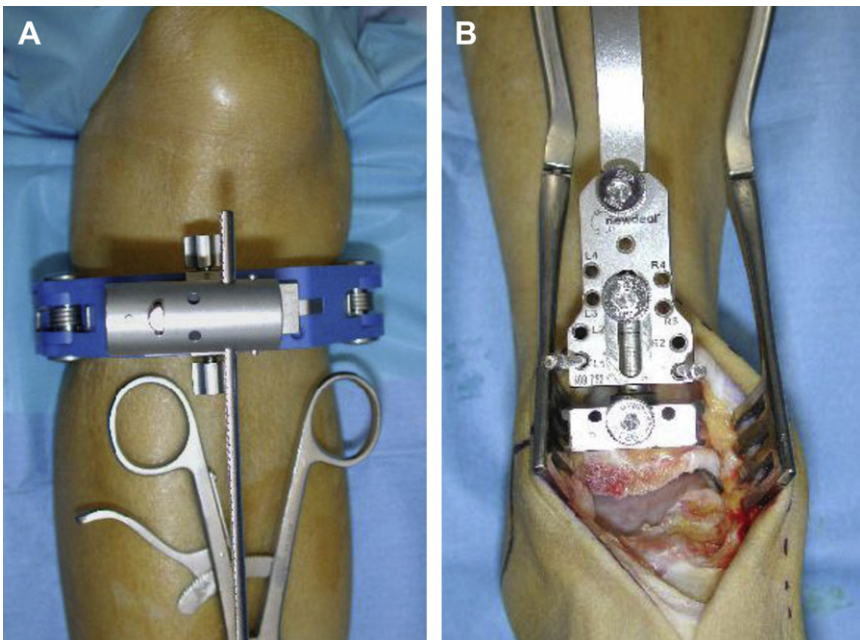**Fig. 11.** Alignment of the tibial cutting block in the frontal and sagittal plane with orientation to (*A*) the tibial tuberosity as the proximal reference and (*B*) the middle of the anterior border of the tibiotalar joint as the distal reference.

debridement of the posterior capsule is performed and ossifications are removed if necessary. A measuring gauge is used to determine the size of the tibial component. In cases in which the anterior border of the tibia is projected between 2 markers on the gauge, the bigger size should be selected to avoid undersizing the tibial component.

Talar Preparation

The talar resection block is placed into the tibial cutting block. To achieve the proper tension of collateral ligaments of the ankle, the talar resection should be moved distally as much as possible. All distractors and spreaders should be removed to avoid any influence on foot/ankle position. Once the foot is held in a neutral position, the talar resection block is fixed by 2 pins. First, the talar dome is cut through the cutting slot using an oscillating saw. Both the tibial and talar resection blocks are removed and the joint is exposed using a Hintermann distractor. In order to achieve physiologic range of motion (especially dorsiflexion), posterior debridement is performed until fatty tissue and tendon structures are visible. The 12-mm-thick spacer is inserted into the joint. This measurement corresponds to the thickness of the tibial and talar prosthesis components and the insert with minimum thickness of 5 mm. The foot and ankle should be held in a neutral position and the following aspects should be checked: (1) whether an appropriate amount of bone has been removed; (2) whether the hindfoot alignment; and (3) whether stability is appropriate. When the spacer cannot be inserted properly without pressure, contracture of the remaining posterior capsule should be checked and if necessary addressed by careful debridement. Otherwise, additional bony resection should be performed (mostly on the tibial side using the tibial resection block). If hindfoot alignment is not appropriate, the origin of deformity should be determined. A corrective cut should be performed only in cases in which associated deformities (eg, valgus or varus heel position) can be excluded. A corrective cut can be performed on the tibial side after angular position is corrected. In cases with obvious ligamental instability, a thicker inlay may be used to increase the intrinsic stability. When the desired stability cannot be achieved, a release of the contralateral ligament, or ligament reconstruction on the affected side, should be performed. The ligament reconstruction procedure should be performed after the insertion of the definitive implants (and only if the instability still persists). The medial side of the talus is used as the reference for determining the size of the talar resection block: approximately 2 mm of bone is removed from the medial side of the talus. The size of the talar component should not be different from the previously determined tibial component by more than 1 size. The final talar resection block is fixed by short pins (**Fig. 12**). First, posterior resection of the talus is performed using an oscillating saw, followed by medial and lateral resections of the talus. The anterior slot of the talar resection block is used for the anterior resection of the talus. After the resection block is removed, all cuts are finalized using a chisel. The medial and lateral gutters should be cleaned using a rongeur and, if necessary, the remaining ossifications and posterior joint capsule removed.

