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Technical Note

Tuber-to-Anterior Process Angle (TAPA): A cadaveric study and surgical technique for placing axial calcaneal screws

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ABSTRACT

We describe results of a cadaveric study and an accompanying surgical technique which simplifies posterior-to-anterior axial screw placement into the calcaneus, often utilized during fixation of displaced intra-articular calcaneus fractures or calcaneal osteotomies. By defining the Tuber-to-Anterior Process Angle (TAPA), this technique facilitates axial screw placement, thereby decreasing reliance on intraoperative fluoroscopy and reducing operative time.

Introduction

Operative management of displaced intra-articular calcaneus fractures is evolving. While traditional treatment consisted of an open extensile lateral approach and plate fixation, high rates of associated wound complications has led to the increased use of minimally invasive reduction and fixation techniques [1,2]. Generally, these techniques rely on a combination of ligamentotaxis and stepwise manipulation of displaced fracture fragments under image intensification, either percutaneously or through a small lateral incision.

Regardless of fracture pattern, the primary goals are to elevate the depressed joint surface and to restore calcaneal height, length and alignment. While fixation is tailored to each individual fracture, the strategy generally requires at least 1–2 screws placed lateral-to-medial to stabilize the posterior facet. When screw-only fixation is performed, additional screws are placed from posterior-to-anterior (P:A) to stabilize calcaneal length and axial alignment (Fig. 1).

Directing fixation from the tuber into the anterior process can be challenging due to calcaneal anatomy, disorienting prone or lateral patient positioning, and the difficulty of obtaining adequate axial imaging intraoperatively. In fact, cannulated screws are typically chosen over solid ones for the sake of increasing accuracy and preserving bone stock during screw placement, as it is not uncommon for initial fixation attempts to be unsatisfactory, requiring repositioning and reimaging. Understanding the calcaneal long-axis as it relates to the long-axis of the foot, a measurement we call the Tuber-to-Anterior Process Angle (TAPA, Fig. 2), can facilitate the ease and accuracy of guide-wire and cannulated screw placement.

The goals of this study are to define the TAPA, which is the lateral deviation angle of the long-axis of the calcaneus as it relates to the long-axis of the foot, and to report a surgical technique which uses this angle to facilitate axial screw placement.

Methods

Eight fresh-frozen, morphologically normal cadaver feet were utilized for this study. The long-axis of the foot was marked on the skin of all eight specimens for reference, as shown in Fig. 3. Starting at the anatomic and radiographic center of the posterior calcaneal tuber, a longitudinal pin was placed which exited between the 2nd and 3rd metatarsal heads. This pin roughly represents the long-axis of the foot as described by Haskell and Mann [3]. The calcaneocuboid joint was then exposed, and a small wedge of cuboid was removed to allow access to the articular surface of the anterior calcaneus. Using an ACL tibial drill guide with the tip aimer placed at the same starting point in the tuber, a calcaneal pin was placed, exiting at the center of the articular surface of the anterior process. The tips of two small K-wires were also impacted into the medial and lateral-most aspects of the articular surface,

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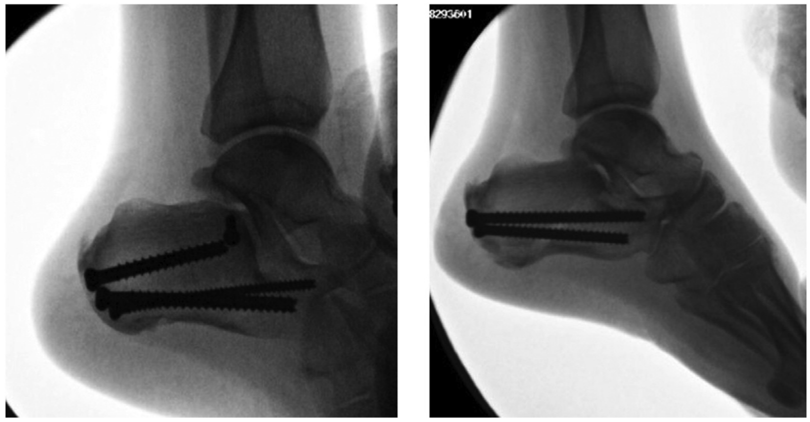

Fig. 1. Posterior-to-anterior calcaneal screws placed to stabilize length and axial alignment in a patient with bilateral calcaneus fractures.

representing the medial-to-lateral extent of the anterior process. A true axial view of each specimen was then obtained. On these images, a digital line was drawn between the posterior tuber starting point and the central calcaneal process pin, representing the calcaneal long-axis. The angle subtended by this line and the long-axis of the foot was measured and represents the TAPA (Fig. 4). Similarly, digital lines were drawn between the posterior tuber starting point and the medial and lateral K wire tips, and their subtending angles were measured by two independent observers (ImageJ Software, National Institutes of Health, Bethesda, MD) [4]. The range between these latter two measurements represents the axial plane tolerance for screw placement within the anterior calcaneus (Fig. 4).

