18 Alignment/Rebalancing Procedures for Total Ankle Replacement

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Balancing an unstable ankle joint soft tissue and osseous structures is mandatory in order to experience a successful implantation of an ankle joint prothesis. Repair of a pathologic ankle with multiple planes of deformity can be complex and demanding. This could be isolated to bone and or soft tissue or a combination of both. When the talus has extruded anteriorly or tilted into valgus or varus malalignment, this is represented typically with lateral collateral and/or medial deltoid ligament injuries that have been damaged. A single or two staged approach may be elected when the hind foot and or ankle is malaligned into valgus or varus involving the subtalar joint, midtarsal joint or in conjunction with other deformities involving the midfoot and forefoot. In order for an ankle joint prothesis to be implanted and survive long term, the foot and ankle must be balanced and realigned into a neutral position prior to performing the total ankle replacement (TAR). Commonly associated with this complex pathology is a tight posterior muscle group and the surgeon must assess and address this contracture.

The theory behind the survival of TAR is anatomic restoration of the foot and ankle. Reestablishment of ankle alignment and stability is perhaps the most important technical consideration and goal for a successful TAR surgery. The dynamic function of an ankle joint may have an impact of the survival of ankle joint replacement surgery. The literature demonstrates the more anatomic and well aligned ankle with stability will result with greater longevity of the prosthesis [1–3].

Attention to detail and a deep understanding of balancing an unstable foot, ankle and lower extremity when implanting a TAR is essential. The ankle and foot must be balanced and plantigrade with both the static and dynamic phases of gait. Balancing a foot, ankle joint and lower extremity in both a static and dynamic phase will provide anatomic alignment and stability about the ankle joint. Alignment and stability of the ankle joint are not mutually exclusive or independent of one another, rather they coincide tremendously during ankle joint function. The osseous quality and quantity (or lack of) will determine ankle alignment. The stability of an ankle joint is dependent upon the osseous topography and volume (or lack of) as well as the soft tissue quality. The soft tissues provide stability and balance around the ankle joint. This balance is essential for the successful performance and durability of an ankle joint prothesis (Figs. 18.1, 18.2 and 18.3).

Fig. 18.1 An intraoperative ankle view of the patient who sustained a talus fracture as well as a significant distal tibial fracture. This fluoroscopy view demonstrates the remaining hardware prior to removal of this hardware. Note the loss of the medial malleolus from the index trauma which leads to instability of the ankle joint

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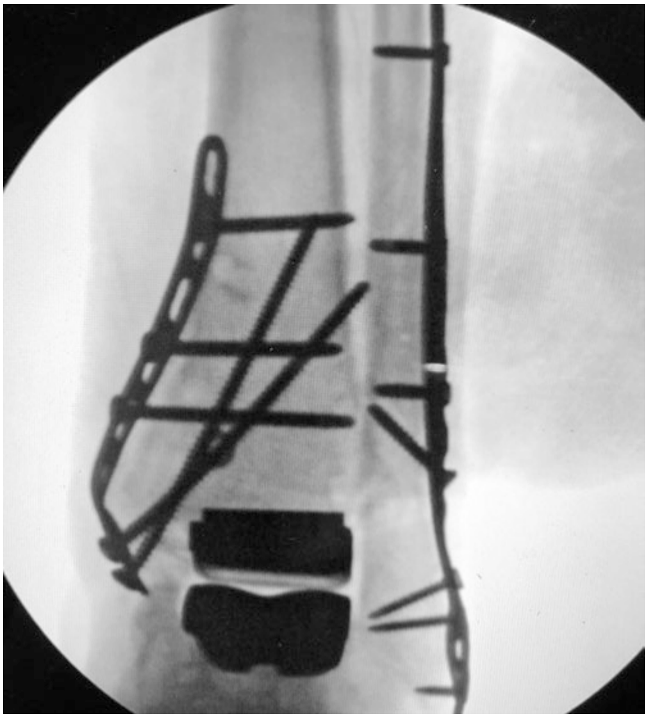

Fig. 18.2 An intraoperative ankle view demonstrating medial support and bone grafting to the remaining medial malleolus providing structural support and stability to the ankle joint prothesis

Fig. 18.3 A postoperative ankle view demonstrating medial support and well consolidated bone graft of the "built up" medial aspect of the ankle joint providing structural support and stability to the ankle joint prothesis

Alignment

Alignment is instrumental for success and long-term survival of TAR. The supramalleolar and inframalleolar deformities must be identified and addressed. This is both a clinical and radiographically analogy the surgeon must address. The ankle, foot and hindfoot alignment views allow visualization of the foot, ankle and hindfoot position relative to the tibia.