Final Surface Preparation

Tibial and talar surfaces are checked for any cysts, which must be carefully removed, debrided, and filled with cancellous bone left over from previous bone cuts. The sclerotic areas of the prepared surfaces should be drilled with a 2.0-mm drill. The talar trial component is used for final preparation of the anterior talar surface. Two drill holes are made using 4.5-mm drill through both drill guide holes for the talar pegs (**Fig. 13**). The tibial trial component is inserted until close contact with the medial malleolus and the
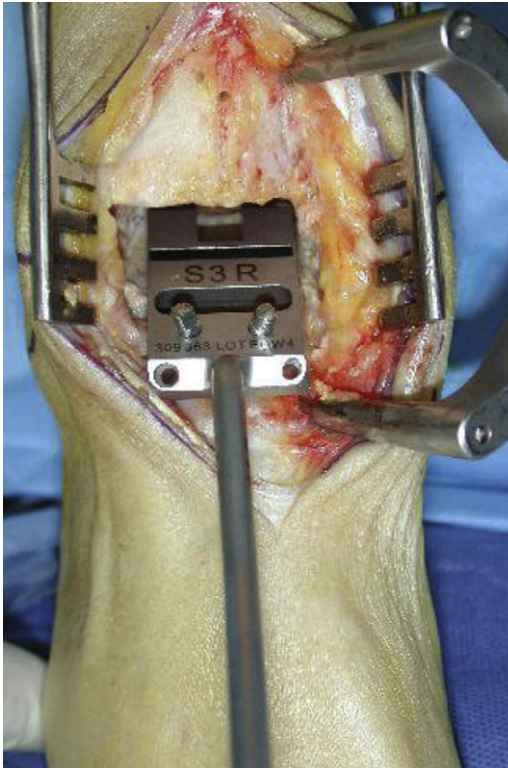
Fig. 12. Pin fixation of the talar resection block.

anterior surface of tibia is achieved. If necessary, the anterior border of the tibia should be smoothed with an oscillating saw or rongeur. After both metallic trial components are inserted, the 5-mm trial inlay is placed and all distractors are released. Soft tissue tension can be checked and if necessary a thicker trial inlay (7-mm or 9-mm inlay) is inserted. With all 3 components in place, fluoroscopy is then used to verify the component position with regard to proper fit and alignment (eg, anteroposterior offset ratio[46,60]) of prosthesis components to the prepared joint surfaces.

Insertion of Final Prosthesis Components

The talar component is inserted by placing the 2 pegs into the 2 drilled holes on the talar side. Talar insertion is performed with a press-fit technique using a hammer and special impactor. Then the tibial component is inserted along the medial malleolus until the proper contact between the component shield and anterior border of the tibia is achieved. The inlay with the same size as the talar component is inserted (**Fig. 14**). All distractors are removed, and the stability and motion of the ankle are checked (**Fig. 15**). We typically do not recommend screw fixation on the tibial or talar side if the initial stability of the prosthesis is sufficient. The position of the prosthesis is checked and documented using fluoroscopy. If any remaining bony fragments or osteophytes are visible, they should be removed to avoid future pain or range-of-motion restriction. Wound closure is performed sequentially (**Fig. 16**). We use drainage without suction. Soft wound dressing is used to avoid any pressure so as not to compromise wound healing (**Fig. 17**). A splint is used to keep the foot in a neutral position (**Fig. 18**).
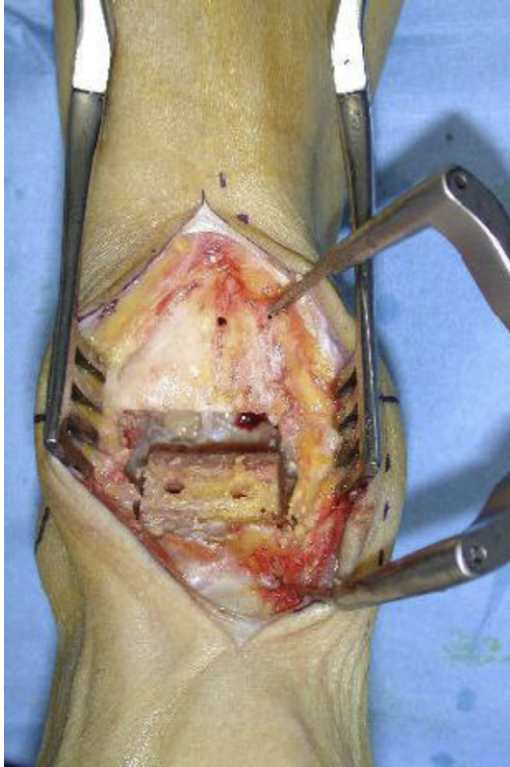
Fig. 13. Final preparation of bone surfaces before insertion of final prosthesis components. Two drill holes are made using 4.5-mm drill for the pegs of the talar prosthesis component. All ossifications are removed and the posterior joint capsule is debrided.