Results

The average TAPA measured 10.8 ± 1.7 degrees (range: 8.4–13.0). The average angle, as measured to the medial extent of the anterior calcaneus, measured 2.8 ± 1.2 degrees (range: 0.4–4.3). The average angle, as measured to the lateral extent of the anterior calcaneus, measured 19.0 ± 2.7 degrees (range: 15.7–22.7). (Table 1)

Surgical technique

While the TAPA is relevant regardless of surgical positioning, we describe its use as it relates to prone positioning for illustrative purposes. The patient is positioned prone on the operating table with care taken to pad boney prominences and areas of possible soft tissue or nerve compression. The operative foot is elevated over a stack of blankets above the contralateral limb so as to offer a clear field of view when obtaining intraoperative images. The patient is prepped and draped in sterile fashion. The C-arm is positioned to perform a perfect lateral of the foot, and under fluoroscopic guidance a radiodense instrument is used to locate and mark the level of the calcaneocuboid joint on the skin (Fig. 5).

After fracture reduction is achieved, with attention paid to restoration of calcaneal length and axial alignment, the long-axis of the foot is estimated based on a theoretical line drawn between the central posterior calcaneal tuber and the interspace between the 2nd and 3rd rays; this can be marked on the skin to facilitate visualization). A guide-wire for cannulated screws is positioned axially at the posterior starting point represented by the clinical center of the posterior tuber. Adjustment in the sagittal plane is estimated by triangulating to the anterior calcaneus using the calcaneocuboid marking on the skin. To adjust in the axial plane, the guide-wire is then angulated approximately 10 degrees laterally (TAPA) and inserted under intermittent lateral fluoroscopic guidance, advancing past the primary fracture line into the anterior calcaneus, stopping just prior to violation of the calcaneocuboid joint (Fig. 6). Screw fixation is performed in standard fashion and an axial view is obtained to confirm proper placement.

Discussion

Operative management of displaced intra-articular calcaneus fractures frequently involves placement of P:A screws in order to maintain calcaneal length and axial alignment. While plate fixation may still be more commonly utilized, screw-only fixation for the treatment of these fractures has been demonstrated by several authors to be safe and effective [5–11].

Placement of axial calcaneal screws can be challenging and time-intensive, however, and may require extensive use of intraoperative fluoroscopy. The unique bony anatomy of the calcaneus contributes foremost to this challenge and is compounded by disorienting patient positioning and often suboptimal intraoperative imaging capabilities. Despite these challenges, it is important to minimize errors when placing these screws, as malpositioning can result in bone loss, medial cortical breach leading to iatrogenic injury to adjacent structures or possibly inadequate fixation [12–14].

Knowledge of the TAPA, found to be 10.8 degrees (± 1.7 degrees) laterally deviated from the long-axis of the foot, simplifies placement of P:A screws in the calcaneus. Understanding this relationship reduces reliance on intraoperative axial fluoroscopy and increases operative efficiency. Furthermore, this knowledge can be applied during other procedures in which axial screw placement is performed, such as with corrective calcaneal osteotomy.

The primary weaknesses of this study are inherent to any cadaveric study. While the specimens utilized were morphologically normal, anatomic variation from congenital malformation or previous fracture (and subsequent malunion) may alter the TAPA. While this technique allows for more precise and efficient placement of screw fixation, an axial view of the calcaneus should be obtained intraoperatively to confirm proper screw placement. Furthermore, the TAPA as defined in this investigation relies on a center starting point in the calcaneal tuber. Medial or laterally based starting points will alter the tolerance for proper screw placement.