Bone quantity and quality are needed for the success of an ankle joint prosthesis especially for those patients who suffer from a previous history of trauma or patient with advanced comorbidities such as rheumatoid arthritis. TAR failures have been hampered by loosening and subsidence due to poor bone quality resulting in the malalignment and subsidence. The bone quality must be sufficient to hold, support and bond to the ankle joint prosthesis. The loss of cubic volume of bone from trauma may cause instability. If there is a loss of cubic volume of bone, the ankle will tend to become unstable and/or malaligned. The more bone present lends to stability, therefore shortening should be avoided. Following removal of bone beyond the subchondral plate in the ankle joint, compressive resistance may be found to be reduced. Removing bone near the subchondral plate may provide a reduction with bone quality and compressive resistance, thus putting the ankle prosthesis at risk for subsidence. In general, to avoid subsidence, one should perform minimal bone resection to preserve the sturdier subchondral bone. One of the benefits of utilizing the Zimmer Biomet™ Ankle Replacement System is the curvature resection on both the tibial and talar sides mimic natural anatomy. This resection yields less bone on the tibial and talar side, thus the shallow resection of bone, leaves the ankle joint with more structurally sound bone to hold the prothesis. Additionally the curvature prosthesis will provide more bone-implant interface and is more suggested of the natural anatomy of an ankle joint. This is helpful with the surgical outcome and may be useful should revision become needed or if a conversion to an arthrodesis is necessary.

Biomechanics and Stability

The biomechanics of an ankle presents a unique set of challenges for ankle joint arthroplasty surgeon. The biomechanics are not easily understood and can be challenging. In a normal ankle joint and relative normal congruency, the axis of rotation does not stay constant during range of motion. Therefore, accomplishing this in a pathologic ankle joint makes this a challenge for the foot and ankle surgeon. Permitting for rotational forces, while maintaining stability of the joint, is also demanding and challenging. Success of the prothesis depends on how successful the surgeon understands and creates an environment for the ankle joint prosthesis. It is extremely important that the ankle joint maintains stability and alignment. It is consequential from the biomechanical standpoint that the ankle joint prosthesis mimics the alignment and stability of a normal ankle joint as much as possible. The forces exuded on the bony and soft tissue structures should be as close to normal as possible. Careful assessment of the entire lower extremity for balance and stability is required. End stage osteoarthritis of the foot and ankle can lead to erosion of the articular surfaces, consequentially changing the architecture and the dynamics of the ankle joint. Diseased articular surfaces can affect the gait drastically and affect the relationship between osseous, muscles, tendons and ligaments which in turn causes pain, breakdown, instability and eventual disability of the ankle joint.

The stability of the ankle joint depends upon the joint's osseous and ligamentous structures [4–8].

Congruity of the articular surface of an ankle joint creates a stable articulation. The soft tissue structures along with well-maintained articular structures are the main stabilizers of a nonpathologic ankle. These structures are the major inversion and eversion stabilizer along with the collateral ligaments [5, 7, 9, 10].

Ankle ligaments have a stabilizing effect on the ankle joint. Studies have shown that the deep deltoid ligament is resistive against lateral and anterior talar excursion, whereas the anterior talofibular ligament is the restraint against anterior talar excursion [4, 10, 11]. The anterior talofibular ligament is the ligament that is most commonly injured and subsequent insufficiency/instability often lead to anterolateral subluxation/dislocation of the talus from the mortise [12, 13]. An ankle joint prosthesis should be as anatomic as possible to mimic physiological joint motion and assist in ensuring proper bony and soft tissue balancing.

Soft Tissue Balancing

Proper osseous and soft tissue balancing of the prosthetic ankle is an integral component in attaining and maintaining functional alignment and stability of an ankle joint prothesis [14–19]. Correcting osseous malalignment and addressing soft tissue imbalances of the foot, ankle and lower leg during primary or revision ankle joint prothesis procedure provides a functional balance. Failure to address these features properly may lead to edge loading with asymmetric forces that can affect the wear of the polyethylene spacer, and indirectly the prosthesis bone interface, causing a breakdown. The development of edge loading may increase the risk of prosthetic component complication and ultimately failure [14–19].

