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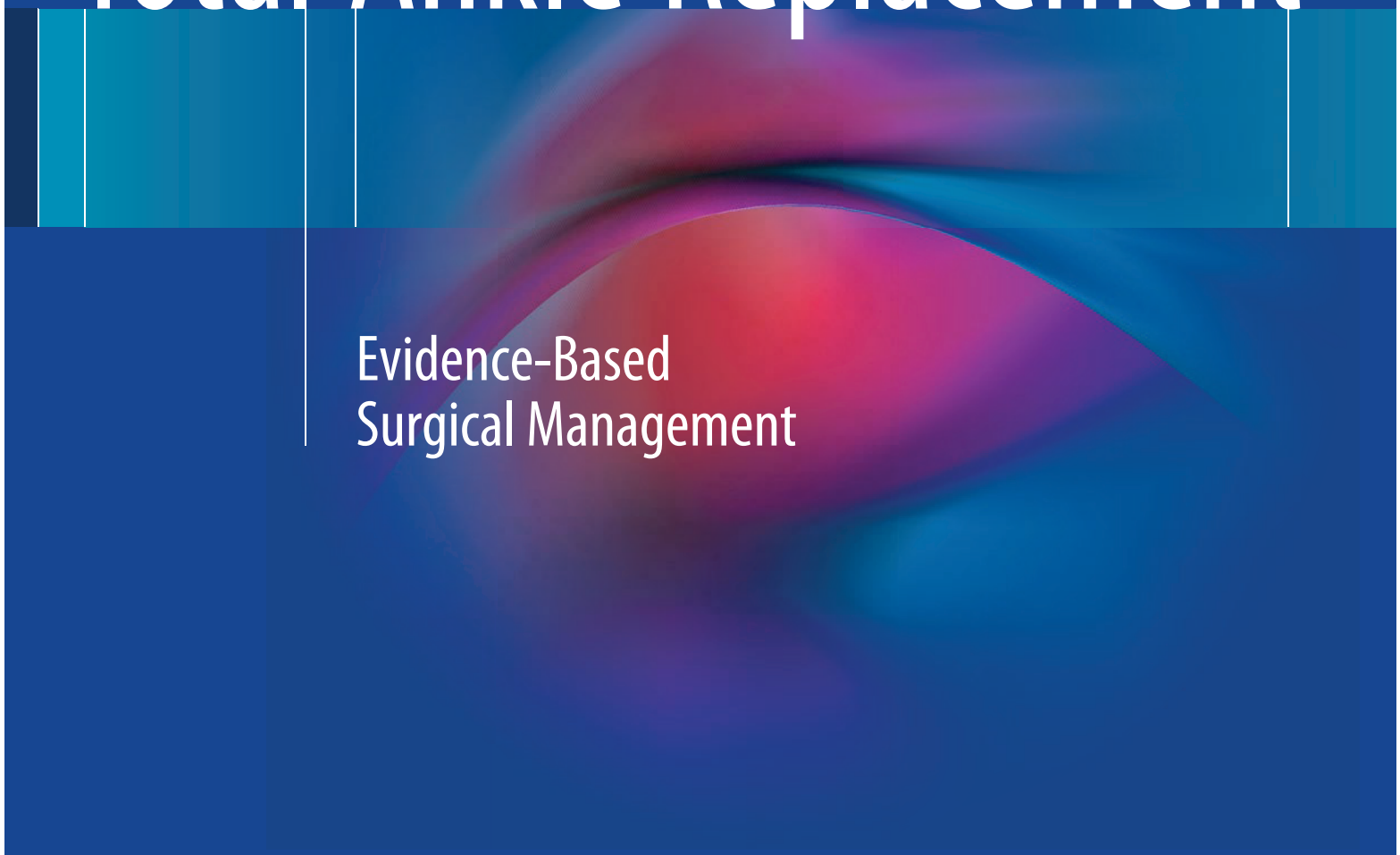
Primary and Revision Total Ankle Replacement

Evidence-Based Surgical Management



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Primary Zimmer Trabecular Metal Total Ankle Replacement

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Stephen A. Brigido and Lawrence A. DiDomenico

Introduction

Despite increased popularity over the last several decades, total ankle replacement (TAR) continues to provide challenges for surgeons, patients, and device engineers. The Zimmer Trabecular Metal TAR (Zimmer, Warsaw, IN) was designed to address the challenges that are routinely encountered with primary TAR, such as bone fixation, excess osseous resection, and wound healing issues. This third-generation prosthetic is a semi-constrained, fixed-bearing device that is implanted through a lateral, transfibular approach. The system comes equipped with alignment and cutting guides to optimize implantation. Traditionally, TARs have utilized flat, nonanatomic tibial resection; this prosthetic differs from traditional prostheses in that the guides are designed to preserve the normal arched contour of the ankle joint, potentially maximizing joint range of motion.

The Zimmer Trabecular Metal TAR combines two formerly established patents: the "Iowa/Hospital for Special Surgery (HSS)" and the "Baltimore." The Iowa/HSS patent introduced the concepts of an alignment guide and anatomically designed implant components. The alignment guide aims to stabilize the leg in an anatomic position, minimizing error during implantation, and the anatomic prosthetic components seek to more closely mirror normal joint kinematics and biomechanics. Alternatively, the Baltimore patent contributed the use of a "cutting guide" to perform reproducible, anatomically contoured bone cuts on the opposing joint surfaces. This concept was derived from ankle allograft transplant technology where matched cuts from both the resected damaged articular surface and the donor surface were utilized to recreate an anatomically aligned joint. Incorporating these concepts, the Zimmer Trabecular Metal implant was designed with the following goals: minimize bone resection, maximize surface area, and mimic the natural anatomy of the ankle joint.

Given that survivorship is often associated with TAR component alignment, this prosthetic uses a combination of intramedullary and extramedullary guidance. The surgeon aligns the intramedullary axis guide in line with or parallel to the anatomic axis of the tibia. The extramedullary alignment guide is aligned perpendicular to the anatomic axis and is utilized to adjust for any frontal plane malalignment issues. This hybrid approach allows the surgeon to adjust the cutting guide and precisely select the joint's axis of rotation, based upon the patient's individual anatomy. The axis of rotation then serves as a reference for tibial and talar bone resection. Notably, bone resection yields one radius of curvature for the talus and a second, longer radius of curvature for the tibia, simulating normal anatomic features. Because minimal osseous resection is required for implantation, the prosthesis sits in solid subchondral/metaphyseal bone (Fig. 12.1), and in the event of revision and/or conversion to ankle arthrodesis, the subsequent procedure requires minimal bone grafting.

A unique feature of Zimmer Trabecular Metal TAR is its articular surface, which arches like the frustum of a cone (Fig. 12.2). The medial side of the prosthesis has a smaller radius of curvature than the lateral side, which avoids increased strain on the medial and lateral ligament complexes and permits dorsiflexion with slight eversion and plantar flexion with slight inversion. Within the joint, the center point of contact shifts anteriorly with dorsiflexion and posteriorly with plantar flexion, mimicking normal biomechanics. This prevents pressure discontinuity across the implant surface during gait. Compared with the flat design of the Agility and Agility LP TAR (DePuy Synthes, Warsaw, IN), the contoured design of the Zimmer

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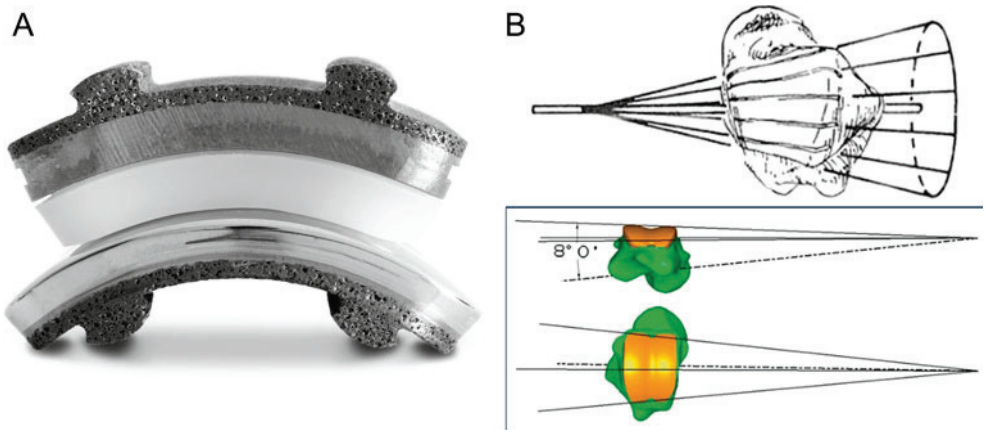

Fig. 12.1 Osseous resection. The implant rests on the subchondral bone, requiring minimal bony resection for implantation (**a**). A comparison of the arched cut and a flat cut and the amount of bony resection (**b**). Note that the Zimmer Trabecular Metal Total Ankle replacement system requires minimal, more anatomic resection (**b**). Utilized with permission from Zimmer

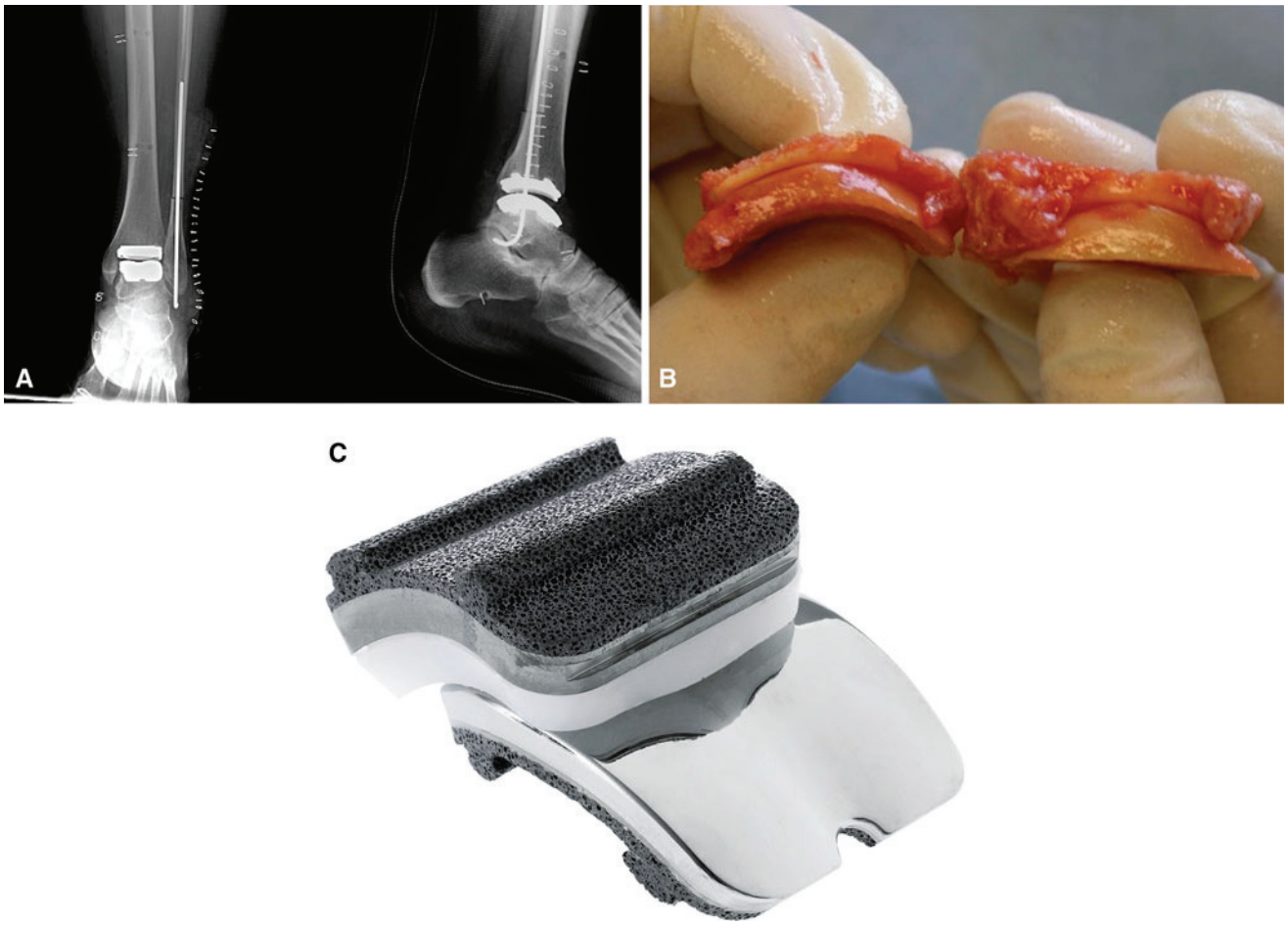

Fig. 12.2 Implant design. Medially, the talar articular surface has a smaller radius of curvature (**a**, **b**), allowing continuity during ankle joint range of motion and mimicking the frustum of a cone (**c**). Images utilized with permission from Zimmer

Trabecular Metal TAR provides twice the contact area with lower peak contact pressures [1]. The semi-constrained design of the prosthesis also permits anterior–posterior and axial rotation up to 3°. Moreover, the tibial and talar rails located at the component–bone interfaces are perpendicular to the ankle joint axis of motion, which increases initial stability of the implant permitting early range of motion without the consequence of component displacement. Since the curvature of the prosthesis aligns with the natural trabecular architecture of the tibia and talus (Fig. 12.3), bone remodeling in response to implant stresses may be reduced, while the bicondylar design may limit edge loading and resultant osteolysis.

