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Getting the Hindfoot Alignment and Starting Point Correct: A Technique Tip for Accurate Placement of Hindfoot Fusion Nails

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Introduction

Tibiotalar-calcaneal (TTC) arthrodesis offers a solution for patients with joint destruction or malalignment resulting from various pathologies including posttraumatic arthritis, avascular necrosis, neuropathic arthropathy, neuromuscular disorders, nonunion, and failed ankle arthroplasty.[3-5] The use of an intramedullary nail may provide superior mechanical stability compared to other constructs while reducing soft tissue complications in select patients with literature demonstrating good union rates and improved patient outcomes.[1,2,4]

Deformity correction and optimizing hindfoot alignment is a critical step in TTC arthrodesis and should always precede instrumentation. The hindfoot has inherent anatomic considerations that can make proper guidewire placement challenging. Mainly, the coronal axis of the calcaneus aligns lateral to the tibial mechanical axis. Hyer and Cheney[3] demonstrated in a cadaveric model that a wire placed anterograde through the tibial canal in line with its mechanical axis can miss the calcaneal body medially. Advanced 3D imaging modalities and computer-assisted techniques have better elucidated anatomic variation and ideal individualized starting points. Utilizing segmented 3D TTC weightbearing CT models, research performed by our group (publication pending) further corroborates that the inferior exit point falls medial along the sustentaculum tali (Figure 1).

As such, placement of a hindfoot nail has a narrow anatomic window as it relates to the starting point, given that most currently available are straight. Although ease of nail insertion can be increased by varus positioning of the hindfoot, this is not desirable in achieving optimal alignment and function. McGarvey et al,[5] in a cadaveric study, proposed a medial malleolus resection and medial translation of the foot. Although this technique may improve bony contact at the tibiotalar joint and decrease risk of neurovascular injury during nail insertion, it can negatively alter the mechanical and anatomic axis of the lower extremity.

True to the anatomy and functional position of the foot, optimizing coronal hindfoot alignment to neutral or slight valgus may result in some loss of collinearity between the calcaneal body and the mechanical axis of the tibia. This

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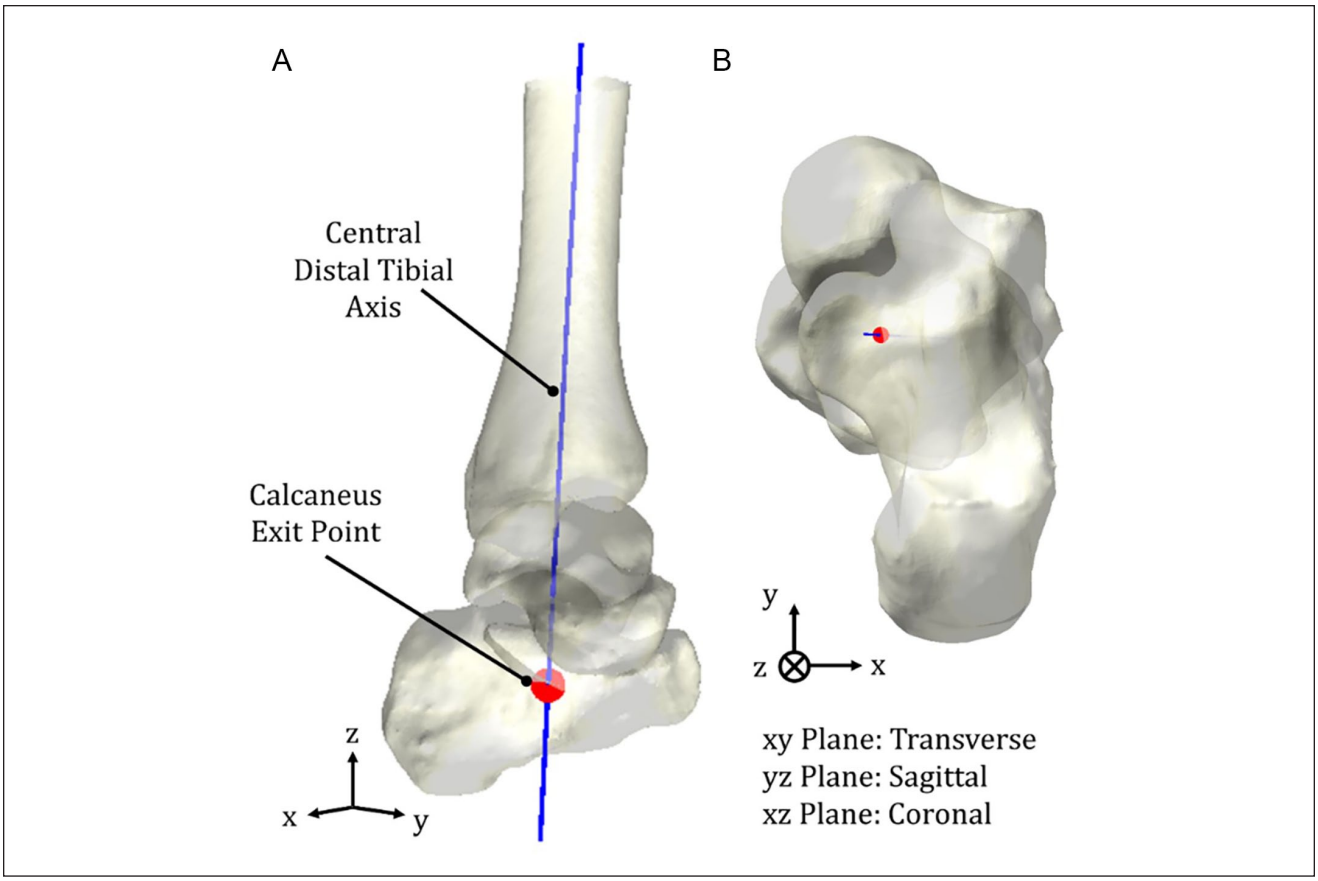