The foot and ankle surgeon must assess the ankle joint balance preoperatively. Intraoperatively the foot and ankle surgeon must stress the ankle joint and use an assortment of instruments such as laminar spreaders and multiple trial sizes and placement of components to appropriately tension the ankle joint [20]. Symmetrical soft tissue balancing during TAR is an important step in optimizing the mechanical balance of an ankle joint. A soft tissue contracture that results with frontal plane deformities can pose a difficult problem. Soft tissue balancing, in the frontal plane, is critical for long-term success and patient satisfaction. Correction with a frontal plane imbalance, including malalignment or instability, has traditionally involved a sequence of procedures that complement one another or work in combination. The general theory of soft tissue balancing involves the release or loosening of the contracted soft tissue on the concave side and plication or tightening on the convex side of the ankle [14–19]. Techniques for balancing the varus ankle during TAR include, but are not limited to posterior muscle lengthening procedures (gastrocnemius lengthening vs. Achilles tendon lengthening), osteophyte resection, medial deltoid release/peal, soft tissue releases (posterior tibial recession), soft tissue tightening, tendon transfers, osteotomies and arthrodesis procedures. Techniques for balancing the valgus ankle during TAR may include, but are not limited to posterior muscle lengthening procedures, calcaneal osteotomies, hind foot arthrodesis procedures, midfoot osteotomies, stabilization of the midfoot or forefoot and tendon transfers. Based on the extent of the pathology and the extent of the disease process coupled with the patients history, these can be done in a single stage or in two staged surgical reconstruction (Figs. 18.4, 18.5, 18.6, 18.7, 18.8, 18.9 and 18.10).

Correction of a Varus Imbalance

Varus imbalance correction during primary and revision TAR involves a posterior muscle lengthening procedures, release of medial soft tissues including osteophyte resection, medial deltoid peal, soft tissue releases (posterior tibial recession), reinforcement of the lateral procedures such as tendon transfers, osteotomies and arthrodesis procedures. This may include the removal of periarticular osteophytes and debridement of the medial and lateral gutters. Release of the deltoid ligament from the medial malleolus and/or possible lengthening osteotomy of the medial malleolus. Recession of the posterior tibial tendon, correction of pedal deformities with a dorsiflexory first metatarsal osteotomy/tarsal metatarsal arthrodesis or calcaneal osteotomy slide laterally and lateral ankle ligamentous stabilization with or without tendon transfer to reinforce lateral soft tissue

Fig. 18.4 A patient on the operating table prior to the surgery. The ankle is in significant valgus with a severe flatfoot deformity (peritalar subluxation)

Fig. 18.5 Intraoperative stress view demonstrating medial deltoid insufficiency of the right ankle

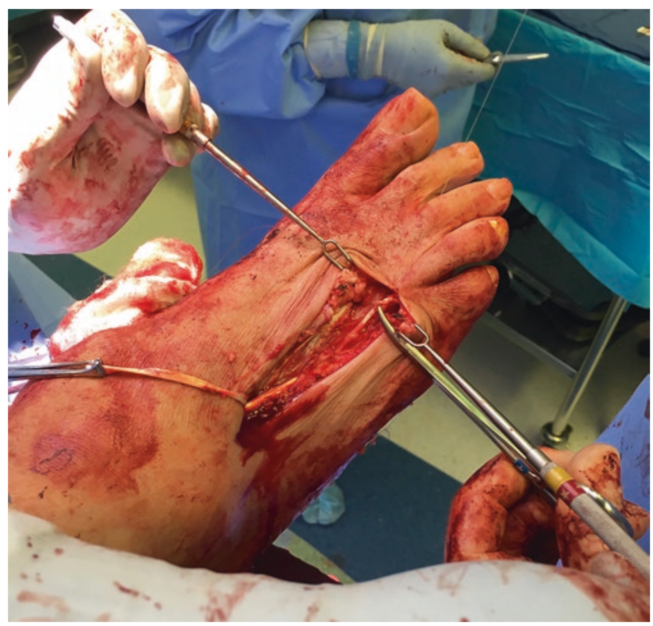

Fig. 18.6 Intraoperative view demonstrating a harvest of the proximal EDL 4th tendon. The EDL 4th tendon will be used to recreate/reconstruct the medial deltoid ligament. A tendon transfer of the proximal EDB tendon into the proximal stump of the EDL distal tendon to the toe to assist with function and dorsiflexion of the 4th toe