AFTERCARE

The dressing and splint are removed and changed at the second postoperative day. Physiotherapy with lymphatic drainage and active motion is begun. A pneumatic foot cuff (with intermittent pressure up to 130 mm Hg) may be used to reduce postoperative swelling (**Fig. 19**). Active dorsal extension should be avoided in the first 4 weeks postoperatively to ensure the proper healing of the extensor tendon retinaculum. Active and passive mobilization in the first metatarsophalangeal joint may increase venous blood flow, which has an antiedema and thromboprophylactic effect (**Fig. 20**).[67] All patients receive thromboprophylaxis with subcutaneous low-molecular-weight heparin (Fragmin, 5000 IU; Pfizer AG, Zürich, Switzerland), starting 12 hours preoperatively and continuing daily for 6 weeks postoperatively.[68] When the wound conditions are appropriate (dry wound, no secretion), the foot is placed in a stabilizing walker or cast for 6 to 8 weeks (**Fig. 21**): in patients with additional procedures (eg, fusion of adjacent joint or corrective osteotomies), the immobilization is longer. Weight-bearing is allowed as tolerated with the exception of patients who underwent additional corrective osteotomies.[42,69,70] After the cast or walker is removed, a rehabilitation program is continued, including active and passive ankle motion, stretching and strengthening of the triceps surae, and proprioceptive exercises. In patients with persistent swelling, we recommend compression stockings. A
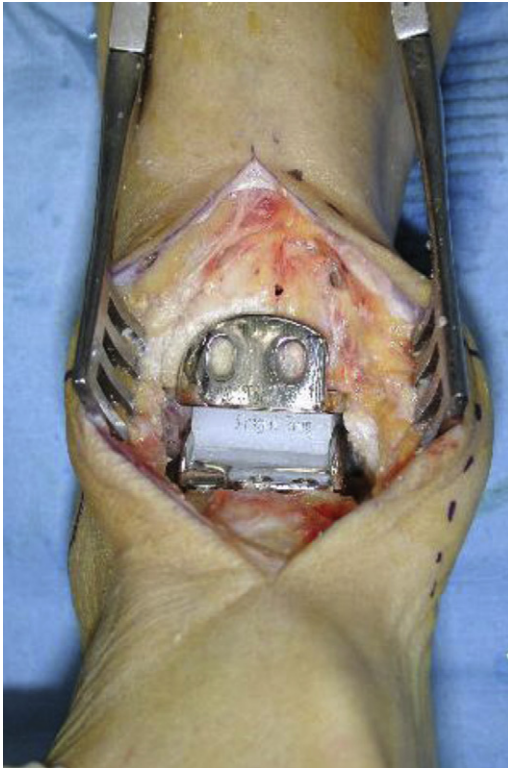
Fig. 14. Final surgery situs with inserted prosthesis components and inlay.

low level (eg, hiking, swimming, biking, golfing) and a normal level (eg, jogging, tennis, downhill skiing) of sports activities are recommended and allowed. Contact sports or activities involving jumping should be avoided.[44]

CLINICAL AND RADIOGRAPHIC FOLLOW-UP

The first clinical and radiographic follow-up is made at 6 to 8 weeks to check the healing of soft tissues including skin and osteointegration/position of the prosthesis components. The next clinical and radiographic follow-ups are performed at 4 months, 1 year, and then annually thereafter.

For appropriate analysis of the clinical outcome, the following parameters/scores are used. We measure the range of motion clinically with a goniometer along the lateral border of the leg and foot.[3,46] To assess the postoperative pain relief, all patients rate their pain on a visual analogue scale (VAS) of 0 points (no pain) to 10 points (maximal pain).[71] The American Orthopedic Foot and Ankle Society (AOFAS) hindfoot score is calculated.[72] The AOFAS score has been shown to have the discriminatory capacity to assess the postoperative improvement in patients with TAR.[73] However, this score is not validated and the research committee of the AOFAS recently published a statement recommending against its use.[74] SF-36 questionnaires are used to assess the quality of life.[75] Patients indicate their satisfaction with the procedure using a modified Coughlin rating for category scale: very satisfied, satisfied, partially satisfied, and not

Fig. 15. Motion of the replaced ankle is checked clinically: (*A*) dorsiflexion and (*B*) plantar flexion.

satisfied.[76] Sports activity level is documented using a Valderrabano score: grade 0, none; grade 1, moderate; grade 2, normal; grade 3, high; and grade 4, elite.[44] Gait is observed clinically and then analyzed using pedobarography.[77]