Figure 1. Using computer-assisted techniques for preoperative planning of tibiotalar-calcaneal (TTC) arthrodesis. (A) Sagittal view showing the algorithm-calculated central distal tibial axis (blue line) used to determine optimal nail insertion location and trajectory. The calcaneal exit point (red dot) is also calculated by the software (MATLAB, v R2022b, MathWorks, Natick, MA). (B) Transverse inferior view visualizing the nonoptimal exit point on the sustentaculum tali when the distal tibial axis is extended.

exacerbates the challenge of a narrow anatomic window for straight TTC nail insertion. Furthermore, it introduces the risk of breaching the medial calcaneal wall and injury to neurovascular structures. To maintain anatomic hindfoot valgus alignment when performing TTC arthrodesis, precise guidewire placement is crucial. Additionally, guidewire placement is often challenging because of difficulties in fluoroscopic visualization of the osseous anatomy of the hindfoot.

Despite the importance of precise guidewire placement for nail insertion, there is a relative lack of literature to assist surgeons.[7] Furthermore, with indications expanding to the primary management of pilon/ankle fractures in select patients, it is crucial this scarcity in technique be addressed.[6,8] Thorough preoperative planning and careful surgical technique remain imperative to achieve accurate placement and maximize the benefits of TTC nailing.

The purpose of this work is to aid surgeons with precise guidewire placement after appropriate hindfoot alignment has been attained for the placement of straight hindfoot intramedullary nails.

Technique

Although multiple factors can influence positioning and approach, the following description details TTC arthrodesis in the supine position. A fibulectomy through a direct lateral incision is performed to allow access to the ankle and subtalar joints although fibula-sparing approaches can be used. After adequate joint preparation, the hindfoot is placed in neutral dorsiflexion with appropriate rotation and valgus positioning. Optimal hindfoot position and alignment is essential prior to TTC nail insertion.