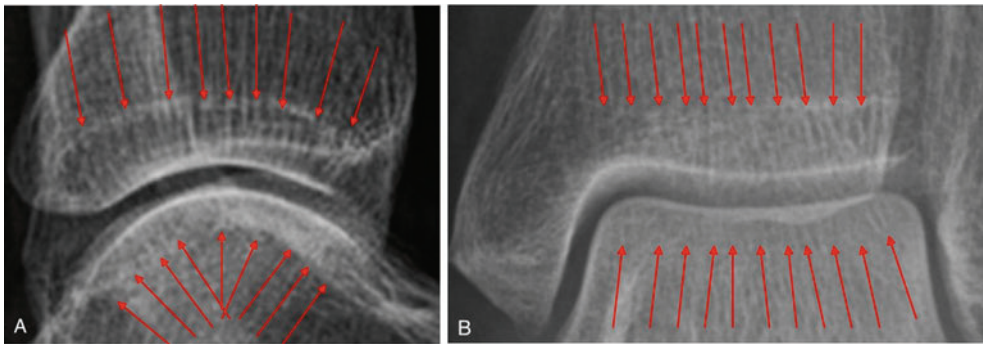

Fig. 12.3 Bone trabecular pattern. *Red arrows* indicate the natural trabecular pattern of the tibia and talus at the level of the ankle joint from a medial view (**a**) and from an anterior view (**b**). The implant aligns with the trabecular pattern, which decreases the bony response to stresses around the implant following insertion. Images utilized with permission from Zimmer

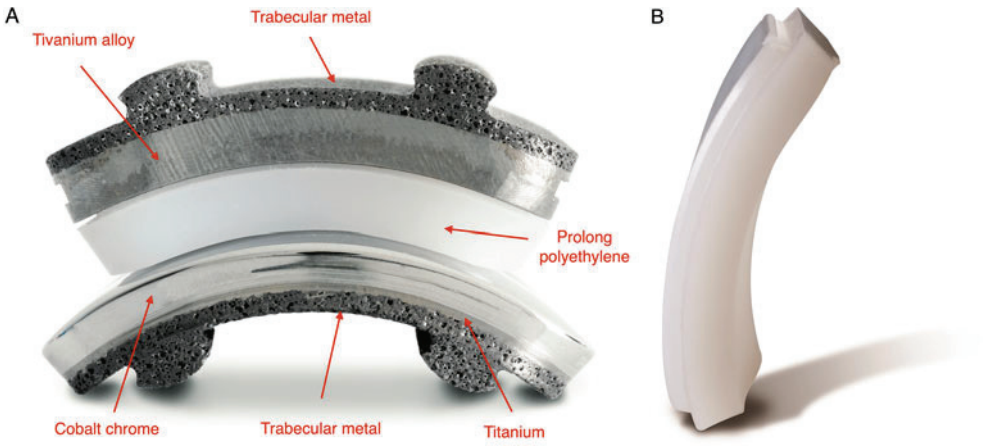

Fig. 12.4 Component materials. The tibial and talar components are comprised of multiple materials allowing for biocompatibility, bony ingrowth, and implant stability (**a**). The Prolong highly cross-linked polyethylene (HXLPE) is manufactured to create less debris and wear more slowly than traditional polyethylene components, decreasing the risk of osteolysis and failure (**b**). Images utilized with permission from Zimmer

Prosthetic Components

Tibial and Talar Components (Fig. 12.4)

The tibial component is made of a Tivanium alloy, diffusion bonded to trabecular metal. Tivanium is titanium with 6 % aluminum and 4 % vanadium (Ti-6Al-4V). The talar component consists of a Zimaloy articular surface, which is a combination of cobalt chrome and molybdenum (CoCrMo) and a trabecular metal and titanium distal surface. Trabecular metal is a highly porous biomaterial [2, 3] made of tantalum, which resembles trabecular bone [3]. Tantalum is a biocompatible metal that is chemically stable and inert, rendering it resistant to corrosion with mechanical properties that are superior to titanium [4]. The metal is 80 % porous, allowing for enhanced bone ingrowth [2, 5], improving the long-term fixation of the prosthetic components [3]. Statistically significant increases in new bone formation and greater fixation strength have been reported to occur earlier in the postoperative period when comparing a highly porous tantalum metal component with a porous-coated component [2]. Additionally, tantalum has been shown to have a high coefficient of friction [2, 6], high fatigue strength, and a modulus that allows bending before breakage [4], all of which contribute to a decreased risk of osteolysis [7] and subsequent implant failure. The use of this highly porous metal for total knee replacement has demonstrated a statistically significant lower risk of aseptic loosening at 5 years, compared with traditional cemented modular tibial components [3, 8, 9]. Trabecular metal total hip replacements have also resulted in less stress shielding of the underlying subchondral bone, compared with titanium implants. Ultimately, the changes in bone mineral density surrounding the implant are minimized [10], which lends to greater implant stability and a decreased risk of failure [10].

Polyethylene

The modular articular surface of the implant is made of Prolong highly cross-linked polyethylene (HXLPE) and is available in three thicknesses (+0-mm, +2-mm, and +4-mm) (Fig. 12.4). It is well documented that polyethylene wear can create debris and lead to aseptic loosening of the prosthesis with subsequent implant failure [11, 12]. Therefore, polyethylene components that wear more slowly generate less debris and are advantageous to the long-term success of the implant. The HXLPE utilized by the Zimmer Trabecular Metal TAR system has been shown to exhibit enhanced wear properties [13–17], resistance to oxidative degeneration [15, 16], and delamination [15] with the absence of free radicals [16], all of which decrease the risk of osteolysis and premature implant failure.

The Science behind the Transfibular Approach

The authors believe that the lateral transfibular approach yields several key benefits to TAR implantation. First, entry through the lateral aspect of the ankle respects the angiosomes of the lower extremity [18]. Attinger and colleagues recommend making foot and ankle incisions at the junction of two angiosomes to provide both sides of the incision with an adequate blood supply [18] (Fig. 12.5). With the lateral approach, an incision is placed at the junction of the anterior tibial artery and peroneal artery angiosomes. With the traditional anterior approach, however, an incision is placed roughly down the middle of the anterior tibial artery angiosome [18, 19]. Therefore, lateral incision placement may decrease postoperative wound healing complications [19].

Examining the complications following TARs implanted via an anterior midline incision, a review of the literature demonstrated that superficial wound healing complications range from 0 to 14.7 %, with a mean of 8 % [20] and deep wound complications with postoperative infections range from 0 to 4.6 %, with a mean of 0.8 % [20]. Alternatively, using a lateral approach for TAR, Rudigier reported a 5 % (8 of 159 patients) wound complication rate [21]. Notably, all wounds healed without additional complication [21]. While encouraging, additional comparative investigations are needed to draw definitive conclusions regarding the incidence of postoperative wound healing complications following TAR with an anterior approach versus a lateral approach.

A second benefit of the lateral approach is the direct visualization of the lateral tibiotalar joint once the fibula is reflected distally. This approach allows the surgeon to accurately assess the normal arc of rotation and precisely identify the center axis of each patient's ankle joint. Through the lateral cortical window, the alignment guide can be rotated around the center axis to dictate accurate bony resection and subsequent implant placement. Additionally, if a procurvatum or recurvatum deformity exists, the cutting guide can be rotated more anteriorly or posteriorly for deformity correction.

It is well known among foot and ankle surgeons that soft tissue balancing procedures are paramount to successful TAR stability and reduction of varus/valgus malalignment. However, osseous deformity that goes unaddressed can also contribute to postoperative malalignment. Through the lateral transfibular approach, the fibula can be shortened to correct for varus malalignment or lengthened to correct for valgus malalignment. Brooke and colleagues reported two cases of postoperative valgus after TAR that were successfully corrected with a fibular osteotomy [22]. These findings demonstrate that fibular osteotomies can be successfully utilized for rebalancing osseous deformity of the ankle [22].

While there are many benefits to the lateral transfibular approach, there are also drawbacks. The creation of a fibular osteotomy introduces the risk of nonunion and malunion. Following implantation of the ESKA^{T} TAR (ESKA implants, GmbH, Lubeck, Germany) through a lateral transfibular approach, Rudigier reported three (1.9 %) delayed unions and one (0.6 %) nonunion [21]. Although the risk of nonunion is minimal, postoperative protocols must be adjusted to allow for osteotomy healing. Some cases may require prolonged immobilization, which introduces the risk

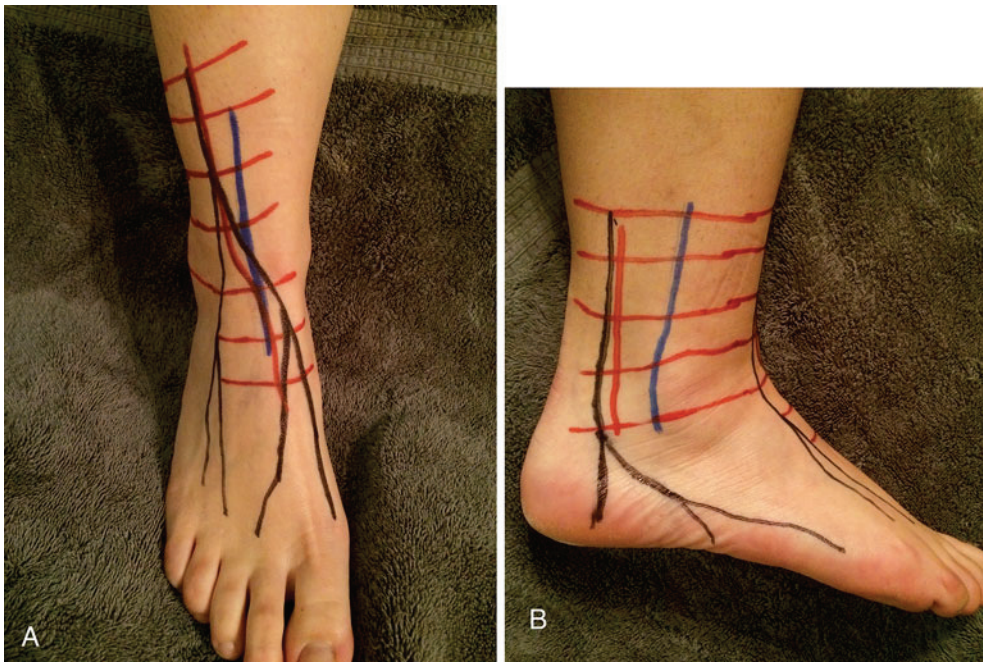

Fig. 12.5 Angiosomes. Skin incisions, for the anterior midline approach (**a**) and lateral transfibular approach (**b**), are shown in *blue*. The vascular anatomy and angiosomes are indicated in *red*, while the innervation is indicated in *black*. The anterior midline incision cuts through the anterior tibial angiosome. The lateral transfibular incision is located at the junction of the anterior tibial and peroneal angiosomes, a more ideal location for incision healing

of postoperative stiffness, while others may necessitate reoperation. Nonunion of the fibula can lead to instability of the prosthesis and subsequent malalignment and/or implant failure. The anterior talofibular ligament is sectioned to gain access to the joint and must be repaired upon closure. Delayed healing or inadequate repair can also render the ankle unstable postoperatively. Surgeons must also make a separate incision to correct or balance any medial soft tissue pathology. In many instances, this can be achieved with a "mini-open" medial arthrotomy.

