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Optimal Starting Point for Fifth Metatarsal Zone II Fractures: A Cadaveric Study

Geoffrey I. Watson, MD[1], Sydney C. Karnovsky, BA[2], Gabrielle Konin, MD[2], and Mark C. Drakos, MD[2]

Abstract

Background: Identifying the optimal starting point for intramedullary fixation of tibia and femur fractures is well described in the literature using a retrograde or anterograde technique. This technique has not been applied to the fifth metatarsal, where screw trajectory can cause iatrogenic malreduction. The generally accepted starting point for the fifth metatarsal is "high and inside" to accommodate the fifth metatarsal's dorsal apex and medial curvature. We used a retrograde technique to identify the optimal starting position for intramedullary fixation of fifth metatarsal fractures.
Methods: Five matched cadaveric lower extremity pairs were dissected to the fifth metatarsal neck. An osteotomy was made to access the intramedullary canal. A retrograde reamer was passed to the base of the fifth metatarsal to ascertain the ideal entry point. Distances from each major structure on the lateral aspect of the foot were measured. Computed tomography scans helped assess base edge measurements.
Results: In 6 of 10 specimens, the retrograde reamer hit the cuboid with a cuboid invasion averaging 0.7 mm. The peroneus brevis and longus were closest to the starting position with an average distance of 5.1 mm and 5.7 mm, respectively. Distances from the entry point to the dorsal, plantar, medial, and lateral edges of the metatarsal base were 8.3 mm, 6.9 mm, 9.7 mm, and 9.7 mm, respectively.
Conclusion: Optimal starting position was found to be essentially at the center of the base of the fifth metatarsal at the lateral margin of the cartilage. Osteoplasty of the cuboid or forefoot adduction may be required to gain access to this site.
Clinical Relevance: This study evaluated the ideal starting position for screw placement of zone II base of the fifth metatarsal fractures, which should be considered when performing internal fixation for these fractures.

Keywords: foot, general sports trauma, anatomy, biomechanics of bone

Intramedullary fixation is considered the treatment of choice for operative management of zone II fifth metatarsal fractures.[4] In high-performance athletes and patients with delayed union, operative treatment is commonly indicated in fractures occurring in zones II and III, or Jones fractures and proximal diaphyseal fractures, respectively. Jones fractures are acute fractures "occurring in the proximal portion of the fifth metatarsal base at the metaphyseal/diaphyseal junction with a fracture exiting into the intermetatarsal 4-5 joint."[13] Zone III fractures occur distal to the ligament attachments that attach the fourth and fifth metatarsal bases and are usually stress fractures.[2] Screw head prominence, nonunion, delayed union, plantar gapping, and distal fractures have been associated with complications despite operative fixation.[3,8,10,16]

A cause for plantar and lateral gapping related to intramedullary fixation may be attributed to technical considerations regarding screw insertion. The fifth metatarsal is a curved bone with an apex that occurs on the dorsomedial cortex.[14] This difference in the mechanical and anatomic axes explains why insertion of a straight screw with a starting point too lateral will cause a gap on the lateral cortex; as the screw travels down the distal canal, it abuts the medial cortex, creating an angular deformity. Similarly, a starting point too plantar causes a gap along the plantar cortex. This is why several articles on the operative technique discuss the "high and inside" (dorsal and medial) starting position to prevent these malreductions.[4,11-13] Ideally, the insertion point would allow the screw to follow the center of the canal the entire distance of the bone. However, due to the curved nature of the bone, screw length should be shortened such that it ends prior to engaging the cortex distal to the apex of the bone curvature, which can lead to malreduction.

[1]Vanderbilt University Medical Center, Franklin, TN, USA
[2]Hospital for Special Surgery, New York, NY, USA

Corresponding Author:
Sydney C. Karnovsky, BA, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA.
Email: s.karnovsky@gmail.com

Previous literature investigating the ideal starting point for intramedullary fixation of long bone fractures used cadaveric specimens to gain access to the intramedullary canal and using guide wires and reamers to exit the bone proximally or distally to assess the ideal starting point for anterograde and retrograde fixation, respectively.[1,7,15] As this entry point gains access for a relatively large intramedullary implant, it is important that the implant follow the path of least resistance. The area that is most studied is the proximal femur. Literature on this topic reveals that an anterior starting position of just 6 mm significantly increases the risk of an iatrogenic proximal femur fracture.[9] Implant design has also been modified to allow for a radius of curvature for the femur, whereas old designs were straight implants. With the radius of curvature built into the designed implants, a more posterior starting point can be used to access the canal, and the nail can travel further distally without perforation of the anterior cortex. Clearly, the starting point has a significant impact on the path of the implant and fracture fixation, as it has a vital role in performing this operative procedure.