Sagittal Plane Realignment

Sagittal plane realignment should aim for a plantigrade position of the foot relative to the mechanical axis of the

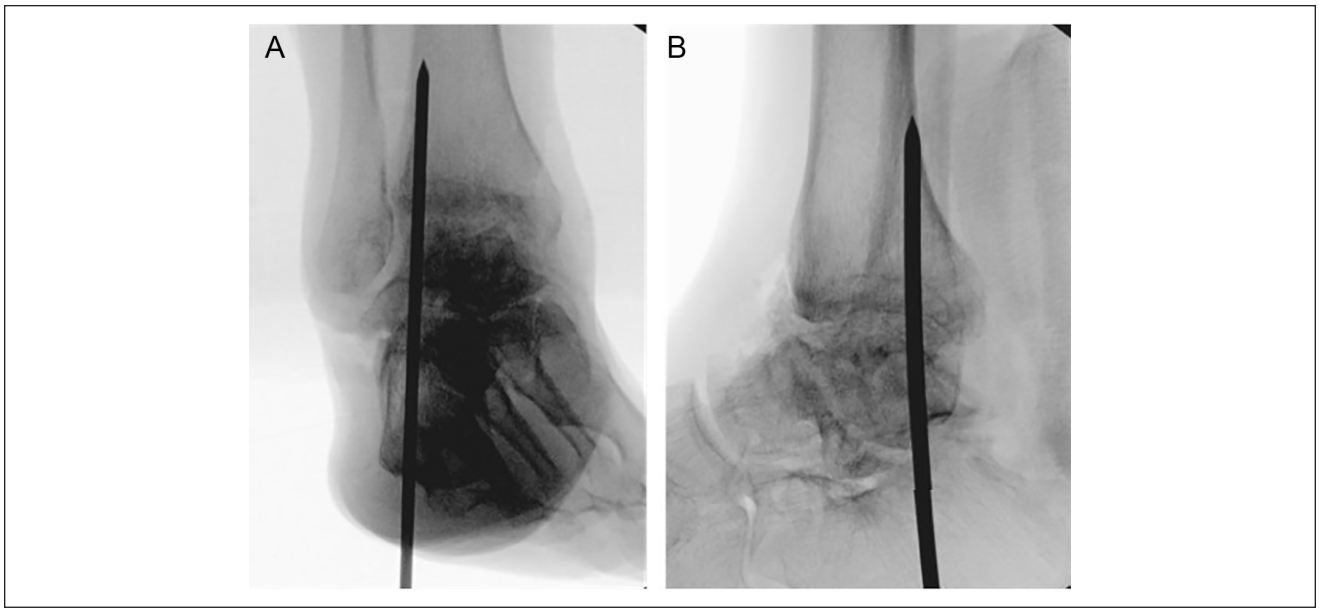

Figure 2. Intraoperative fluoroscopic (A) anteroposterior and (B) lateral images showing provisional Kirschner wire placement for maintaining reduction.

tibia. Although neutral foot alignment is the goal, equinus malpositioning is more poorly tolerated than a slight calcaneal position. It is the authors' preference to achieve a neutral hindfoot alignment with approximately 15 to 20 degrees of dorsiflexion past this position through the transverse tarsal joints for the planned position of fusion. After provisional Kirschner wire stabilization of the hindfoot, we assess this clinically by applying dorsiflexion force through the fore/midfoot and visually inspect the angle subtended by the lateral border of the foot and lower leg. Surgical techniques required to achieve appropriate sagittal plane alignment vary depending on the patient's underlying pathology and may require a combination of both soft-tissue and osseous procedures. For example, percutaneous tendo-Achilles lengthening or removal of any impinging anterior ankle osteophytes further improve sagittal alignment to attain neutral dorsiflexion.

Coronal Plane Realignment

Irrespective of indications and preexisting deformity, correction of coronal hindfoot alignment remains a critical step in TTC arthrodesis. This can be achieved through numerous techniques and with lesser deformities can typically be achieved through soft tissue procedures alone. For example, lateral ankle ligament release and peroneal tendon lengthening may aid in correction of hindfoot valgus. Deltoid ligament release and posterior tibial tendon lengthening may be required for equino-varus deformities.

More significant deformities often require concomitant osseous procedures. Although various options exist, they are largely dictated by whether the deformity exists at the tibiotalar joint, subtalar joint, or both. For example, modified subtalar joint preparation (increased joint leveling medially or laterally) with release of the cervical and interosseous talocalcaneal ligaments may facilitate correction through the subtalar joint. Larger deformities often require correction through the tibiotalar joint and include differential leveling of the tibial plafond (ie, intraarticular osteotomy) or even shortening.