Alignment System

The alignment system is designed to hold the extremity static in an anatomic position, permitting accurate bone resection (Fig. 12.6). Prior to the procedure, the majority of the alignment guide is constructed on the back surgical table. The position of the lateral cut guide, talar pin connector, and footplate is dependent upon the operative side; therefore, this information must be conveyed to the surgical technician prior to the procedure. Once the extremity is appropriately

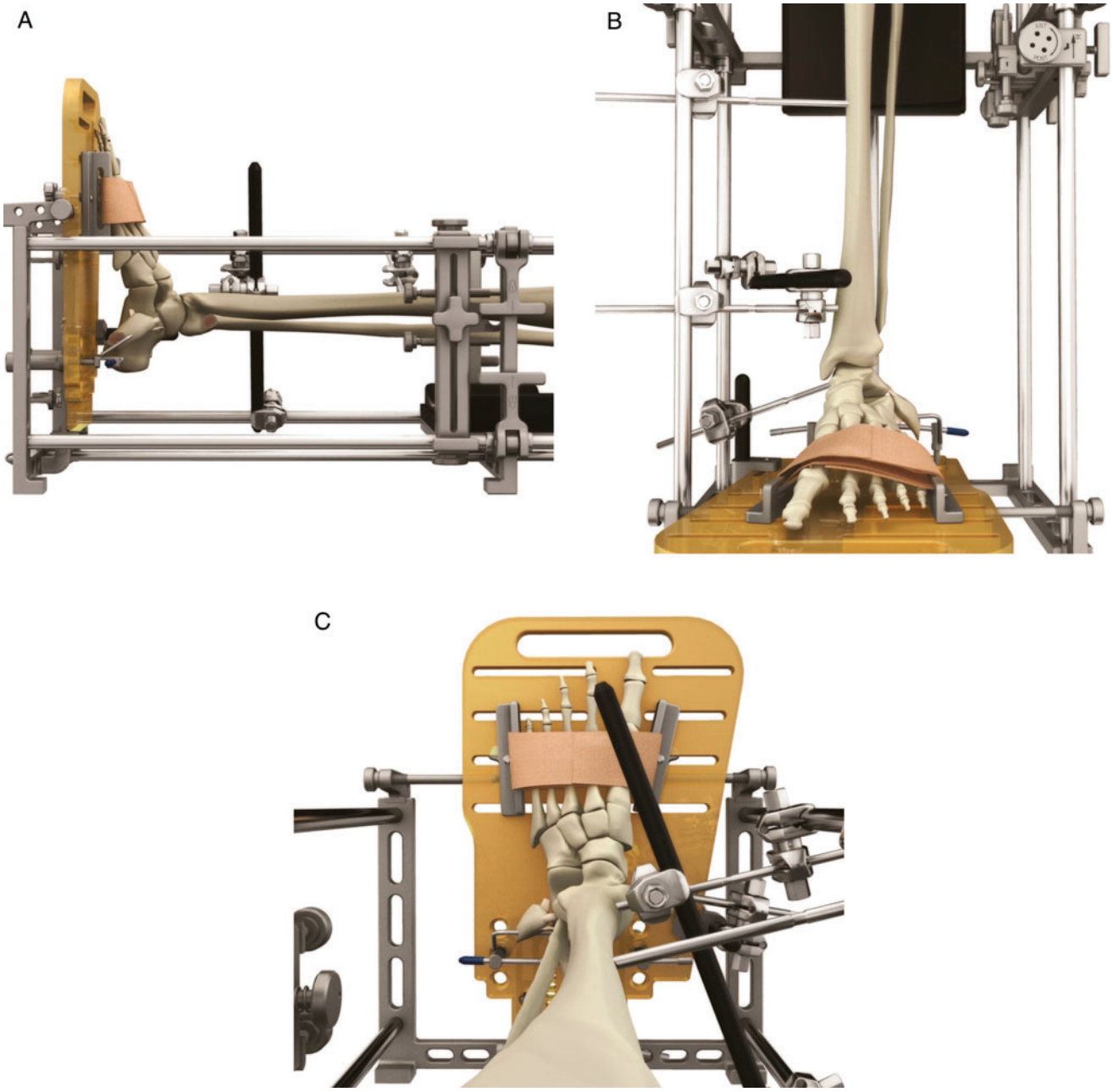

Fig. 12.6 Alignment frame. The alignment frame is specifically designed to anatomically align and hold the extremity static throughout implantation that permits reproducible osseous resection. Correct extremity positioning within the alignment frame is provided from a lateral view (**a**), an anterior view (**b**), and a top-down view (**c**). Images utilized with permission from Zimmer

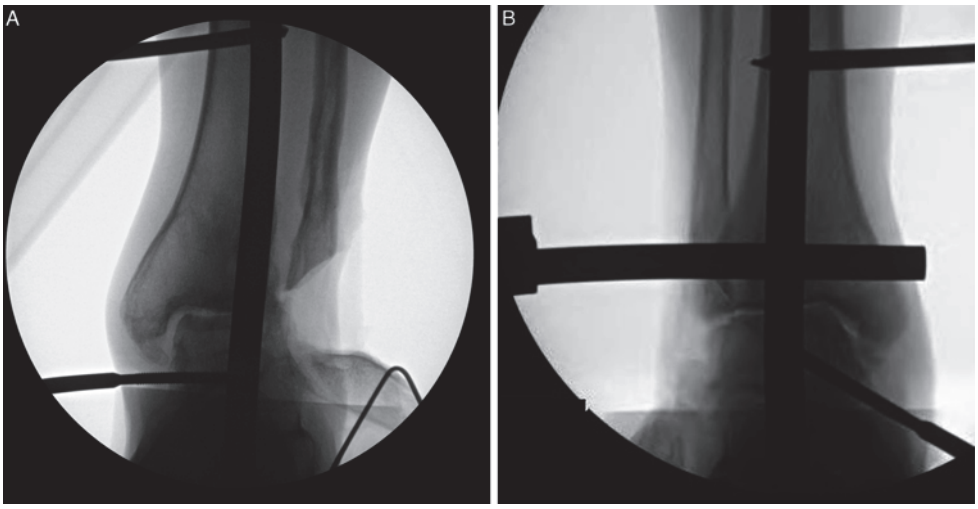

Fig. 12.7 Anterior–posterior alignment rod. The rod, which is located centrally and posteriorly within the alignment frame, provides intramedullary guidance. Before placement of the tibial half pins, the alignment rod must parallel to the anatomic axis of the tibia (**a**). Prior to resection, the "Iron Cross" is created by placing a rod through the lateral incision, in line with the projected tibial resection (**b**). The alignment rod and the lateral to medial rod should align perpendicular to one another, suggesting neutral placement of the implant

stabilized within the alignment guide, the remainder of the procedure is easily performed.

To construct the skeleton of the alignment guide, four frame rods are utilized to connect the distal base of the frame and the proximal U-frame. A tibial alignment rod is located posteriorly and centrally through the frame base and the U-frame. Extremity alignment is highly dependent upon this rod. Prior to securing the tibia to the alignment guide, this rod is aligned parallel to the anatomic axis of the tibia (Fig. 12.7). Calf supports, in varying heights, are located within the U-frame, allowing the surgeon to align the long axis of the tibia, on the sagittal plane, parallel to the longitudinal frame rods. The U-frame can be unlocked to slide distally and proximally, accommodating the patient's anatomy. These adjustments are made intraoperatively. Once the extremity is correctly positioned, the U-frame is locked.

A footplate attaches distally to the frame base, which helps to appropriately position and secure the foot with the appropriate amount of internal rotation. As previously mentioned, footplate position is dependent upon the surgical extremity. In the case of a right TAR, the word "right" should be visualized from the end of the bed looking cephalad. The reverse is true for a left TAR.

A matching footplate support attaches to the plantar surface of the footplate, and the construct is affixed to the frame base at a 90° angle to the frame rods. When the foot is fixed, it will form a 90° angle with the leg. The medial side of the footplate is sloped 10°, which is helpful when internally rotating the leg/ankle. If the surgeon aligns the forefoot with the medial slope of the footplate, 10° of internal rotation is achieved. The internal rotation ensures the appropriate orientation of the medial clear space.

An adjustable heel support cup is attached to the footplate to stabilize the heel. A talar pin connector is located medially within the footplate, which is needed for intraoperative placement of a talar half pin. Two calcaneal pin hooks thread

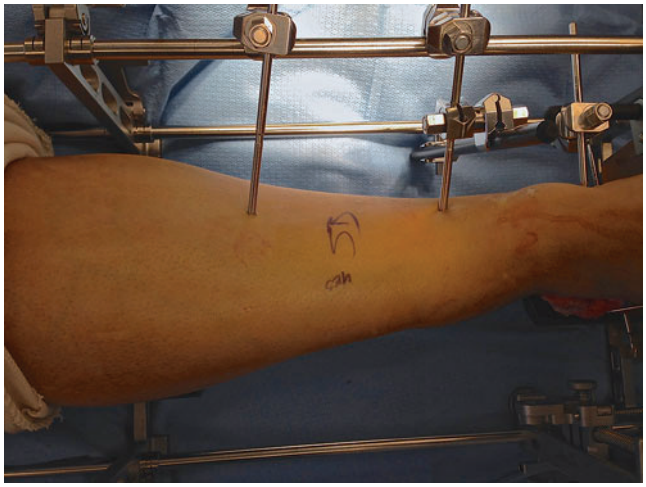

Fig. 12.8 Tibial half pins. The pins are placed in the medial tibial face at approximately 5 and 15 cm proximal to the ankle joint and are then clamped to the medial anterior frame rod

through the footplate from plantar to dorsal, which are used intraoperatively to secure the transcalcaneal pin. When the foot is aligned, the forefoot brackets, located dorsally within the footplate, are tightened, and an elastic wrap is attached to further stabilize the foot. Care should be taken to ensure that the foot and heel are firmly seated against the footplate. An insecure or improperly placed foot can result in prosthetic misalignment.

The frame rods on the medial side are utilized to secure the tibia to the alignment guide. Intraoperatively, the tibial half pins are placed (Fig. 12.8) and clamps are used to secure them to the medial anterior frame rod. A pin-to-rod clamp is then utilized with a carbon fiber rod for additional stabilization. It is placed medially and connected between the distal tibial half pin and the medial posterior frame rod.

The lateral cut guide is located on the lateral side of the alignment frame and slides along the anterior and posterior

frame rods. As previously mentioned, the lateral cut guide is dependent upon the surgical extremity. In the case of a right TAR, the letter "R" should be facing up and an arrow pointing toward the footplate. In the case of a left TAR, the letter "L" should be facing up an arrow pointing toward the footplate. The cut guide lock is located on the central lateral aspect of the cut guide, and the two slide locks are located on the anterior and posterior lateral aspects of the cut guide. Two anterior–posterior stops are located distally within the lateral cut guide. To perform tibial and talar resection, a precutting guide and cutting guide are locked into the lateral cut guide.

Surgical Indications and Contraindications

Indications

The Zimmer Trabecular Metal TAR is indicated for primary or revision surgery in patients with end-stage rheumatoid, posttraumatic, or primary degenerative arthritis of the ankle joint. The authors typically reserve this approach for patients who:

- Demonstrate compromised anterior soft tissue structures
- Are considered young for TAR
- Exhibit a low physical demand

While discussion of the appropriate patient age for TAR is beyond the scope of this chapter, the authors believe that this particular prosthetic can be considered in a wider spectrum of cases. The Zimmer Trabecular Metal TAR minimizes bone resection, averaging approximately 15 mm for both the tibia and talus, and permits revision arthroplasty or arthrodesis later in life (Fig. 12.1). It is important to note that currently no revision system is available specifically for the Zimmer Trabecular Metal TAR system. Any revisions must be performed with an alternate TAR system.

Contraindications

Contraindications to the procedure adhere to those of other TAR systems. These include, but are not limited to:

- Uncontrolled diabetes
- Charcot neuroarthropathy
- Peripheral vascular disease
- The lack of an intact fibula
- Significant tibial metaphyseal bone cyst
- Significant talar loss due to avascular necrosis

Surgical Techniques

Exposure and Sizing

Patients are situated on the operating table in the supine position. An ipsilateral hip bump can be used to position the tibial tuberosity in a rectus position. A lateral longitudinal incision is made a few millimeters posterior to the midline of the fibula, beginning approximately 15 cm proximal to the level of the joint and carried distally to the tip of the lateral malleolus (Fig. 12.9). Subperiosteal dissection of the distal fibula delivers the fibula through the surgical incision. The anterior talofibular ligament is identified and sectioned. The calcaneal-fibular and posterior talofibular ligaments should not be sectioned. If the surgeon plans to use a fibular plate for fixation, the holes can be drilled prior to creation of the fibular osteotomy. When performing the fibular osteotomy, the surgeon must follow several key steps to make the bone cut without detriment.