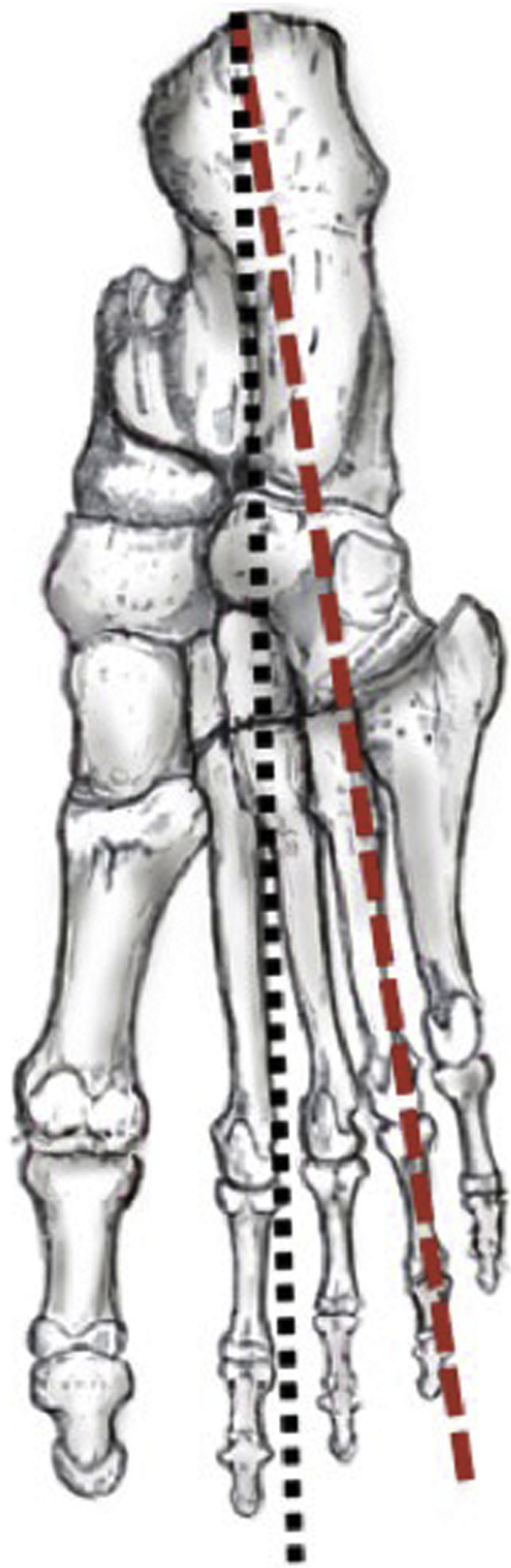

Fig. 2. Tuber-to-Anterior-Process Angle (TAPA): the angle subtended by a line starting at the posterior tuber and extending along the long-axis of the foot and a line from the same point at the posterior tuber which extends through the center of the articular surface of the anterior process.

Fig. 3. Cadaver specimen marked to indicate the long-axis of foot.

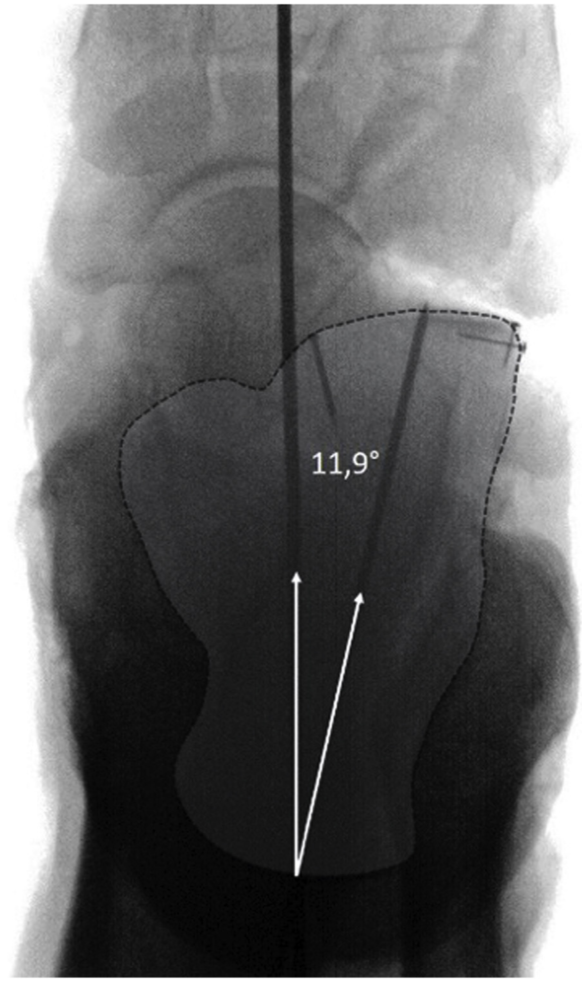

Fig. 4. Fluoroscopic image of Specimen #2 depicting the TAPA, which is the angle portended by a digital line drawn to represent the long-axis of the foot, and the K-wire placed along the long-axis of the calcaneus. The small K-wires represent the medial and lateral-most extent of the anterior process.

Table 1
TAPA results for each specimen.

Specimen	Degrees from long axis of the foot to		
	Medial Border	Lateral Border	Center
1	3.5	18.9	11.2
2	3.6	20.1	11.9
3	2.8	17.6	10.2
4	2.7	22.7	12.7
5	2.4	17.8	9.7
6	4.3	21.7	13.0
7	0.4	16.4	8.4
8	2.5	15.7	9.1
Mean ± SD	2.8 ± 1.3	19.0 ± 2.7	10.8 ± 1.7

Fig. 5. Prone positioning and set up, with operative foot elevated on blankets and a roll of sterile towels. The C-arm is positioned to obtain a lateral image of the foot, which was used to mark the calcaneocuboid joint on the skin as shown. This simple step aids in placement of guidewire for P:A screw. In this representative lateral fluoroscopic image, the additional Schantz pin was utilized in the style of Essex-Lopresti, reducing and elevating the depressed posterior facet while the P:A guidewire was placed.

Fig. 6. Demonstration of use of the TAPA: The guidewire is started at the clinical center of the tuber posteriorly, the TAPA estimates that the surgeon's hand position should aim ~10 degrees lateral in the axial plane of the calcaneus, while simultaneously using the free hand to triangulate to the calcaneocuboid in the sagittal plane.

Conclusion

The Tuber-to-Anterior Process Angle (TAPA) is approximately 10 degrees laterally deviated from the long-axis of the foot. Knowledge of this angle simplifies placement of posterior-to-anterior screws in the calcaneus, reducing reliance on intraoperative axial fluoroscopy and increasing operative efficiency.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article

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