Radiographic assessment is performed using weight-bearing radiographs with fluoroscopy. The postoperative hindfoot alignment is assessed using a Saltzman view.[55,78] The following angular values are used for standardized assessment of prosthesis components: α-angles, β-angles, and γ-angles (**Fig. 22**).[3,28,79] α-Angles and β-angles are used for assessment of the tibial component and measured between the longitudinal axis of the tibia and the articular surface of the tibial component in the anteroposterior and lateral views, respectively.[3,79] γ-Angle is used for assessment of the talar component and measured between a line drawn through the anterior shield and the posterior edge of the talar component and a line drawn along the center of the talar neck on the lateral view.[64] All radiographs are analyzed regarding the localization and degree of heterotopic ossifications. Heterotopic ossifications are described according to the Brooker classification[80] as modified by Lee and colleagues[81] and Choi and Lee[82]: 0, no heterotopic ossifications; I, islands of bone within the soft tissues about the ankle: II and III, bone spurs from the tibial or talus, reducing the posterior joint space by less than 50% or 50% or greater, respectively; and IV, bridging bone continuous between the tibia and the talus. Change in position of the flat base of the tibial
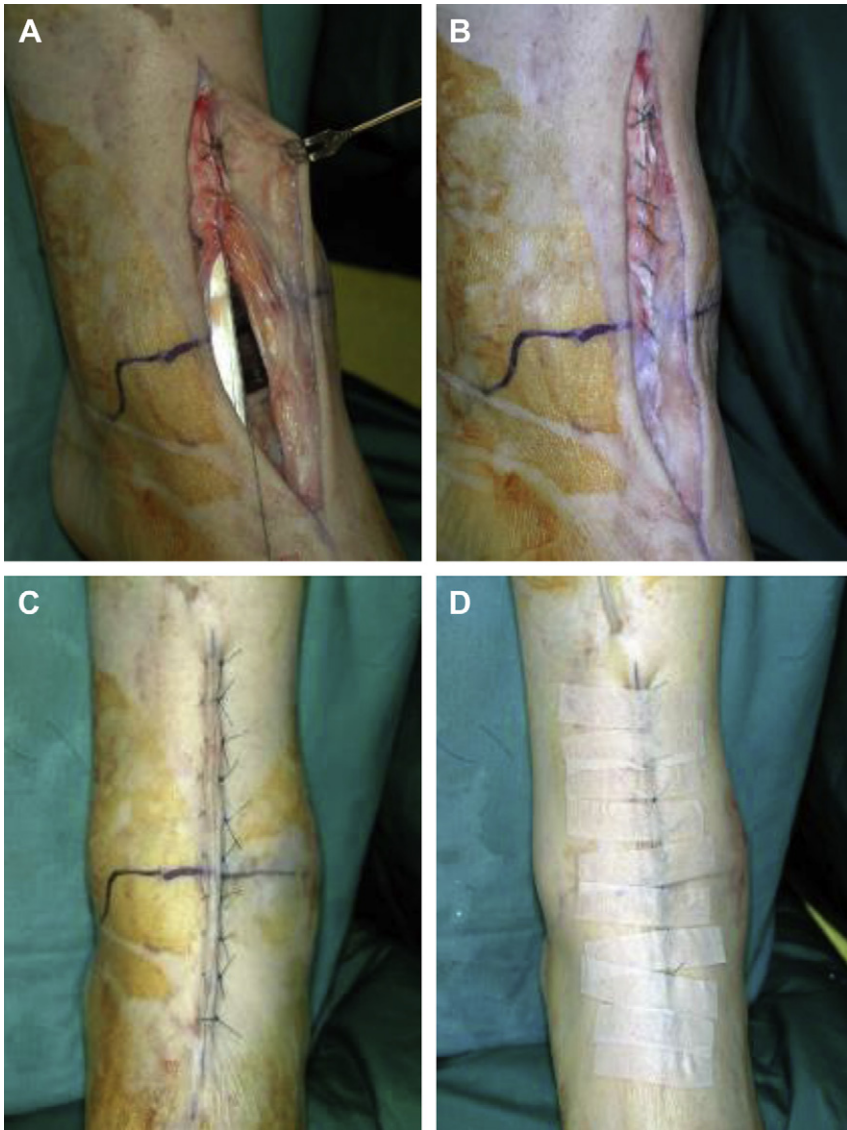
Fig. 16. Wound closure after insertion of the final prosthesis components. (*A*, *B*) Extensor retinaculum is closed using resorbable fibers (eg, Dexon 0; Covidien, Mansfield, MA). (*C*) Skin is closed using Donati technique with nonresorbable fibers (eg, Prolene 3-0; Ethicon, Johnson & Johnson Medical GmbH, Nordersted, Germany). (*D*) Steri-Strips (3M, Neuss, Germany) are used to protect the skin stitches.

component by more than 2° relative to the longitudinal axis of the tibia, or progressive radiolucency greater than 2 mm on the anteroposterior or lateral radiographs, is defined as loosening of the tibial component.[3,79] Subsidence of the talar component by more than 5 mm or a position change of greater than 5° relative to a line drawn from the top of the talonavicular joint to the tuberosity of the calcaneus is defined as loosening of the talar component.[3,79,83] Because of prosthesis design, it is difficult to assess the

Fig. 17. Soft wound dress without any pressure on the surgery wounds.

position changes of the talar component, so in cases with suspicion of loosening or subsidence, computed tomography or SPECT should be performed.[56,57]

TAR IN VARUS/VALGUS OSTEOARTHRITIC ANKLE

In more than 60% of all patients with end-stage ankle OA, a significant varus or valgus malalignment of the hindfoot is observed.[19] Because of significantly altered ankle/hindfoot biomechanics, the asymmetric load consecutively leads to asymmetric joint wear and generative changes. The varus/valgus osteoarthritic ankle is often combined with significant joint instability.[84,85]

Fig. 18. Foot is kept in neutral position using a splint.