Step One

The first step to success is determining the proper location to create the osteotomy. Regardless of osteotomy type, the bone cut must be placed at the distal portion of the ankle syndesmosis (Fig. 12.10). Location is imperative to prevent instability of the ankle joint and widening of the distal tibiofibular joint. When evaluating the location of the distal syndesmosis, the surgeon must ensure that enough of the tibia is visible. If in an effort to preserve the syndesmosis the osteotomy was made too distal, the surgeon may have difficulty placing the tibial cutting block. In this situation, an additional fibular osteotomy may be required, which, in turn, increases the risk of poor fixation and nonunion.

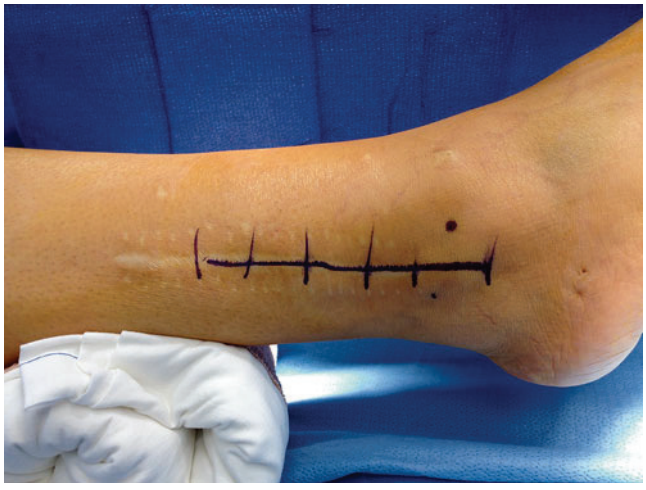

Fig. 12.9 Skin incision. The transfibular skin incision lies just posterior to the midline of the fibula, starting 15 cm proximal to the joint level and ending at the distal tip of the fibula

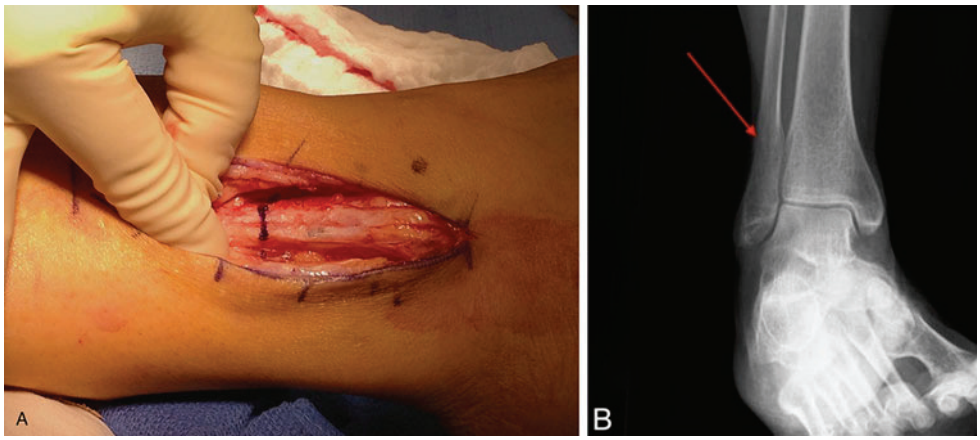

Fig. 12.10 Osteotomy location. The fibular osteotomy should be made proximally enough to allow adequate exposure of the lateral ankle joint while maintaining as much of the syndesmosis as possible to prevent postoperative tibiofibular widening and instability. Intraoperative (**a**) and radiographic (**b**) images demonstrate the proper osteotomy location

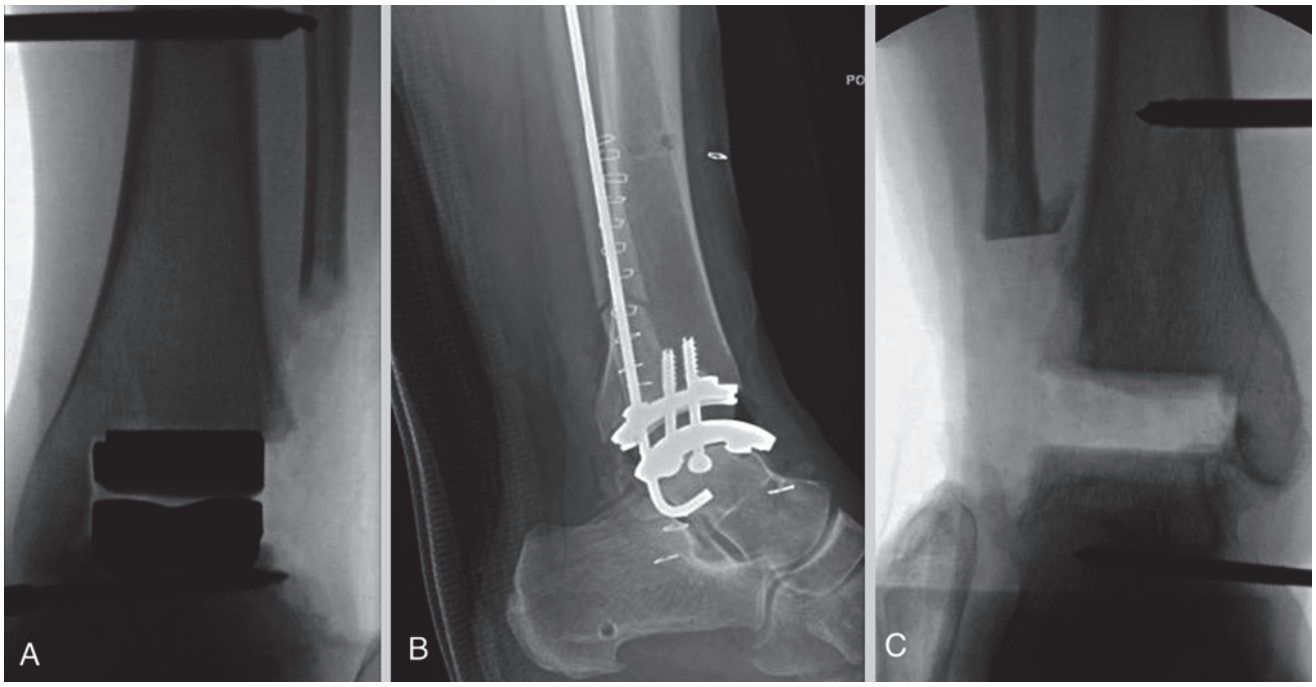

Fig. 12.11 Fibular osteotomy. The osteotomy can be performed in the surgeon's preferred fashion: oblique (**a**), chevron (**b**), or transverse (**c**). Most commonly, the oblique osteotomy is utilized

Step Two

The next step to a successful transfibular approach is determining the type of osteotomy that will be performed (e.g., oblique, chevron, or transverse) (Fig. 12.11). The authors believe that the oblique osteotomy is the most reproducible and has the highest tolerance for error, which may be beneficial for surgeons new to the transfibular approach. Dependent upon the surgeon's preference, the oblique osteotomy can be made in two orientations.

Most commonly, the oblique osteotomy is performed in the frontal plane with the osteotomy starting proximal lateral and ending distal medial. This orientation is advantageous because it allows for preservation of the syndesmosis, and a plane is easily created between the bone and soft tissue for reflection of the distal fibula. However, it can prove difficult to place inter-fragmentary compression across this osteotomy as an adjunct to plate fixation. Alternatively, the oblique osteotomy can be performed in the sagittal plane from proximal-posterior to distal-anterior. This approach also allows for syndesmosis preservation and can more easily accommodate placement of inter-fragmentary compression; however, separation of the distal fibula from the soft tissues for reflection is slightly more difficulty. For surgeons with more experience in performing the transfibular approach, the transverse and chevron osteotomies may be used, although

the authors are not convinced of any clinical benefit. If lengthening or shortening of the fibula is anticipated, the osteotomy should be selected to allow for the correction.

Step Three

The final step to success is proper fixation. Fixation of the osteotomy ranges from inter-fragmentary screw fixation with a 3.5-mm partially threaded screw and a neutralization plate or a fibular locking plate to the use of intramedullary "rush-rod" with a Steinmann pin (Fig. 12.12). All techniques have demonstrated clinical efficacy. Plate fixation provides the benefit of rigid fixation, while an intramedullary rod improves the speed of insertion and limits lateral soft tissue irritation that can be problematic with plate fixation. Once the osteotomy is created, the distal fibular segment is reflected in a distal-posterior direction and stabilized to the lateral wall of the calcaneus with a temporary wire. The wire is bent posteriorly to avoid interfering with the remainder of the procedure.

A medial ankle arthrotomy is then performed through a small "mini-open" incision, directly overlying the medial gutter. Any osteophytes identified within the lateral incision or the medial gutter should be excised. Through the lateral incision, the medial–lateral sizer is inserted and visualized on intraoperative fluoroscopy to determine the medial–lateral implant size (Fig. 12.13). Etch marks on the sizer aid in

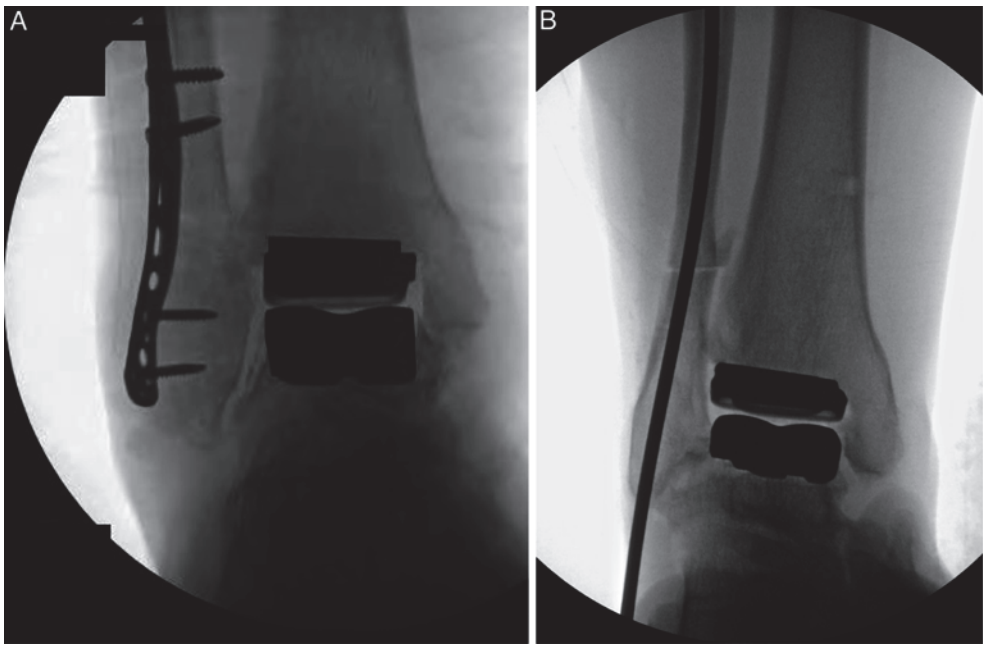

Fig. 12.12 Osteotomy fixation. Locking plate fixation (**a**) or an intramedullary rod (**b**) can be utilized to fixate the fibular osteotomy. Fixation selection is dictated by surgeon preference, osteotomy type, and the need for lengthening or shortening of the fibula for varus/valgus correction