To our knowledge, this is the first study to report on the ideal insertion point for proximal fifth metatarsal fracture intramedullary fixation using this retrograde technique. The primary aim of our study was to identify the ideal starting point to create the least amount of angular deformity with intramedullary screw insertion. A secondary aim of our study was to identify the proximity of structures at risk with percutaneous insertion using this ideal starting point.

Materials and Methods

Five cadaveric matched pairs for a total of 10 lower extremity specimens were used for this investigation. Dissection of the distal portion of the fifth metatarsal was carried down to the bone to visualize the metatarsal head and neck. The metatarsal neck was transversely cut with a microsagittal saw. The fifth metatarsal head, neck, and fifth toe were displaced to gain access to the canal (Figure 1). The anteroposterior (AP) and medial/lateral diameters of the canal were measured. The diameter measurement was then cut in half and the center position was then marked. A Smith and Nephew (Andover, MA) ACL flexible guide pin (2.4 mm) was passed through the center of the canal in a retrograde fashion through the proximal end of the bone. The reamer traversed the center of the canal through the path of least resistance exiting the proximal metatarsal. The relationship to structures at risk, including the main and inferior branches of the sural nerve, sural vein, cuboid, fourth metatarsal, peroneus longus, and brevis tendons, was measured and documented (Figure 2). In addition, measurements of the distance from the exit hole to the medial, lateral, superior, and inferior edges of the proximal fifth metatarsal base were measured in addition to the edge of the lateral articular surface edge. The average height and width were also measured. Computed tomography (CT) scans following reaming were also performed to assess the fifth metatarsal base edge measurements (Figure 3).

Results

The proximal surface of the fifth metatarsal was trapezoid in shape. Measuring from the exit hole to the medial, lateral, dorsal, and plantar surfaces showed an average distance of 8.8 mm, 11.8 mm, 7.5 mm, and 5.4 mm, respectively. Furthermore, the exit point was, on average, 2.4 mm medial to the lateral margin of the articular surface of the fifth metatarsal and was violated in 8 of 10 specimens. Average base width was 20.6 mm and average base height was 12.9 mm (Tables 1 and 2). Next, measurements to the structures at risk were taken (Tables 3 and 4). The cuboid was the structure most at risk as it was reamed in 6 of 10 specimens, with an average of −0.7 mm, indicating that amount of bone was removed from the cuboid. The inferior branch of the sural nerve was only identified in 6 of the 10 exposures. The main sural nerve branch was the furthest from the ideal insertion point at an average of 15.1 mm, while the inferior branch was closer at 7.5 mm, when identified. The peroneus brevis and longus were relatively close to the insertion point at 5.1 mm and 5.7 mm on average, respectively. The sural vein and the lateral border of the fourth metatarsal articular surface were also identified as 8.9 mm and 9.4 mm away from the insertion site, respectively.

Discussion

Intramedullary screw fixation for proximal fifth metatarsal fractures has become an increasingly popular method for operative intervention. Yet, fixation of a curved bone with a straight intramedullary implant requires significant understanding of the osseous anatomy as well as the geometric and mechanical properties that define the desired implant. Misunderstanding of these concepts can lead to malreduction or gapping of the fracture, thus predisposing the prescribed treatment to complications, including hardware irritation, delayed union, nonunion, and refracture.[3,8,13]

The geometric anatomy of the fifth metatarsal has been described in previous literature. A radiographic study by Ebraheim et al[6] described taking radiographs following the sectioning of 20 cadaveric specimens and placement of a radiopaque solder wire along the inner cortices. These radiographs revealed that the fifth metatarsal has a wider canal width from medial to lateral than from dorsal to plantar, leading to the conclusion that using the lateral view to define screw width is more appropriate. Furthermore, their description also included identification of the bowed intramedullary canal that "lends to vulnerability of the medial cortex at roughly the midshaft of the 5th metatarsal."[6] A