Nail Insertion

To hold reduction, a provisional large Kirschner wire is inserted starting in the posterior half of the calcaneus and into the tibia. On the anterior-posterior (AP) image, the wire should be positioned laterally so as not to obstruct subsequent placement of the guidewire and/or further instrumentation. Positioning of the provisional Kirschner wire is confirmed with lateral and AP imaging (Figure 2).

Three fluoroscopic views (sagittal, coronal, and axial) are then used in sequence to ensure accurate placement of the guidewire.

Sagittal View

The guidewire should be inserted with the C-arm in the lateral position. Specific distances from calcaneal or joint

Figure 3. Guidewire placement in a cavus foot. The increased calcaneal pitch necessitates a more posterior starting point (red arrow) to achieve an appropriate sagittal trajectory in line with the tibia axis.

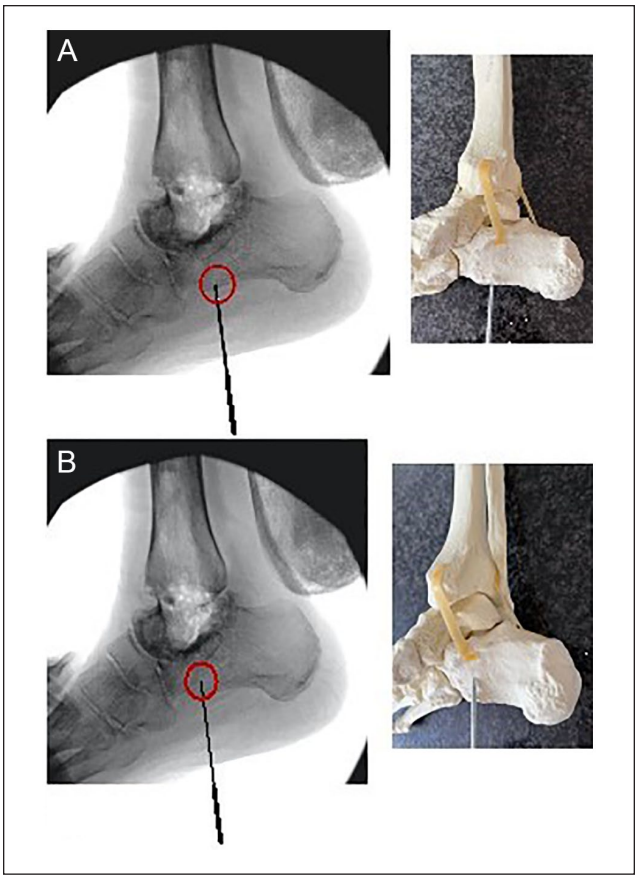

Figure 4. Lateral radiographic view with corresponding clinical illustration demonstrating (A) optimal start point and (B) a medialized start point along the plantar surface of the calcaneus toward the sustentaculum and neurovascular structures.

landmarks are not used to determine the starting point given that preexisting foot deformities may affect this determination (ie, a cavus foot results in a more posterior start point because of increased calcaneal pitch (Figure 3). Placement of the guidewire on the calcaneus is simply dictated by matching the coronal tibial intramedullary anatomic axis. It is crucial to ensure the tip of the guidewire directly abuts the plantar calcaneal cortex. As the guidewire has not yet been inserted, apparent overlap of the wire with the calcaneal body seen on imaging represents an inappropriately medialized starting point along the medial calcaneal cortex (Figure 4). Although theoretically a medial start point allows for easier nail insertion and is collinear with the mechanical axis of the tibia, it puts the neurovascular structures at risk for injury and compromises the distal stability/fixation of the nail with it not centered within the calcaneal body (Figure 5). Next, the wire is inserted under fluoroscopy with the C-arm still in the lateral position. Advance the guidewire to the level of the distal tibia as the radiographic densities of the foot make it challenging to discern wire position and trajectory on the subsequent AP image.

Coronal View

We then reposition the C-arm to obtain an AP image, and adjustments to the guidewire in the coronal plane are either performed using the same wire (while maintaining sagittal plane alignment) or an additional wire referencing off the first guidewire (Figure 6). If the same wire is used, it is critical to not remove the wire entirely from its initial starting point as this would necessitate reverification using the lateral view. If an additional wire is used and placed medial to the initial guidewire, its position on the plantar cortex should be verified with the C-arm in the lateral positioning before insertion.