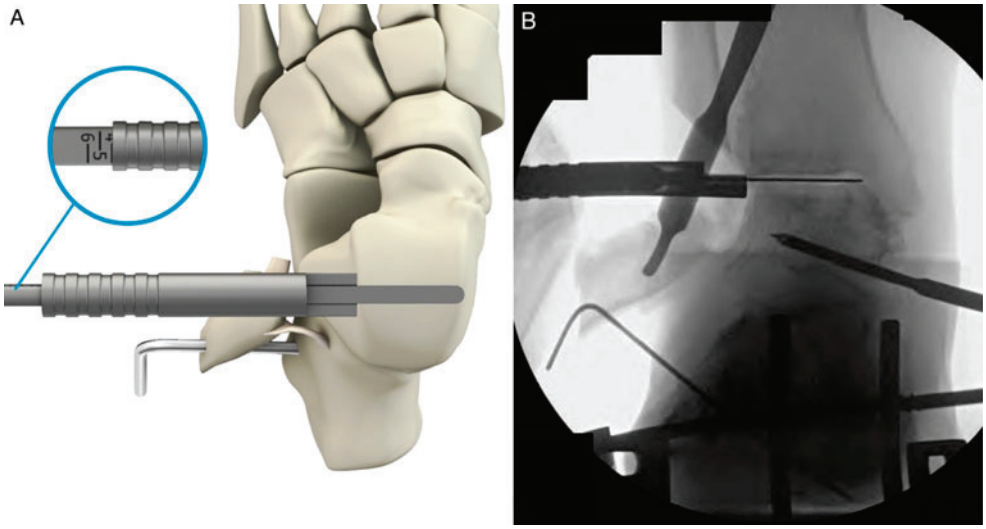

Fig. 12.13 Medial–lateral sizing. The medial–lateral sizer should be inserted into the joint and placed flush with the lateral talus. It contains etch marks to indicate the implant size (**a**). Confirmation on intraoperative C-arm image intensification is imperative to ensure no medial–lateral overhang exists (**b**). If the patient's anatomy lies between two sizes, the smaller size should be selected (**a**). Utilized with permission from Zimmer

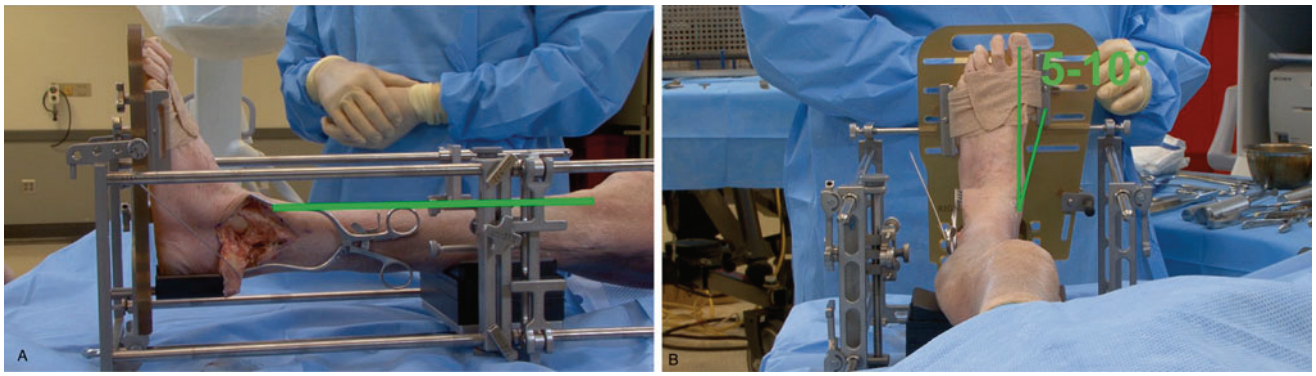

Fig. 12.14 Alignment of the lower leg in the guide. The tibial crest should parallel the frame rods in the sagittal plane (**a**), while the foot/ankle should be internally rotated 5°–10° to place the anterior half of the lateral talus vertical during bony resection (**b**). Images utilized with permission from Zimmer

appropriate selection. If the patient's anatomy is between two sizes of the implant, the smaller size should be utilized to prevent medial–lateral overhang.

Alignment and Fixation

The alignment guide that was previously constructed on the back surgical table is now brought onto the operating table, and the foot is appropriately positioned into the guide. The heel is placed into the heel cup, and the position of the heel cup is adjusted until the center of the heel is equidistant between the alignment rods in the sagittal plane. The calf supports are adjusted with insertion or removal of additional support blocks, and the U-frame is slid distally or proximally until it rests under the midportion of the proximal calf. The tibial crest should run parallel to the frame rods in the sagittal plane. Once achieved, the U-frame is locked into place (Fig. 12.14).

The foot is then appropriately positioned onto the footplate with 5°–10° of internal leg rotation (Fig. 12.14). To ensure the talus is appropriately aligned, a malleable retractor can be placed into the medial ankle arthrotomy site. It is important to understand that the internal rotation positions the anterior half of the lateral talus vertically during resection. The footplate brackets are tightened, and the elastic wrap secures the foot. The position of the foot through the plantar aspect of the footplate should be assessed. Ensure that the foot is flush with the footplate. If it is not, adjust the alignment of the extremity. If a deformity (varus/valgus) is preventing flush contact between the foot and the footplate, additional procedures or alignment guide adjustments may be needed. Intraoperative C-arm image intensification should confirm appropriate ankle joint position before securing the leg into the guide.

To secure the extremity into the alignment guide, a transcalcaneal pin and three half pins are placed. All pins are inserted from the medial side to prevent interference with lateral implantation. First, the transcalcaneal pin is placed within the posterior and plantar half of the calcaneus, parallel to the tibial plafond and footplate. Intraoperative C-arm image intensification should be utilized to ensure appropriate placement. Once placed, the calcaneal pin is secured to the footplate with calcaneal pin hooks. The hooks should be tightened simultaneously, pulling the heel against the footplate until slight bowing of the pin is appreciated. The heel support cup is then removed. The talar half pin is placed next. The pin should be inserted medially into the talar neck, just distal and anterior to the tip of the medial malleolus. The pin should be placed unicortically and on an angle from distal to proximal to avoid interfering with intraoperative imaging and bone resection. The talar pin must stay below the talar resection site, otherwise when resection is undertaken, the pin will interfere (Fig. 12.15). Once the proper position is confirmed, the pin is secured medially to the footplate with the appropriate clamp. With the talus and calcaneus secured to the alignment frame, tibial stabilization is performed. On anterior–posterior C-arm image intensification, confirm that the tibial alignment rod parallels the lateral border of the tibia at the mid-shaft level. A second rod placed lateral to medial in line with the projected tibial resection forms an "Iron Cross" and demonstrates that alignment of the implant will be perpendicular to the tibial axis (Fig. 12.7). Once confirmed, two tibial half pins are placed at 5 and 15 cm proximal to the ankle joint. The half pins can be placed unicortically or bicortically, depending on surgeon preference and bone quality. They are secured to the medial anterior frame rods with the appropriate clamps. A pin-to-rod clamp, with a carbon fiber rod for additional stabilization, is placed medially and connected between the distal tibial half pin and the medial posterior frame rod. The tibial alignment rod and calf supports can be removed. Adjustments in the setup of the alignment guide can be made to address mild deformities during implantation of the TAR (Table 12.1).

Sizing and Positioning

Prosthetic component size should be confirmed utilizing the anterior–posterior sizer. The size determined for the medial–lateral sizing at the beginning of the procedure should be used. The anterior–posterior sizer will mirror the resection curves for that implant size. The sizer should demonstrate complete coverage without anterior or posterior overhang (Fig. 12.17). If overhang is present, the next size down should be trialed. Note that the sizer can be rotated to evaluate tibial and talar resection independently. Additionally, the component sizes are not interchangeable; therefore, the same tibial and talar size must be implanted.

The cutting guide is attached to the lateral cut guide for provisional resection alignment. A probe is placed through the "position" hole on the cutting guide and aligned with the superior-most aspect of the lateral talar dome. In the unlocked

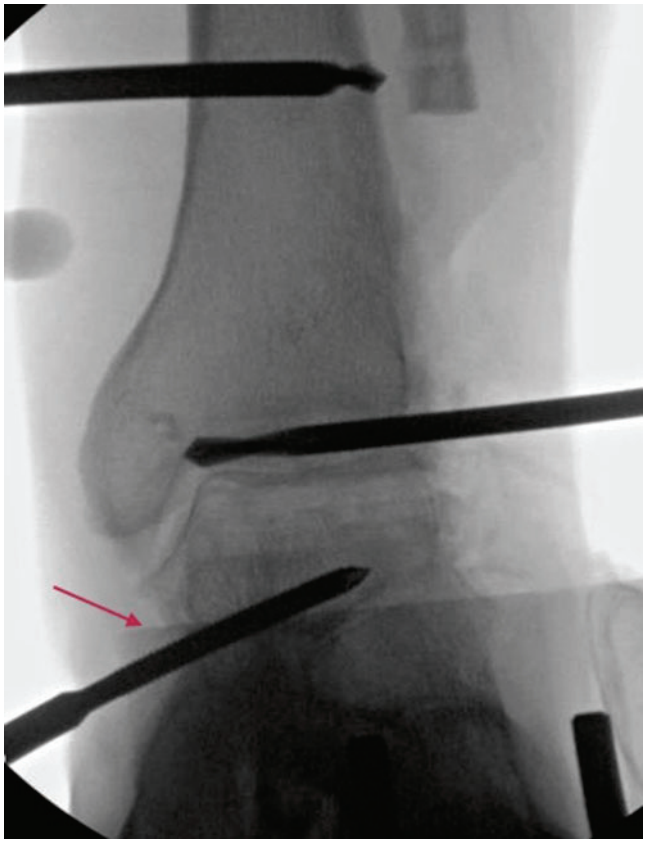

Fig. 12.15 Talar half pin placement. The talar half pin should be angulated from distal medial to proximal lateral with caution not to advance the pin too close to the joint line. If this occurs, the pin will interfere with intraoperative imaging and joint resection

Table 12.1 Patients with limb deformity

For sagittal plane deformity
• Once the leg has been secured to the alignment guide, a third tibial half pin is placed directly anterior, just proximal to the ankle joint. This half pin is secured to the alignment guide with a transverse carbon fiber rod and clamp (Fig. 12.16)
• Once the half pin is inserted, manual power is utilized to:
– Pull the tibia anteriorly to address recurvatum
– Push the tibia posteriorly to correct procurvatum
• Once the deformity is reduced, the half pin is locked into place along the carbon fiber rod, holding the reduction stable. The index procedure is then performed according to the previously described protocol
For frontal plane deformity
• Adjustments are made prior to insertion of the talar pin. Typically, half pins are placed consecutively in the calcaneus, talus, and tibia, securing the leg to the alignment guide. When addressing varus/valgus malalignment, the talar half pin should be inserted last
• Once the calcaneus and tibia are stabilized, a temporary half pin is placed into the lateral talus. This half pin is utilized as a "joystick" to manually correct varus/valgus deformity. If required, a deltoid peal can be performed to aid in correction of varus malalignment
• Once the deformity is reduced, the medial stabilizing talar half pin is inserted and secured to the footplate. The temporary lateral half pin is removed, and the index procedure is performed according to the previously described protocol

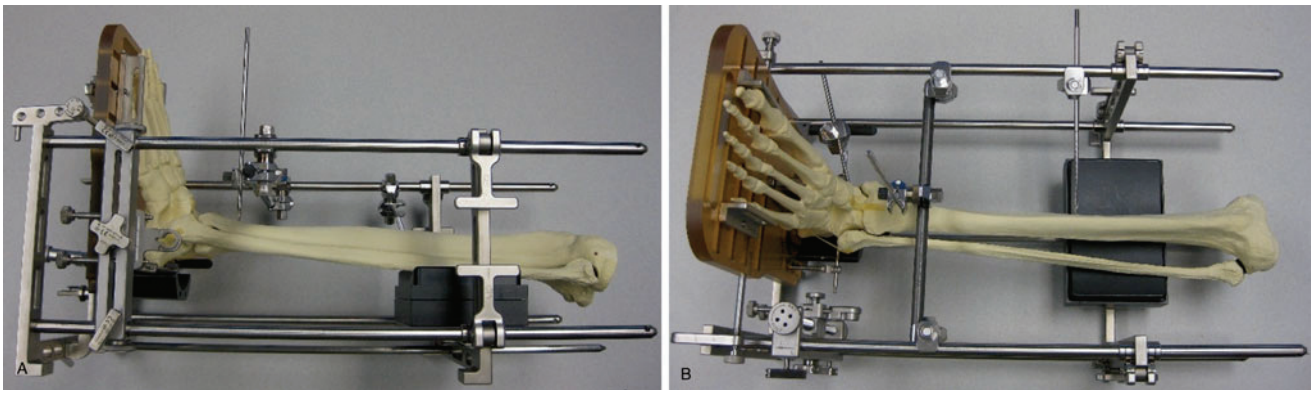

Fig. 12.16 Alignment frame for sagittal plane deformity. Placement of an anterior tibial half pin can allow the surgeon to manually adjust for recurvatum or procurvatum prior to bony resection. Placement of an anterior tibial half pin frame is shown from a lateral view (**a**) and an anterior view (**b**). Images utilized with permission from Zimmer

position, the probe should be taken through the arc of resection for visualization of the reconstructed joint line (Fig. 12.18). The slide locks and the anterior–posterior stops on the lateral cut guide can be loosened to allow adjustments to the arch of resection and locked into place when the appropriate alignment has been established. Adjustments can be made to allow for exact replication of the joint line (Fig. 12.19). The probe can be removed from the "position" hole and placed into the talus and tibial holes to evaluate the amount of tibial and talar osseous resection independently. Loosening the slide locks allows for adjustments in the proximal and distal directions. When satisfied with the alignment, verify that all assembly pieces are locked and initiate osseous resection.