Fig. 19. Pneumatic foot pump (with intermittent pressure up to 130 mm Hg) may be used to reduce postoperative swelling of the foot and ankle.

Varus Osteoarthritic Ankle

In patients with significant varus malalignment, the medial malleolus retains the talus because of the significant talar tilting to the lateral side (**Fig. 23**). We often observe a functional conjunction between the medial malleolus and the talus: so-called neoarthros. Increased pressure on the medial tallus pushes the talus to the lateral side, resulting in development of large osteophytes on the lateral side. Because of asymmetric loading in the talocrural joint, the medial ligaments are contracted, whereas the lateral ligaments are elongated and insufficient. The patients often present with a tight posterior tibial tendon, whereas the tendon of the musculus peroneus brevis is elongated with insufficient tendon pull at the side of the base of the fifth metatarsal bone. This situation leads to plantar flexion of the first metatarsal bone. The significant ligamental and muscular imbalance causes the anterior-ventral tilting of the talus in the mortise view, resulting in an increased inner rotation position.

Fig. 20. The active and passive mobilization in the first metatarsophalangeal joint increases venous blood flow with antiedema and thromboprophylactic effect. (*Data from* Elsner A, Schiffer G, Jubel A, et al. The venous pump of the first metatarsophalangeal joint: clinical implications. Foot Ankle Int 2007;28:902–9.)

Fig. 21. Postoperatively, a (*A*) walker or (*B*) stabilizing cast is used for immobilization for 6 to 8 weeks.

TAR in Varus Osteoarthritic Ankle

We use a standard anterior approach for implantation of the total ankle, as described earlier.

In patients with a congruent tibiotalar joint, the varus deformity of less than 10° may be corrected by modification of the tibial resection. However, the more proximal tibial resection may result in consecutive instability of the replaced ankle; therefore a thicker inlay should be used to achieve ligamental tension. In patients with varus deformity of more than 10°, a medial open-wedge supramalleolar osteotomy is used, which can be performed using the same anterior approach with some extension proximally.[42,69,70,86–88] The supramalleolar osteotomy is fixed by a ventral plate, which should be placed more proximally to avoid contact between the distal end of the plate and the anterior shield of the tibial prosthesis component.

In patients with incongruent tibiotalar joints, the joint contracture at the medial side should be addressed by osteophyte resection of the medial malleolus. If medial contracture persists, a surgical release of the deltoid ligament should be performed.[85,89] In some cases, the lengthening osteotomy of the medial malleolus may resolve the medial contracture.[90] We recommend a so-called flipping osteotomy (**Fig. 24**). The medial malleolus is osteotomized using the main anterior approach for TAR.

After the proximal varus correction is performed, the hindfoot alignment should be verified clinically using fluoroscopy. In patients with a remaining varus position of the
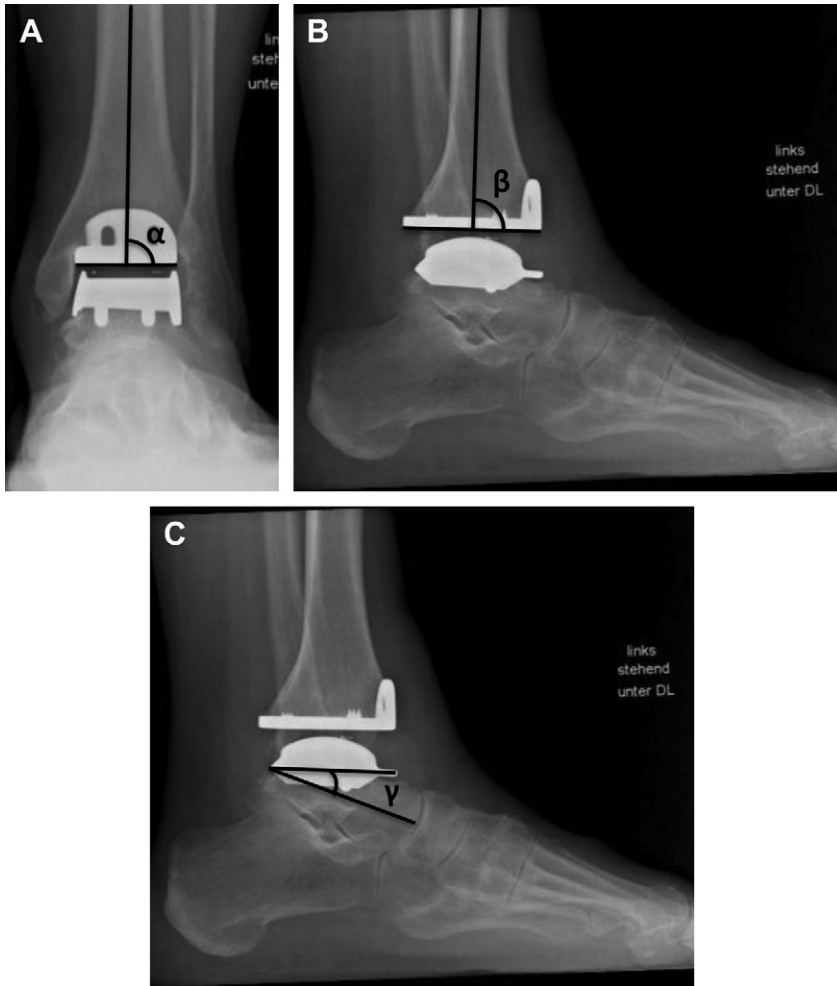
Fig. 22. Angular measurements of prosthesis component using anteroposterior and lateral ankle weight-bearing radiographs. (*A*) α-Angle, in this case 89.5° (normal values 90 ± 2°), (*B*) β-angle, in this case 90.5° (normal value 85 ± 2°), and (*C*) γ-angle, in this case 19° (normal values 20 ± 2°).