Saltzman View

Once the wire appears to be in appropriate coronal and sagittal plane alignment, we then reposition the C-arm to obtain a Saltzman hindfoot view. This axial view is used as final

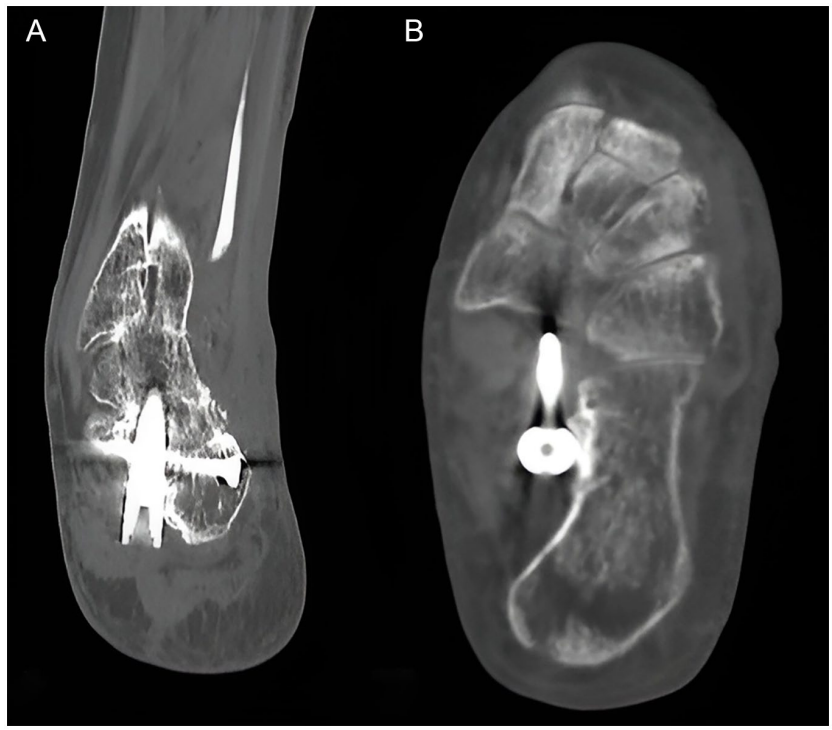

Figure 5. (A) Coronal and (B) axial computed tomography demonstrating nail placement through sustentaculum tali as a result of a medialized start point.

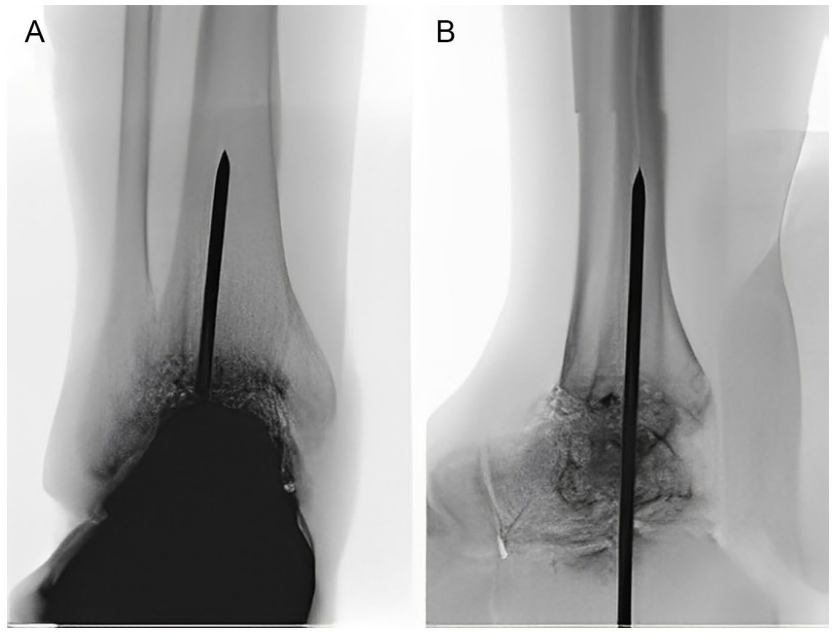

Figure 6. Adjustments and confirmation of optimal wire position made on anteroposterior (AP) and lateral views. (A) AP view confirming central placement in line with the tibial axis. (B) Lateral view verifies appropriate placement within the tibia.