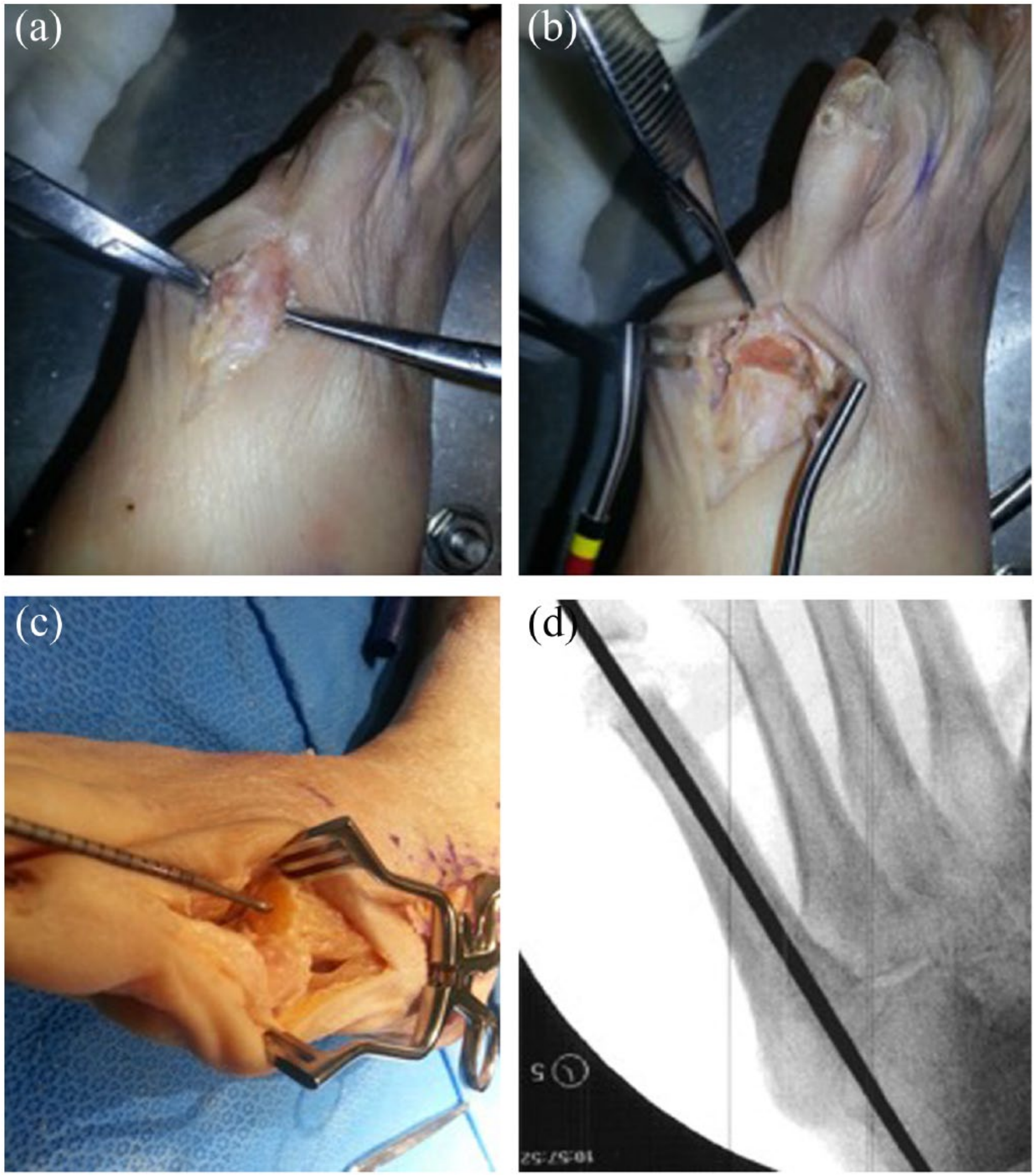

Figure 1. (a) Exposure of the distal fifth metatarsal. (b) Transverse osteotomy of the distal fifth metatarsal. (c) Placement of guidewire in the center-center position. (d) Oblique radiograph revealing placement of the reamer. Note the medial starting position and relationship to the cuboid.

recent CT study of 119 patients described the straight segment length at an average of 52.9 mm (48.9-56.9 mm) for placement of the longest screw to stabilize a Jones fracture without violation of the far cortex as the bone curves plantar and lateral.[14]