heel, the deformity may be corrected by Dwyer osteotomy[91–93] or Z-osteotomy of the calcaneus.[94] In patients with progressive degenerative changes of the subtalar joint, a subtalar arthrodesis should be performed.[95]

In patients with lateral ligamental instability, anatomic repair of the lateral ligament complex using suture anchors should be performed.[96,97] In patients with insufficient ligament tissues, an augmentation with a free plantaris tendon graft is preferred for reconstruction of the anterior fibulotalar ligament and calcaneofibular ligament.[98] Furthermore, the peroneus longus to peroneus brevis tendon transfer may provide reliable soft tissue stabilization and reduce the inversion moment arm of the first ray.[99]

After hindfoot correction and stabilization of the ankle complex in patients with a remaining plantar flexed first ray, a dorsiflexion osteotomy of the first metatarsal
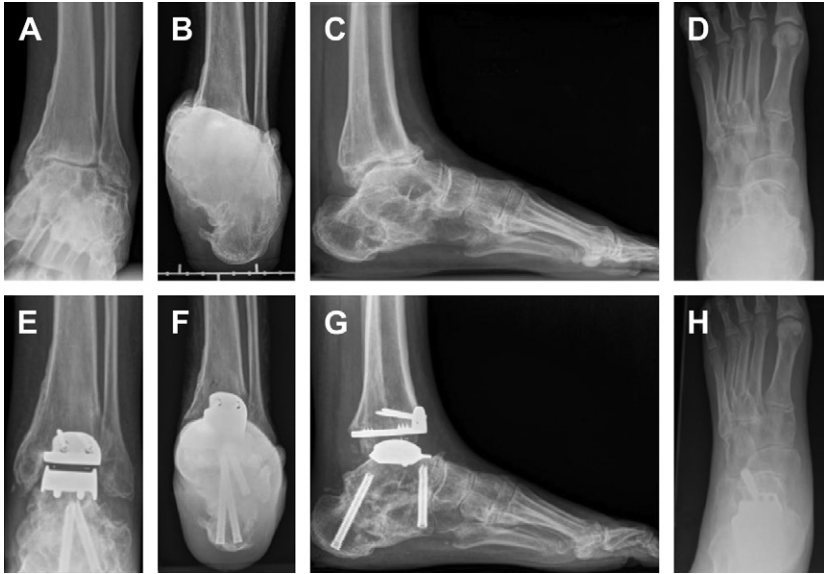
Fig. 23. A 41-year-old woman with painful ankle OA and malunion after subtalar arthrodesis.[119] The pain was localized ventral and subfibular and the preoperative range of motion was measured with 0°/25° (dorsiflexion/plantar flexion). (*A*) Anteroposterior radiograph shows the talus in varus malpositions, with well-preserved congruency of the tibiotalar joint and peritalar subluxation with lateral calcaneus tilt. (*B*) Saltzman view shows valgus position of the calcaneus of more than 1.5 cm. (*C*) Lateral radiograph shows the posteromedial subluxation of the talus with some posterior subsidence and consecutive dorsiflexed position. (*D*) Dorsoplantar view of the foot shows the lateral position of the talar head with medial tilt of the naviculare. (*E–H*) Postoperative radiographs (5 years follow-up) show well-aligned position of prosthesis components, with good osseous integration. Peritalar corrective osteotomy was performed as a 1-stage procedure with allograft interposition. The original height and position of the talus is restored, with a well-aligned hindfoot. The patient is pain free without any restrictions in daily activities and low-demand physical activities.

bone or medial cuneiform bone should be performed to address the pronation position.[100] In patients with varus malalignment of the hindfoot an equinus contracture is often observed, leading to limited ankle dorsiflexion. Depending on the results of the 2-joint muscle test or the Silfverskiold test,[101,102] percutaneous Achilles tendon lengthening or gastrocnemius resection should be performed. We recommend a percutaneous Achilles tendon lengthening by triple hemisection, with 2 incisions on the medial side and 1 incision on the lateral side.[103,104] Surgeons should avoid the failure of triple hemisection at the ankle mobilization.[105]