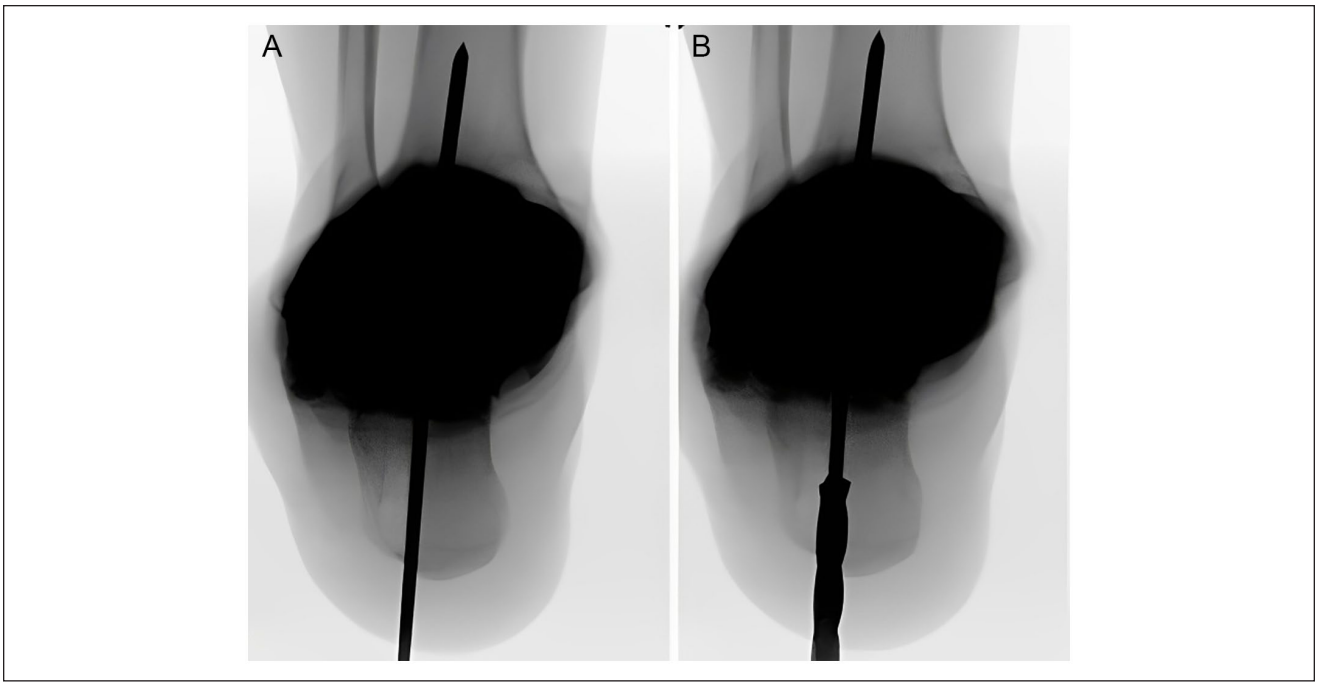

Figure 7. Hindfoot alignment view of the hindfoot showing (A) central placement on entry of the wire through the tibia and (B) confirmation that wire entry is central along the plantar calcaneus by sliding the entry reamer to abut the cortex.