restraint [14–23]. Associated with a contracted varus ankle/foot, often the flexor retinaculum can tether the rearfoot while in varus. In these instances, the surgeon should perform a flexor retinaculum release/tarsal tunnel release in order to provide a soft tissue release of the concave side of the varus deformity. This will decrease the stress to the neurovascular structures as straightening the hind foot and ankle will lead to increased stress on the medial structures [20]. In the case of a lateral ankle instability, one may perform a lateral ankle stabilization procedure.

Correction of a Valgus Imbalance

Medial deltoid insufficiency is one of the most difficult procedures to obtain a reproducible result with predictability. Valgus imbalance correction may involve release of lateral tissues and reinforcement of medial tissues. This may include removal of periarticular osteophytes and debridement of the ankle joint gutters, complete release of the lateral ligament complex from the lateral malleolus and/or lengthening osteotomy of the lateral malleolus, correction of pedal deformities with medializing calcaneal osteotomy or medial column fusion, isolated or combined midfoot/hindfoot arthrodesis, forefoot procedures and deltoid ligament plication and/or tendon transfer to reinforce medial soft tissue restraints [15–21, 24–26].

Fig. 18.7 A intraoperative view following the harvest of the EDL 4th tendon in order to recreate a medial deltoid ligament to provide stability

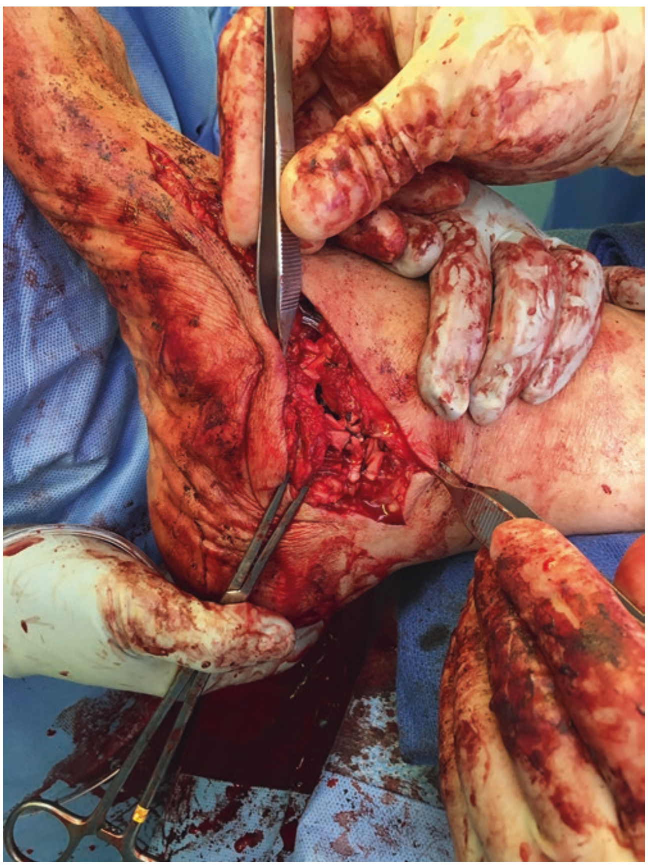

Fig. 18.8 A intraoperative view of the EDL 4th tendon utilized to enhance the medial deltoid ligament

For patients in where the remaining deltoid ligamentous structures are insufficient to provide for medial ankle stability, one may perform a tendon transfer. Once the osseous structures are balanced and the foot is positioned well under the leg, one can harvest the fourth extensor digitorum longus (EDL) which should yield approximately 8–9 cm of tendon graft. This EDL tendon graft can be utilized to recreate the medial deltoid ligament to create soft tissue stabilization to a foot and ankle that is structurally balanced. The proximal extensor digitorum brevis is then transferred into the distal

Fig. 18.9 An intraoperative lateral fluoroscopy views demonstrating a well-balanced foot and ankle following a staged reconstruction with a Zimmer Biomet™ Ankle that appears well positioned

Fig. 18.10 An intraoperative AP fluoroscopy views demonstrating a well-balanced foot and ankle following a staged reconstruction with the Zimmer Biomet™ Ankle that appears well positioned

stump of the EDL stump to the fourth toe for continued dorsiflexion of this digit. The EDL fourth tendon harvest is then inserted into the distal tibia, talus and calcaneus, respectively, to recreate the deltoid ligament (Figs. 18.11, 18.12 and 18.13).