Valgus Osteoarthritic Ankle

In patients with valgus malalignment of the hindfoot, 2 different morphologic types of deformity are observed.[84] In the first type, the insufficiency of the medial ligaments results in valgus tilting of the talus (**Fig. 25**). The patients present with asymmetric joint loading and incongruence of the tibiotalar joint, especially on the lateral side. The joint load increasingly occurs over the fibula, which may result in stress fractures. Because of the lateralization of the heel, the excentric pull of the musculus triceps surae increases the valgus malalignment of the hindfoot and causes foot eversion.[106] In
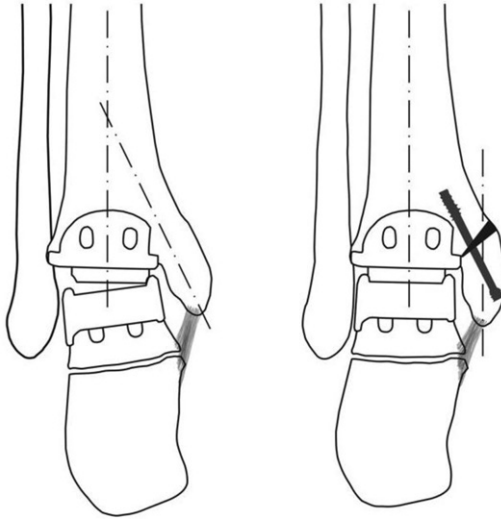
Fig. 24. Flipping osteotomy of the medial osteotomy to restore the incongruence of the tibiotalar joint. (*Data from* Knupp M, Bolliger L, Barg A, et al. Total ankle replacement for varus deformity. Orthopade 2011;40:964–70 [in German].)

the second type of valgus malalignment, impaction of the talus into the lateral part of tibial plafond is observed (**Fig. 26**). The tibiotalar joint shows no incongruence with sufficient medial ligaments. However, the ankle mortise is exposed to increased loading pressures, leading to insufficiency of the ankle syndesmosis. Also in this type of deformity, lateralization of the heel is often observed as a result of excentric pull of the Achilles tendon.[106]

TAR in Valgus Osteoarthritic Ankle

We use the standard anterior approach for implantation of the total ankle, as described earlier.

In patients with valgus malalignment of the distal tibia of more than 5°, we suggest a supramalleolar correcting osteotomy.[42,69,70,87,107] The malunion of the distal fibula may hinder the realignment of the talus within the ankle mortise, and therefore an additional fibula osteotomy should be performed.[108]

After the supramalleolar correction, the heel position should be verified clinically and using fluoroscopy. In patients with a remaining inframalleolar valgus deformity, a medial displacement osteotomy of the calcaneus should be performed, with the aim of the neutral alignment of the heel (0–5° of valgus).[109] In patients with significant subtalar contracture or degenerative changes of the subtalar joint, a subtalar arthrodesis should be performed. In patients with significant ligamental instability, medial or lateral ligament reconstruction should be performed.

PITFALLS

In patients with insufficiently addressed hindfoot misalignment, pain may persist postoperatively. In most cases, the pain is localized on the medial side, and considered medial pain syndrome.[110] We established the following classification of the medial pain syndrome: type I, medial impingement/contracture of medial ligaments; type II, valgus deformity; type III, varus deformity; type IV, combined varus-valgus deformity.[110]

Fig. 25. A 63-year-old man with degenerative changes of the tibiotalar joint 34 years after conservatively treated lower leg fracture.[119] The pains were localized subfibular and in the area of the distal syndesmosis. The subtalar joint is rigid and painful. (*A*) Anteroposterior radiograph shows the varus of the distal tibia of approximately 12°, with inner rotation malposition. The talus shows valgus tilting, with widening of the medial tibiotalar joint space caused by insufficiency of the medial ligaments. (*B*) Saltzman view shows severe valgus malposition of the heel. (*C*) Lateral radiograph shows degenerative changes of the subtalar joint. (*D*) Dorsoplantar view of the foot shows normal articulations of the midfoot. (*E–H*) The patient declined the supramalleolar osteotomy, and therefore corrective arthrodesis of the subtalar joint has been performed. After implantation of ankle prosthesis, a lengthening osteotomy (flipping osteotomy) of the medial osteotomy was performed to restore the ankle mortise. At 3-year follow-up, the patient presented with good outcomes of the replaced ankle; however, medial pain syndrome was observed. Medial displacement osteotomy of the calcaneus was performed, which resolved the medial pain syndrome (radiographic follow-up will be performed).

In patients with significant remaining valgus deformity of the hindfoot, the following problems may occur postoperatively: medial ankle instability, asymmetric wear/dislocation of insert, and type II medial pain syndrome. In patients with insufficiently addressed varus deformity of the hindfoot, the following problems are observed postoperatively: lateral ankle instability, asymmetric wear/dislocation of insert, and type III/IV medial pain syndrome.