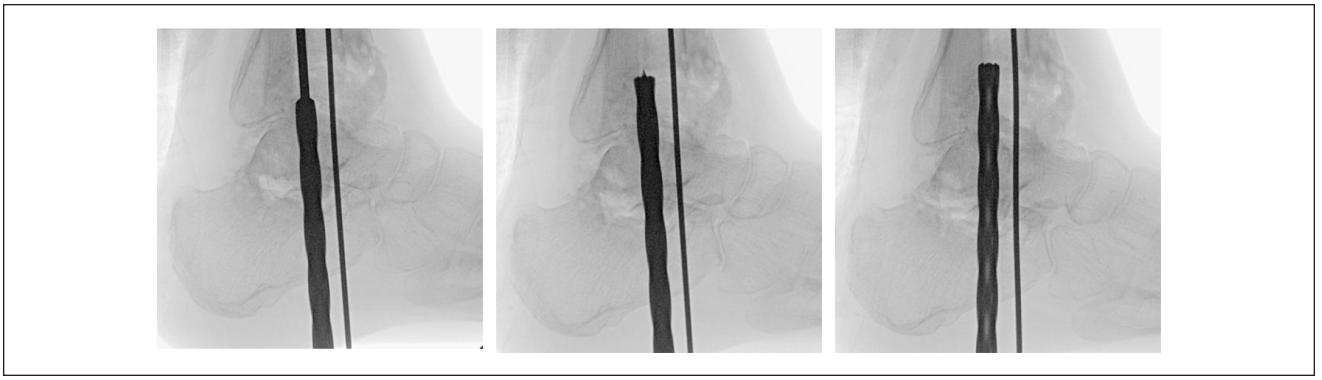

Figure 8. Sagittal view illustrating use of the entry reamer as a lever to finetune the entry and eventual nail position within the tibia.

confirmation that the entry point is central within the body and not along the medial or lateral face of the calcaneus. The most reliable and accurate view is one in which the tibial mechanical axis is perpendicular to the floor. Under- or overrotation of the foot for this view may affect one's ability to accurately confirm a central start point. Next, slide the entry reamer by hand over the wire until it abuts the plantar calcaneal cortex. This maneuver is required to visualize the exact entry point of the guidewire into the calcaneus, which is represented by the position of the reamer. Without the use of this technique, it is impossible to determine the true starting point on the axial view (Figure 7). A starting point that is too medial or lateral can be easily identified using this technique. A start point that is too medial despite a well-positioned guidewire on coronal and sagittal views may be corrected by inserting a new guidewire starting 1 to 2 mm lateral to the existing wire along the plantar calcaneus cortex mimicking its trajectory. In the event of achieving the optimal start point but a suboptimal wire trajectory in the tibia (in either the coronal or the sagittal plane) the senior author's alternative tip is to withdraw the guidewire to the level of the talar dome and use the entry reamer as a lever to slightly correct the entry/position in the tibia (Figure 8). The goal of this is to match the mechanical

Figure 9. (A) Coronal and (B) axial views depicting optimal nail placement within the tibia, talus, and calcaneus using the described technique.

axis of the tibia with the reamer. Nail instrumentation should proceed only after careful verification of the guidewire start point and trajectory (Figure 9).

Residual Deformity Before Nail Insertion

Despite attempts at restoring normal anatomic alignment, the hindfoot may be left with slight residual varus or valgus positioning before implant placement. Although clinically and functionally acceptable, considerations apply to nail insertion and in particular the starting point. Slight varus deformity in fact leads to easier nail insertion given medialization of the calcaneus and increased plantar surface area. Furthermore, the nail is easier aligned with the anatomic axis of the tibia. Slight valgus alignment introduces increased technical challenges especially when using a straight nail without a distal valgus nail configuration. It is our preferred technique to maintain the same plantar starting point as described above and recognize that insertion of the guidewire and eventual implant will require a slight lateralization at the distal tibial plafond with possible valgus angulation of the nail as it relates to the anatomic axis of the tibia (Figure 10). If on inserting the guidewire there appears to be too much valgus angulation (between the wire and the tibial shaft), we recommend attempting to obtain better hindfoot alignment because of the risks of (1) creating a

Figure 10. Valgus angulation of tibiotalar-calcaneal nail in relation to the tibia anatomic axis.

stress riser at the proximal aspect of the implant, (2) iatrogenic tibial shaft fracture intraoperatively, or (3) induced varus foot malalignment as the valgus nail conforms to the intramedullary canal on insertion.

Conclusion

The current literature provides generalized guidance but lacks definitive recommendations for optimal hindfoot nail placement in TTC arthrodesis. By incorporating anatomic pearls, tips on optimizing hindfoot alignment, provisional fixation, and the effective use of intraoperative fluoroscopy, our technique ensures accurate guidewire positioning prior to hindfoot nail insertion.

Ethical Approval

Ethical approval for this study was obtained from the Institutional Review Board (IRB. No. 2015P000464).

Declaration of Conflicting Interests

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