Fig. 18.11 A lateral foot radiograph demonstrating a pes planus with midfoot arthritis and tarsal metatarsal-1 (TMT-1) instability along with osteoarthritis of the ankle joint

Fig. 18.12 A preoperative AP ankle radiograph demonstrating an unbalanced valgus foot and ankle

Osteotomy of the Tibia and Fibula

For deformity above the ankle joint a biplanar opening or closing wedge or a dome shaped osteotomy may correct multiplanar deformity. The osteotomy can be combined with an ankle replacement. The osteotomy is made in the metaphysis, leaving sufficient bone distally for fixation. If the fibula requires an osteotomy, it can be performed at the same level laterally, or obliquely more proximally. The ankle is then manipulated, rotated, translated or angulated in any or all planes until the desired correction is obtained. This osteotomy is particularly useful to correct deformity when the CORA is further away from the ankle joint.

In general, a closing wedge osteotomy is more kinder and predictable in comparison to an opening wedge osteotomy. Typically the medial closing wedge osteotomy heals well and is more predictable as no bone grafting is needed (Figs. 18.14, 18.15, 18.16, 18.17, 18.18, 18.19 and 18.20).

Staging

When adjacent soft tissue balancing, osteotomies or arthrodesis are needed, the surgeon needs to determine if this can be done in one surgery or should it be staged for two separate surgeries. The surgeon needs to consider the stress to the local soft tissues, bone, and take the patient comorbidities into consideration. Additionally the surgeon needs to assess the approximate amount of time the procedures may take and how much stress the patient's limb can handle as well as the surgeon's ability to manage the volume of procedures in one stage vs. two stages. Each patient is different given the circumstances and this also must be taken into consideration. Determining factors consist of how many other procedures are needed to balance the foot, ankle or leg, where the incision locations for the additional procedure are in relation to the TAR procedure. The fixation involved also needs to be kept in mind relative to how this may or may not impact the TAR surgery.

Conclusion

As total ankle prostheses continue to evolve demonstrating increasing longevity because the designs are better but equally important is the knowledge and understanding of balancing the foot, ankle and/or leg. The success of TAR depends largely on many factors including surgeon experience, appropriate patient selection and how balanced the