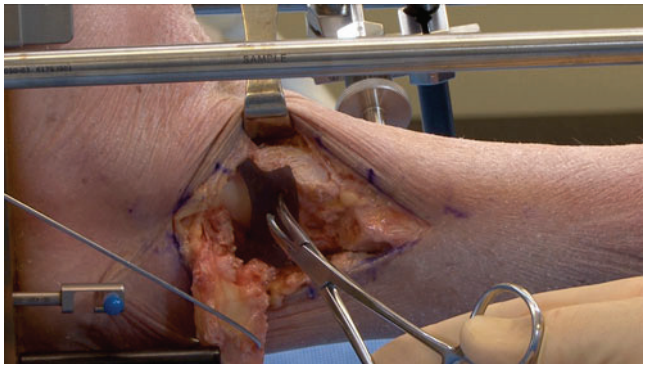

Fig. 12.17 Anterior–posterior sizing. The anterior–posterior sizer, corresponding to the selected implant size, is used to ensure that no anterior or posterior overhang exists. The tibia and talar sizes must be the same, but their resection can be evaluated independently. Image utilized with permission from Zimmer

Bone Preparation

The cutting guide is removed from the lateral cut guide and replaced with the precutting guide. This guide will allow the surgeon to create a series of pilot holes in both the talus and tibia. The precutting guide is locked in a static position, and in a peck fashion the precutting guide drill perforates the opposing joint surfaces (Fig. 12.20). The drill is etched to correspond to the size of the implant. When this etching contacts the precutting guide, intraoperative C-arm image intensification should be utilized to assess the depth, ensuring that the medial malleolus is not violated. In most cases, the drilling will need to be slightly deeper than the etch line to improve cutting efficiency. Re-chuck the drill, so that the drill contacts the edge of the pre-cut guide. This permits the efficient creation of a series of pilot holes without continually having to verify the depth fluoroscopically. The most anterior and

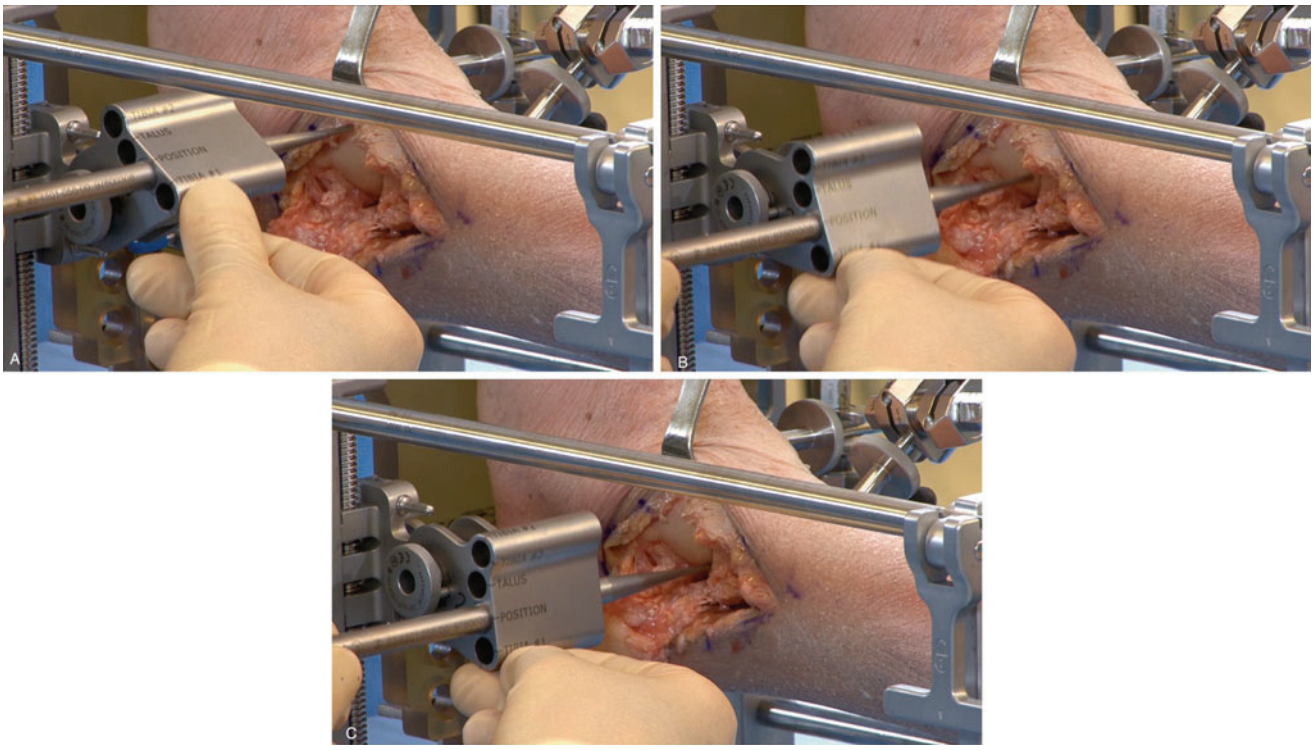

Fig. 12.18 Joint line reconstruction. With the cutting guide in place, a probe is placed through the "position" hole, which allows the surgeon to reconstruct the joint line, mirroring bony resection. Here, the probe shows the anterior (**a**), central (**b**), and posterior (**c**) joint line that matches the bony resection. Images utilized with permission from Zimmer

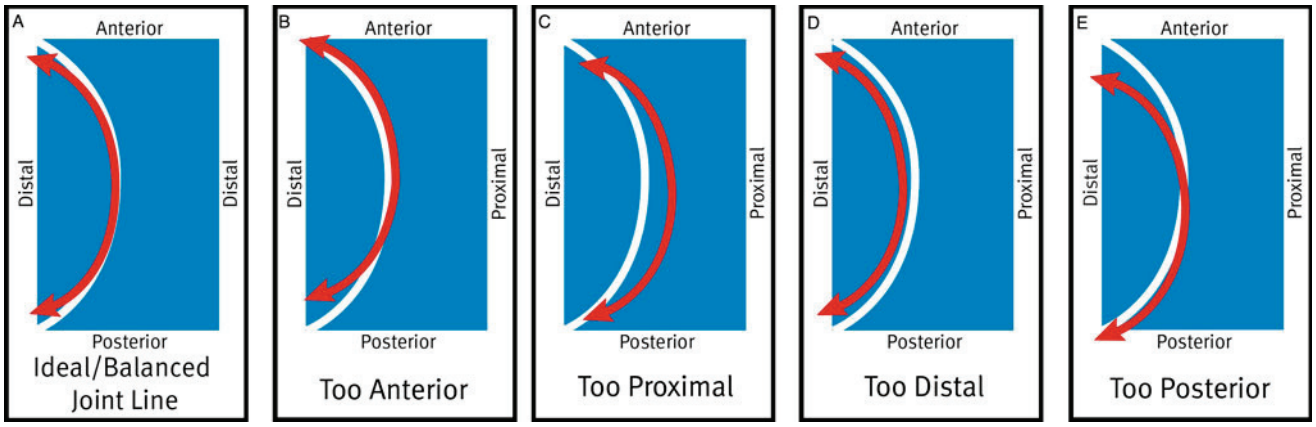

Fig. 12.19 Adjustment guide for joint line reconstruction. The slide locks and anterior–posterior stops are utilized to adjust the cutting guide and allow matching of the joint resection to the joint surfaces. The goal is to establish a balanced joint line (**a**), matching the patient's anatomy. Images show how to adjust the cutting guide if the alignment is too anterior (**b**), too proximal (**c**), too distal (**d**), or too posterior (**e**). Image utilized with permission from Zimmer

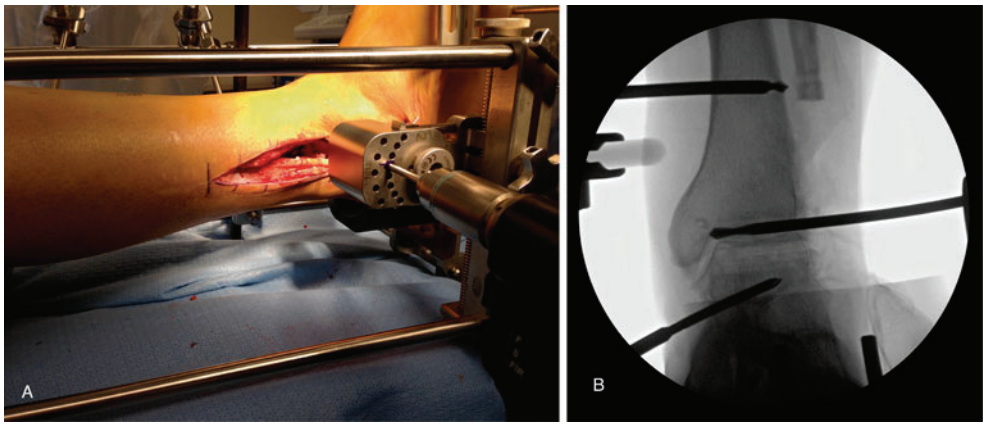

Fig. 12.20 Precutting guide. The precutting guide allows the surgeon to create a series of pilot holes in the tibia and talus to aid in burr resection (**a**). The depth of the drill utilized during the precutting step should be confirmed on intraoperative C-arm image intensification (**b**) to avoid medial malleolar impingement

posterior holes may not contact the bone and, therefore, may not be utilized, depending on the patient's anatomy. Once all of the pilot holes have been created, the precutting guide is removed, and the cutting guide is secured into place.

A burr guard is placed over the burr, and the setup is inserted into the "talus" hole of the cutting guide. The appropriate size talar provisional implant can be utilized to help set the depth (Fig. 12.21). Once the appropriate depth is determined, lock the burr guide into place; this improves efficiency during resection. The talar provision is removed and a 5-mm spacer is snapped onto the burr guard. The spacer removes 5 mm from the depth of the resection during bone preparation, which prevents violation of the medial malleolus and medial neurovascular structures (Fig. 12.21). The use of the 5-mm spacer can be omitted based upon preference. Intraoperative C-arm image intensification should be utilized to confirm resection depth. The cutting guide is unlocked and rotated along the resection arc. Osseous resection of the talus is undertaken utilizing a "plunge and sweep" method in a clockwise direction (Fig. 12.21). The anterior–posterior stops on the lateral cutting guide can be adjusted to ensure that excessive anterior and posterior resection is not performed. Lateral to medial resection is continued until the 5-mm spacer contacts the cutting guide.

The 5-mm spacer is removed and without adjusting the burr guard, the burr is placed into the "tibia #1" hole on the cutting guide. The anterior–posterior stops are adjusted, and the same plunge and sweep method is utilized in a counterclockwise direction to partially prepare the tibia (Fig. 12.21). Resection is continued until the burr guard stop contacts the cutting guide. Resected bone within the joint is removed with a rongeur, and the burr is placed into the "tibia #2" hole, without adjusting the burr guard. The remainder of tibial preparation is completed with the aforementioned technique. If the 5-mm spacer was utilized for talar preparation, the burr is placed back into the "talus" hole, and the remaining 5 mm of the bone on the medial side of the joint is resected. The joint should be irrigated thoroughly with a pulsating lavage and all resected bone should be excised (Fig. 12.21).