Interestingly, the most recent article documenting the theoretical length and diameter of a screw for base of the fifth metatarsal fractures used a starting point beginning at the tip. This is in contrast to the "high-and-inside" (medial and dorsal) starting point currently recommended in the literature for screw placement.[4,11-13] The thinking behind using a high-and-inside starting point is that it helps to gain better access to the bowed intramedullary canal, thus improving the trajectory as the screw is placed along the

Figure 2. A needle has been placed in the cuboid-metatarsal articulation to demonstrate the reamer position exiting the base of the fifth metatarsal to this joint. The peroneus brevis tendon has been resected to improve visualization. The main branch of the sural nerve can be identified traveling lateral and distal to the fifth metatarsal base.

canal. When using longer screws, the high-and-inside technique should be considered. However, we are advocating the use of shorter screws to decrease the risk of malreduction. Our study suggests that the starting point should be in the central portion of the base. The distance between the medial and lateral edges of the bone, on average, measures 8.8 mm and 11.8 mm, respectively. However, the cuboid frequently obscures or abuts the ideal starting point (as noted in 6 of 10 specimens, in which the retrograde reamer penetrated the cuboid). Interestingly, the dorsal cortex to the exit point was 7.5 mm, whereas the distance to the plantar cortex was 5.4 mm, or just slightly low with respect to the base of the fifth metatarsal. These data suggest that the starting point should be essentially in the center of the base of the fifth metatarsal.

This situation is akin to obtaining the starting point for a piriformis start of a femoral nail in a patient with coxa vara and greater trochanteric overhang. To access the ideal starting point, thus allowing the straight implant (in the coronal plane) to reduce the femoral shaft fracture, a portion of the greater trochanter must be reamed away. In the same way, reaming away the distal lateral portion of the cuboid or performing a cuboid osteoplasty may provide access to a more ideal starting position. Another option would be to adduct the forefoot, further exposing the ideal starting point. The starting point often straddles the region between the articular surface of the fifth metatarsal and the metatarsal tuberosity. This is important to minimally violate the articular cartilage of the fifth metatarsal. In addition, this bone is quite mobile, particularly relative to the other metatarsals in this area. Furthermore, complications involving headed screws near the cuboid articulation that can lead to clicking or impingement, which can cause irritation, may be avoided. Another solution to the latter problem is the use of headless compression screws or headless variable pitch screws.

By obtaining the proper starting position, angular deformity caused by screw insertion should be minimized. If the screw is placed too far lateral in the proximal portion of the fracture, as the screw crosses the fracture, it will hit the medial cortex and an angular deformity will occur where the proximal fracture distracts laterally and compresses medially, effectively straightening the curved bone. This gap is believed to be related to poorer outcomes, including refracture, delayed union, and nonunion.[13] We believe that by obtaining a more medial starting position, this will decrease this malreduction as this starting position provides a more direct trajectory for the canal. Furthermore, a starting position too lateral can cause peroneus brevis irritation at its insertion, as well as hardware prominence.[5] Similarly, if the starting point is too superior, the screw will preferentially engage the dorsal cortex gapping the metatarsal plantarly. This plantar gap has also been shown to be problematic.[13] Also, it is important to note that in certain cases, such as metatarsus adductus, the bone may be different or opposite of those that were seen here.

As the retrograde reamer passed proximally through the skin, further measurements were taken to identify the structures at risk and their distance from this starting position. After the cuboid, the peroneus brevis tendon was the structure most at risk at an average of 5.1 mm while the peroneus longus was next at an average distance of 5.7 mm. The sural nerve main branch, inferior branch, and vein were an average of 15.1 mm, 7.5 mm, and 8.9 mm away from the entry point, respectively. These data suggest that each of these structures is in close proximity to the starting point and reaffirm that a cannulated technique with soft tissue protectors is important in decreasing or preventing harm during this procedure. It should be noted that the inferior branch of the sural nerve was only encountered in 6 of the specimens.[5,10]

In conclusion, based on our retrograde technique for assessment of the ideal starting point, a position that was essentially central at the base of the fifth metatarsal was ideal to gain access to the canal. The cuboid commonly interfered with obtaining this position in 6 of 10 of our specimens, and forefoot adduction and cuboid osteoplasty should be considered for gaining access to the starting point and prevention of screw head irritation. It is our contention that obtaining the proper starting position will decrease fracture malreduction that can predispose patients to refracture, delayed union, and nonunion. Further research is needed to confirm or refute this supposition. Furthermore, a cannulated technique can assist in protecting the many structures at risk in the placement of an intramedullary screw.