RESULTS

A total of 301 consecutive patients (150 men, 151 women, mean age 60.7 years, range 25.3–90.0 years) with 311 primary TAR had a minimum follow-up of 4 years. Preoperative diagnosis was posttraumatic OA (243), primary OA (28), and systemic OA (38). All patients were clinically and radiologically assessed after 59.5 (48–108) months. Twenty-three ankles had to be revised (18 revision TAR and 5 ankle fusions) at a mean of 2.8 (0.5–7.1) years. Revision was typically performed in
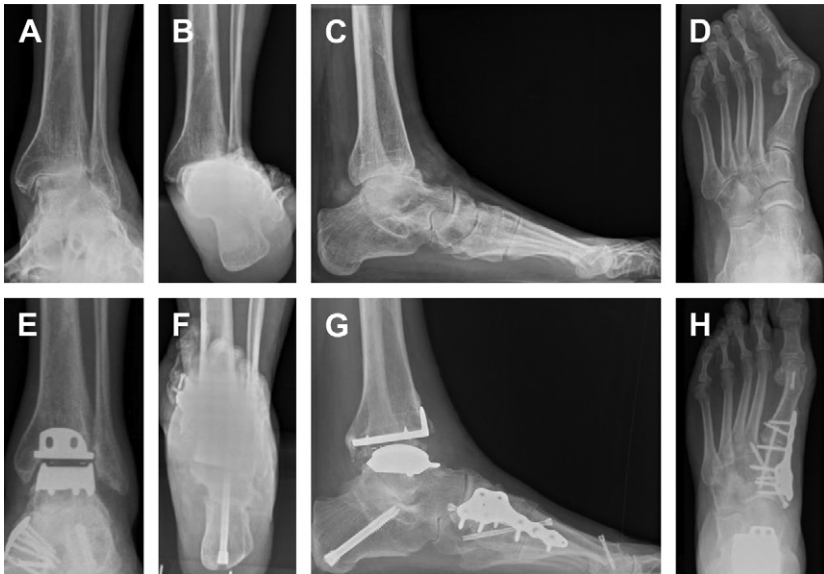
Fig. 26. A 61-year-old man with valgus osteoarthritic ankle.[119] The patient presented with painful instability of the first ray and hallux valgus with painful bunion at the first metatarso-phalangeal joint. (*A*) Anteroposterior radiograph shows valgus impaction of the talus into the lateral part of the tibial plafond. (*B*) Saltzman view shows severe valgus malposition of the heel. (*C*) Lateral radiograph shows slight breakdown at the naviculocuneiform joint, with incongruence of the first tarsometatarsal joint (plantar widening of joint space). (*D*) Dorso-plantar view of the foot shows normal articulation of the Chopart joint and the midfoot, and varus position of the first metatarsal and halgus valgus. (*E–H*) Postoperative radiographs (4 years follow-up) show well-aligned position of prosthesis components, with good osseous integration. The following additional procedures were performed as 1-stage procedures: medial displacement osteotomy of the calcaneus, fusion of the naviculocuneiform joint, and chevron osteotomy. The patient is pain free without any restrictions in daily activities.

patients with first-generation prostheses with a single coating of hydroxyapatite (11), rather than in patients with second-generation (9) or third-generation (3) prostheses. Revision was performed for loosening of 1 or both components (15), subsidence of talar component (6), cyst formation (1), deep infection (1), unmanageable instability (1), and painful arthrofibrosis (2). Of the remaining 288 ankles, radiolucency was seen in 11 ankles; however, none of these showed progression of lucency over time.

The VAS pain score significantly decreased from 6.7 preoperatively to 1.8 (P<.001). The AOFAS score significantly increased from 41.7 preoperatively to 73.7 (P<.001). The mean range of motion at latest follow-up was 33.1° (preoperative 24.0°, P<.001).

SUMMARY

Approximately 1% of the world's adult population is affected by ankle OA, with pain, dysfunction, and impaired mobility.[19,111] The mental and physical disability associated with end-stage ankle OA is at least as severe as that associated with end-stage hip OA.[111] Clinical and epidemiologic studies have identified previous trauma as the most common origin for ankle OA, showing that patients with posttraumatic OA are

younger than patients with primary OA.[18,19,112–115] Furthermore, more than half of all patients with posttraumatic OA have valgus or varus malalignment of the arthritic ankle.[19,116]

In the last 2 decades, TAR has evolved to become a valuable treatment option in patients with end-stage ankle OA, and therefore ankle fusion is no longer the gold standard.[117] However, one of the requirements for good long-term results is the appropriate position of prosthesis components[46] and physiologic osseous balancing of the hindfoot complex.[118] Therefore, TAR is not only a resurfacing procedure addressing the degenerative changes of the tibiotalar joint but has become a reconstruction procedure addressing deformities and instabilities.[42,84,85,118]

We observed encouraging results in patients who underwent TAR using HINTEGRA prostheses, with survivorship comparable with other recently published series. Our data suggest that TAR in patients with end-stage ankle OA produces significant pain relief and functional improvement. Overall favorable results support the belief that TAR has become a viable and superior alternative to ankle fusion.

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