Rail hole preparation occurs next. Tibial and talar rail hole drill guides correspond to the selected implant size and are mated. These guides replicate the dimensions of the

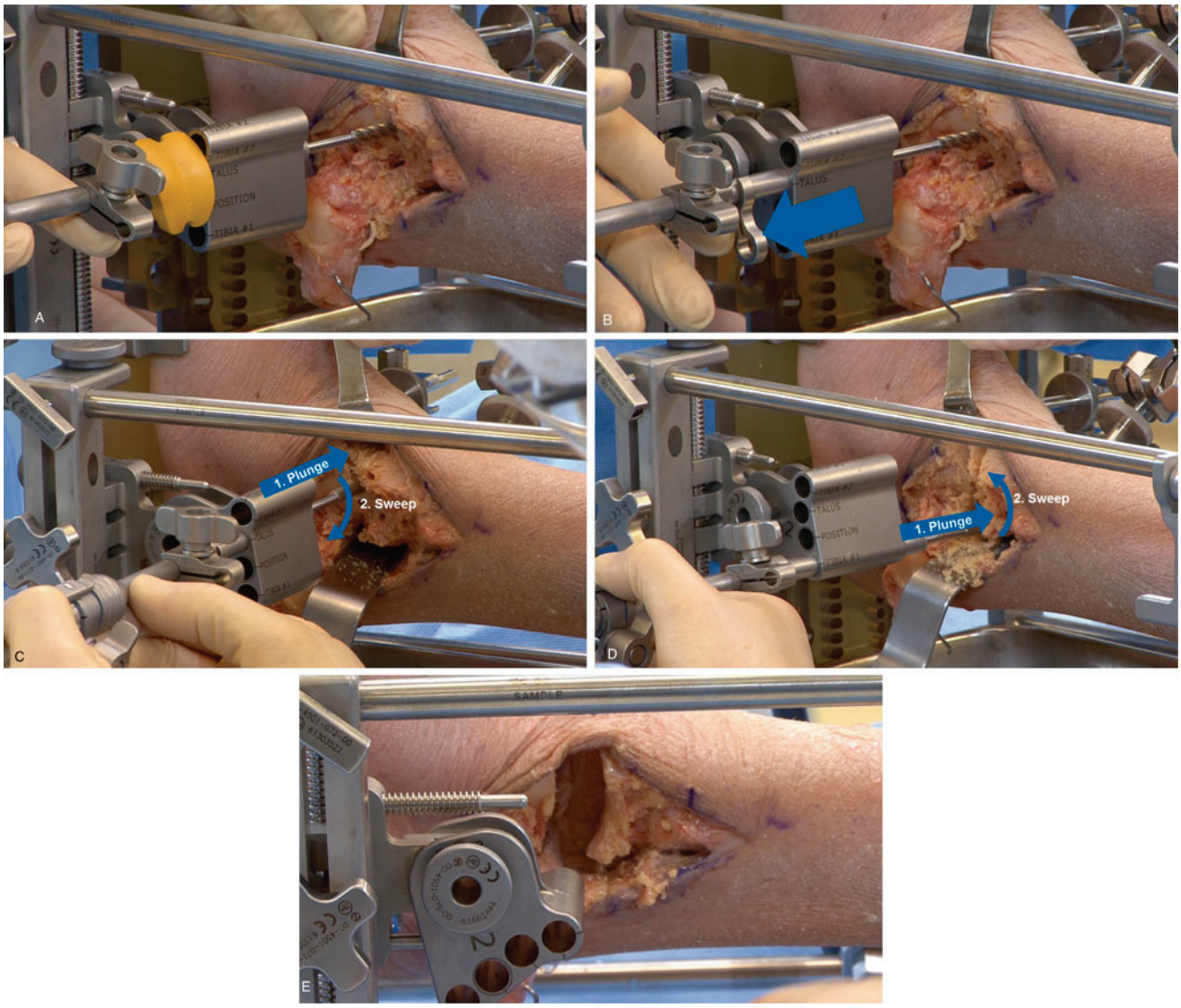

Fig. 12.21 Burr resection. The talar provisional implant is placed between the cutting guide and the burr to determine the depth of resection (**a**). Once confirmed on intraoperative C-arm image intensification, the talar provisional implant is removed and the 5-mm spacer is affixed to the burr guard (**b**), which protects the medial malleolus and medial neurovascular structures during resection. The talus is prepared first utilizing a plunge and sweep method in a clockwise direction (**c**), followed by tibial resection in a counterclockwise direction (**d**). Resected bone is removed, revealing the prepared space for the implant (**e**). Images utilized with permission from Zimmer

implant and provide a strong indication of final component positioning. The linked components should be inserted into the joint together and manually adjusted until the appropriate medial–lateral and anterior–posterior position is achieved. There should be no lateral overhang. The talar and tibial components can be rotated anteriorly and posteriorly independent of each other for implant placement that closely matches the patient's anatomy. When satisfied with the position, a spreader pin is inserted between the components, holding them static, and intraoperative C-arm image intensification is utilized to confirm the position (Fig. 12.22). On an anterior–posterior view, there should be no lateral overhang of the prosthetic components, and a small notch in the tibial rail guide should align with the anatomic axis of the tibia. On the lateral view, confirm that anterior and posterior overhang is minimized. The rail holes should be flush with the resected tibia and talus to ensure appropriate seating of the final components. If any adjustments need to be made, remove the spreader pin, adjust the spreader pin, and replace the spreader pin, confirming the adjusted position under C-arm image intensification. After the rail hole drill guides are appropriately seated, K-wires are inserted from lateral to medial through holes in the guide, securing the guide for rail hole preparation.

The appropriate rail hole drill is used in a peck fashion to prepare each of the four rails until the stop contacts the sleeve of the guide. After each hole is drilled, a rail hole stabilizer is inserted into the prepared rail to ensure the guide remains

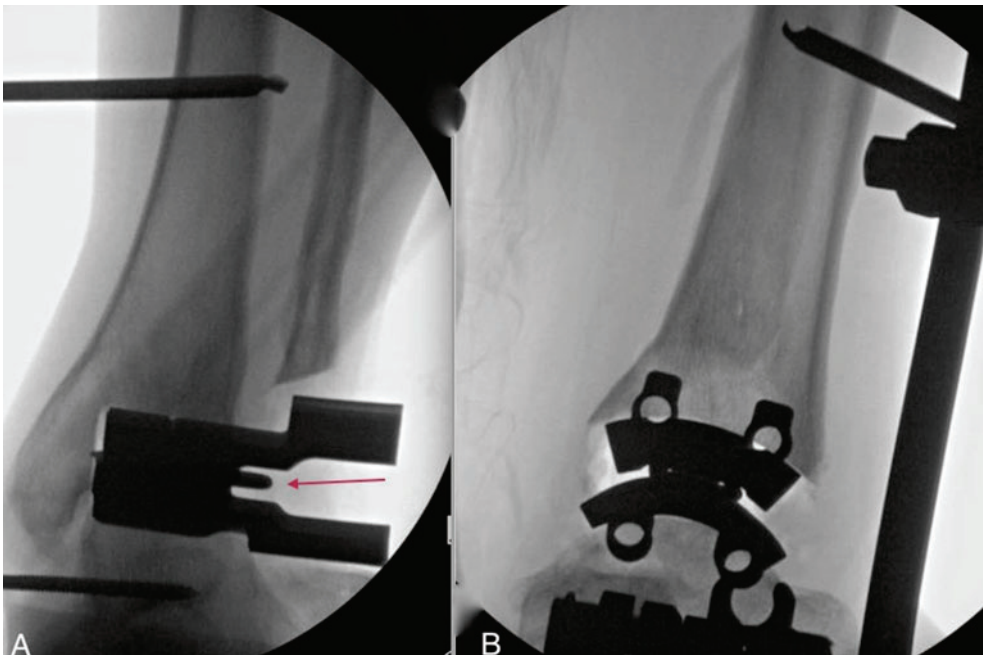

Fig. 12.22 Rail guide. When the rail guide is seated flush within the joint space, the anterior–posterior view shows a notch on the tibial side that should align with the mechanical axis of the tibia (**a**), while the lateral view shows flush placement of the components with minimal to no gapping between the rail guide and the tibia and talus (**b**). When satisfied with the position, the spreader pin, indicated by the red arrow, is inserted

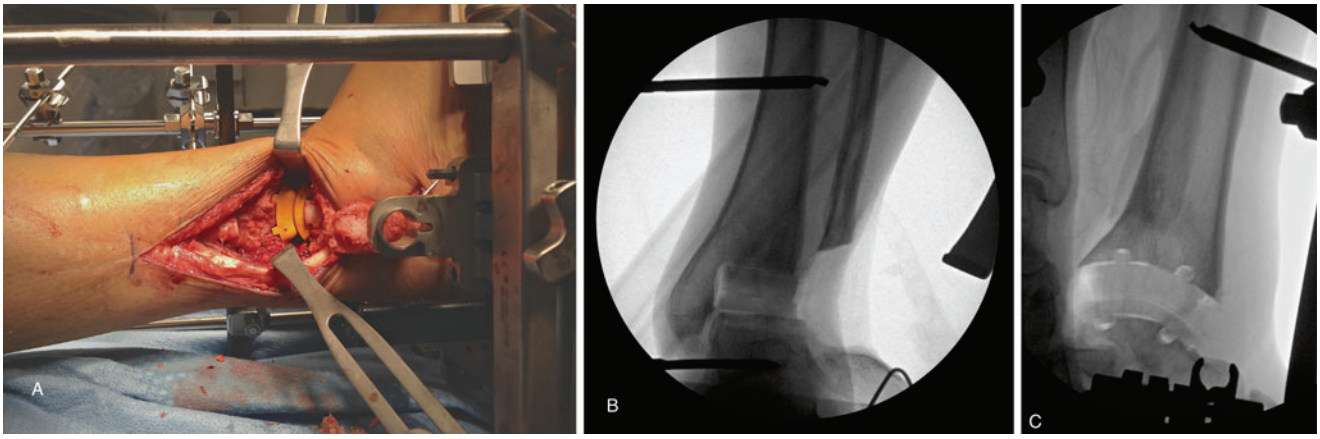

Fig. 12.23 Trial implantation. The tibial and talar trial implants are placed into the prepared joint space (**a**), and implant positioning is confirmed on intraoperative C-arm image intensification both from an anterior view (**b**) and a lateral view (**c**). No medial–lateral or anterior–posterior overhang should be evident and the rails should align with the prepared rail guide holes

seated while the other holes are drilled. Once completed, the K-wires and rail hole drill guides are removed, and the joint is irrigated.

Trial Implantation

The provisional tibial and talar trial implants can be inserted. The trial components should sit flush without overhang in any direction. Alignment of the implant with the rail guide holes should also be confirmed (Fig. 12.23). When the trial implant is seated, the footplate on the alignment guide is temporarily unlocked to assess dorsiflexion and plantar flexion of the ankle joint. The fibula can be unpinned from the calcaneus to ensure lateral impingement does not occur with fibular reduction. Medial gapping and stability through the medial arthrotomy should be evaluated and addressed as needed. If there is a restriction of dorsiflexion motion, without impingement, a tendo-Achilles lengthening or gastrocnemius recession should be considered. Once satisfied with the stability and range of motion of the ankle joint, the footplate is resecured.

Final Component Insertion

With the tibial provision implant in place, the final talar component is seated on the talar inserter in the appropriate orientation and impacted from lateral to medial (Fig. 12.24).