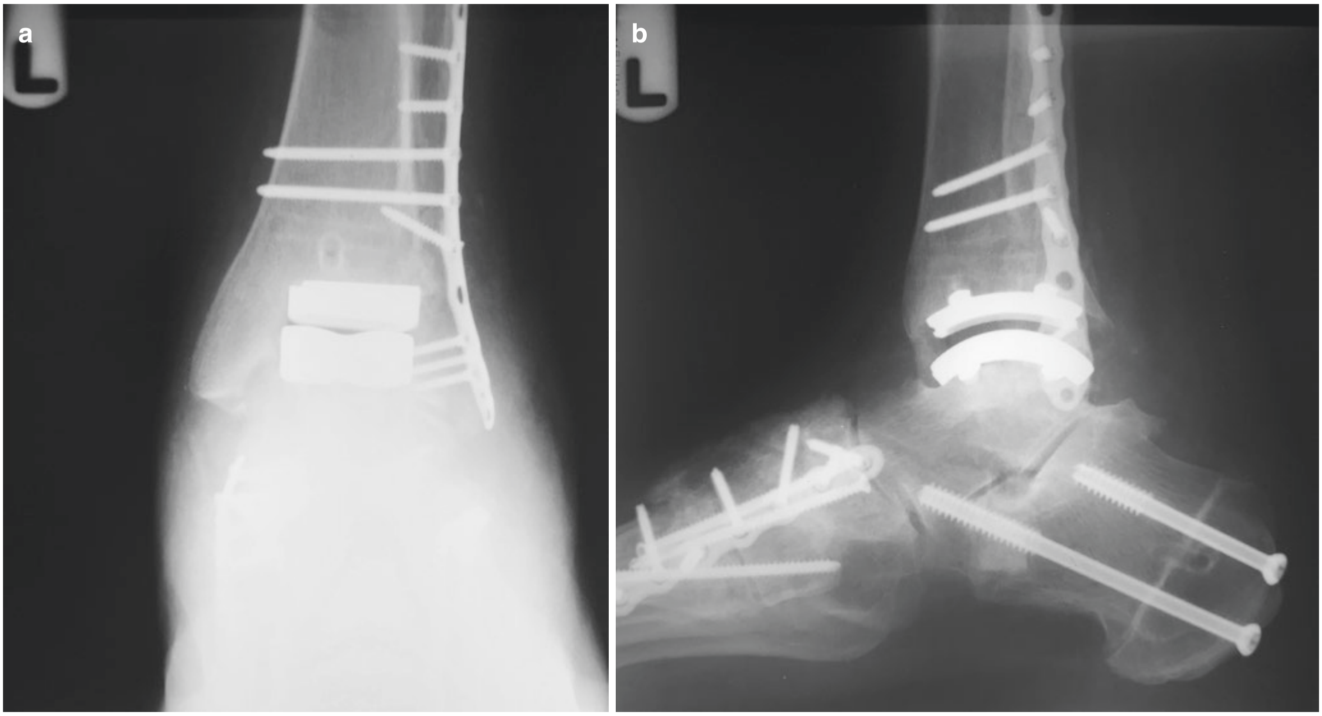

Fig. 18.13 A postoperative AP (**a**) and lateral (**b**) radiograph following insertion of a Zimmer Biomet prosthesis. This was a planned staged reconstruction. The initial surgery consisted of an endoscopic gastrocnemius recession, a double calcaneal osteotomy, a midfoot fusion and a TMT-1 arthrodesis. This balanced the valgus and foot and ankle and subsequently a Zimmer Biomet ™ Ankle joint prosthesis was implanted. The patient was a larger man who was a diabetic without peripheral neuropathy, therefore a syndesmotic fusion was performed for additional stability

Fig. 18.14 Intraoperative stress view demonstrating a patient who suffer from post-traumatic osteoarthritis with an unstable ankle valgus and secondary distal lateral osteonecrosis of the vital lateral tibia. The fibula is shortened and externally rotated with an insufficient syndesmotic ligament as well as an insufficient medial deltoid ligament

Fig. 18.15 An intraoperative view of performing an open tibial osteotomy in order to get the ankle joint realigned more anatomically and to appropriately support the ankle joint prothesis. Additionally the fibula was cut, internally rotated and brought out to length along coupled with a syndesmosis fusion. The medial deltoid ligament was repaired (soft tissue). This was a planned, staged approach surgery in order to balance the ankle to appropriately insert and support the ankle joint prosthesis

Fig. 18.16 An intraoperative view following an open tibial osteotomy to realign the ankle more anatomically. Additionally the fibula was cut, internally rotated and brought out to length along coupled with a syndesmosis fusion. The medial deltoid ligament was repaired (soft tissue). This was a planned, staged approach to balance the ankle prior to insertion of the ankle joint prosthesis

Fig. 18.17 A staged approach was performed. Following confirmation of adequate incorporation of the inserted bone graft within the tibial osteotomy and confirmation or the syndesmotic fusion, an intraoperative ankle view, following a fibular osteotomy and insertion of the trial prosthesis

Fig. 18.18 An intraoperative ankle view demonstrating the insertion of the ankle joint prosthesis along with fibula osteotomy fixated well. This was a planned, staged reconstruction demonstrating a. was fixated a healed supramalleolar osteotomy and medial deltoid ligament repair. This ankle is now balanced ankle to hold the ankle joint prosthesis

Fig. 18.19 A 4-year postoperative lateral radiograph demonstrating a well-balanced ankle with the Zimmer Biomet ankle joint prothesis following multiple planned stage reconstructive procedures

extremity is to near normal biomechanics of the ankle joint. A comprehensive evaluation including clinical, radiographic and advanced imaging assessment is extremely important as a reference for proper procedural selection in addition to the TAR. Awareness of the imbalances about the ankle and how to address them is mandatory in order to provide the most successful best long-term outcome possible.

Fig. 18.20 A postoperative ankle radiograph 8 years postoperatively demonstrating good consolidation of the tibial and fibula syndesmosis fusion as well as a balanced ankle (both osseous and soft tissue) with the Zimmer Biomet ankle joint prothesis

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