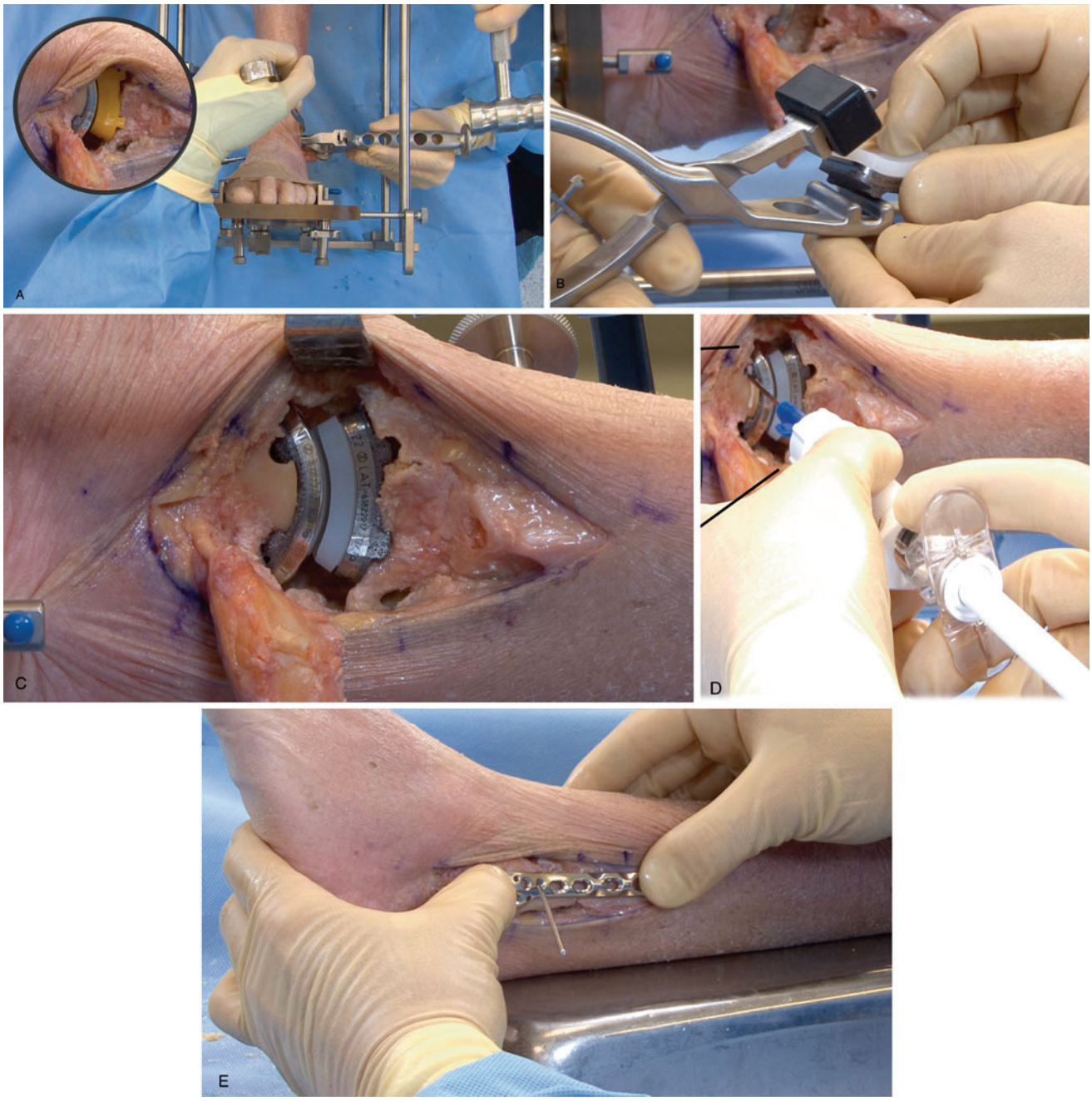

Fig. 12.24 Implant insertion. The talar component is implanted first (**a**). The tibial base and polyethylene components are snapped together (**b**) and inserted into the joint space (**c**). Bone cement is utilized around the rails to secure the implant (**d**). The fibula is reduced and fixated with a neutralization plate (**e**). Images utilized with permission from Zimmer

Be sure to align the rail holes before impaction. Once the component is appropriately seated, the talar inserter is released, completing talar component insertion. The tibial provision implant is removed. The tibial base and polyethylene components are snapped together on the back surgical table in the appropriate orientation and loaded onto the tibial inserter (Fig. 12.24). The tibial component is impacted from lateral to medial, ensuring alignment of the rail holes (Fig. 12.24). Once seated, the tibial inserter is released and C-arm image intensification is utilized to confirm final component position. Polymethylmethacrylate cement is then injected under each of the four implant rails completing implantation (Fig. 12.24).

Closure

Tibial and talar half pins and the transcalcaneal pin are removed, the extremity is freed from the alignment guide, and the guide is passed off the operating table. The temporary stabilizing wire in the fibula is removed from the lateral calcaneal wall, and the fibula is rotated back into position. As necessary to correct for varus or valgus, the fibula can be lengthened or shortened and then stabilized with a lateral fibular plate of the surgeon's choice (Fig. 12.24). Although a fibular locking plate is the most common type of fixation, a fibular "rush-rod" can also be used to stabilize an osteotomy (Fig. 12.12). Syndesmotic fixation can be utilized if the syndesmosis is rendered unstable. The authors have utilized flexible suture fixation for a questionably stable syndesmosis (Fig. 12.25). However, if the fibular osteotomy is made appropriately and does not disrupt the entirety of the distal tibiofibular syndesmosis, this is rarely required. The anterior talofibular ligament is repaired with nonabsorbable suture; if needed a drain is placed, and layered lateral closure is performed.

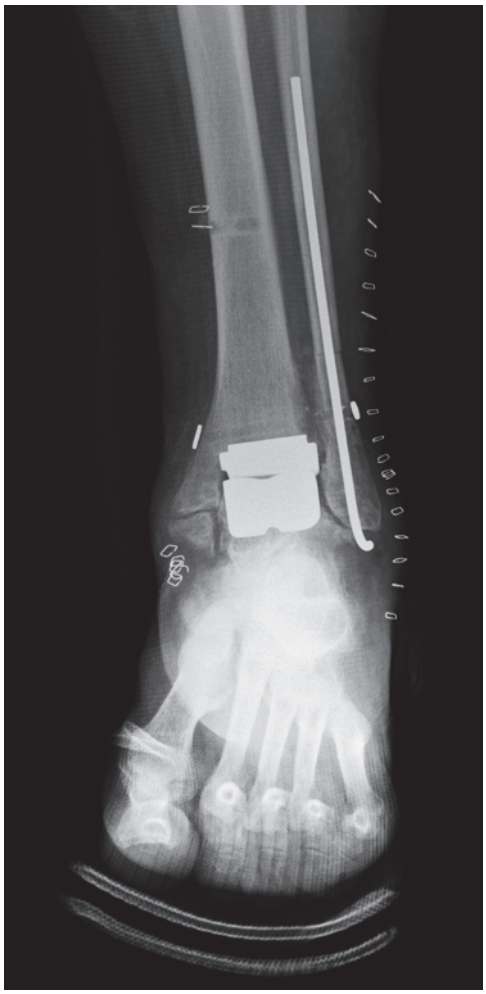

Fig. 12.25 When the syndesmosis is unstable, flexible suture fixation can be utilized

Postoperative Protocol

When TAR is performed without any additional osseous procedures, patients are kept non-weight bearing in a neutral splint for 3 weeks. At which time, the sutures are removed, and weight bearing in a controlled ankle motion device is initiated. Physical therapy is initiated at 3 weeks and continued until the patient is able to weight bear without assistance and navigate stairs safely and has regained full manual muscle strength. When osseous procedures accompany the TAR, the healing of the additional osseous procedure dictates how long the patient will be non-weight bearing. The authors are strong proponents of early weight bearing and range of motion following TAR. Because of this, the authors will often stage concomitant osseous fusions and osteotomies. All soft tissue balancing is done at the time of TAR.

Complications

Revision Patient

As with all TARs, revisions can be challenging with the Zimmer Trabecular Metal TAR. Currently, there is no revision prosthetic specifically designed for the Zimmer Trabecular Metal TAR. In settings where revision TAR is required, an alternate system may be utilized.

In situations where tibio-talo-calcaneal arthrodesis is necessary, the arched bone cuts of the Zimmer prosthetic may provide clinical benefit and technical ease. In patients with minimal bone loss, the arched cuts can be preserved and will mate like puzzle pieces during arthrodesis preparation. Special care must be taken, in the setting of infection, to make sure that the cement spacer does not damage the arched contours (Fig. 12.26). When the ankle is ready for arthrodesis, the surgeon must take care to prepare the tibia and talus to healthy bleeding bone, while following the contour of the arches. Once this occurs, the surgeon may use their fixation of choice, most commonly retrograde intramedullary nailing or plating. Loss of limb length can be reestablished with bone grafting, or in situations where minimal bone was lost, a shoe lift can be incorporated (Fig. 12.26).

Oversizing

Oversizing the prosthetic is a common problem that can cause debilitating pain in the ankle joint. It is imperative for the surgeon to accurately use the medial–lateral sizer and anterior–posterior template to properly size the implant and to confirm sizing with fluoroscopic imaging. An oversized talus can cause friction and pain along the medial gutter.

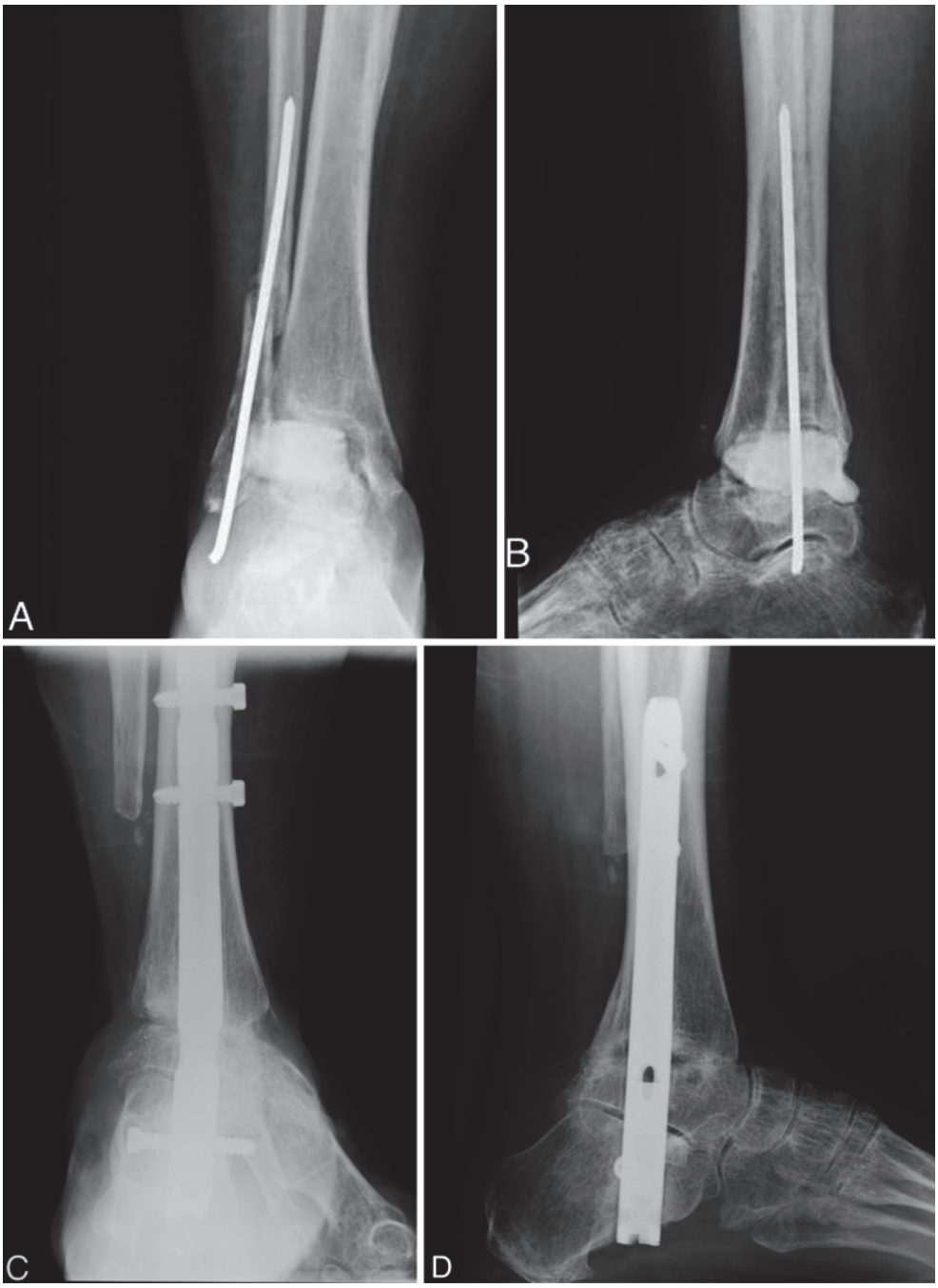

Fig. 12.26 Revision to tibio-talo-calcaneal arthrodesis. In the face of infection, a staged salvage procedure is preferable. An antibiotic-loaded polymethylmethacrylate cement spacer is utilized, with care to match the arched resection of the tibia and talus in both the frontal and sagittal planes (**a**, **b**, respectively). When the infection has resolved, a retrograde intramedullary nail can be utilized with minimal limb length loss as demonstrated on anterior–posterior (**c**) and lateral (**d**) radiographs

This can be evaluated with visual inspection through the medial arthrotomy incision. If there is any question regarding proper sizing, the authors recommend selecting the smaller prosthetic. If a patient presents with an oversized talus postoperatively, arthroscopic debridement of the medial gutter can eliminate some pain and discomfort. In situations where this does not eliminate pain, revision to a smaller prosthetic may be necessary.

Conclusions

Although relatively new, the Zimmer Trabecular Metal TAR system has a novel design that addresses many of the challenges associated with primary TAR. Surgeons should familiarize themselves with the lateral surgical approach and be comfortable performing a fibular osteotomy to gain exposure

to the joint. Surgeons will find that this system's referencing device is accurate and reproducible, and the prosthesis restores normal joint kinematics allowing for comfortable ambulation.

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