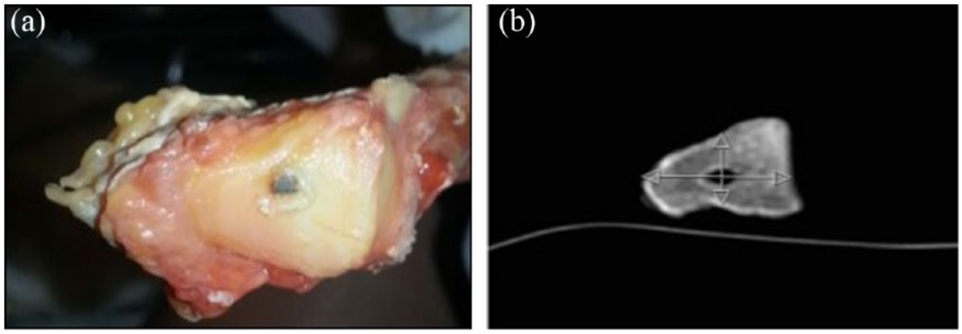

Figure 3. (a) An example of the exit point at the proximal fifth metatarsal essentially in the midpoint of the proximal fifth metatarsal in the specimen. (b) An example of the exit point at the proximal fifth metatarsal essentially in the midpoint of the proximal fifth metatarsal in computed tomography imaging.

Table 1. Distance From Pin Starting Point to Anatomic Landmark of Articular Surface of Proximal 5th Metatarsal.

Characteristic	Mean	SD	Median	Minimum	Maximum
Dorsal surface, mm	7.5	1.6	7	5.3	10.1
Plantar surface, mm	5.4	1.5	5.6	3.1	8.4
Medial surface, mm	8.8	2.2	8.2	5.8	13
Lateral surface, mm	11.8	2.9	12.6	6.4	15
Lateral articular surface, mm	–2.4	1.9	–2.9	–5.1	1.6
Base width, mm	20.5	2.2	20.4	16.1	23.7
Base height, mm	12.9	0.9	12.8	10.9	13.8

Table 2. Distance From Pin Starting Point to Anatomic Landmark of Articular Surface of Proximal 5th Metatarsal by Specimen.

	Overall									
	1	2	3	4	5	6	7	8	9	10
Dorsal surface, mm	5.9	7.2	6.7	6.6	8.7	7.7	6.7	10.1	9.6	5.3
Plantar surface, mm	5	5.5	6.1	5.7	4.7	6.1	6	3.6	3.1	8.4
Medial surface, mm	9.7	7.2	7.7	12	7.5	7.3	13	8.7	8.7	5.8
Lateral surface, mm	6.4	13	12.7	7.5	11.4	14.2	10.4	15	12.5	14.6
Lateral articular surface, mm	–2.9	–2.7	–3.4	0	–3.8	–3.3	1.6	–2.9	–1.5	–5.1
Base width, mm	16.1	20.2	20.4	19.5	18.9	21.5	23.4	23.7	21.2	20.4
Base height, mm	10.9	12.7	12.8	12.3	13.4	13.8	12.7	13.7	12.7	13.7

Table 3. Distance From Pin Starting Point to Structure.

	Overall					
Structure	No.	Mean	SD	Median	Minimum	Maximum
Peroneus longus, mm	10	5.7	2.83	6.5	1	9
Peroneus brevis, mm	10	5.1	2.23	4.5	3	10
Sural nerve main, mm	10	15.1	5.86	14	6	25
Sural nerve inferior, mm	6	7.5	2.66	7	5	12
Sural vein, mm	10	8.9	3.57	9.5	4	14
Cuboid, mm (negative value = reamer hit cuboid)	10	–0.7	2.06	–1	–5	2
Fourth metatarsal, mm	10	9.4	2.37	10	5	12

Table 4. Distance From Pin Starting Point to Structure by Specimen.

	Specimen									
Anatomic Landmark	1	2	3	4	5	6	7	8	9	10
Peroneus longus, mm	8	6	1	7	9	2	3	8	5	8
Peroneus brevis, mm	6	3	4	3	3	7	5	4	6	10
Sural nerve main branch, mm	11	14	20	6	23	11	25	14	13	14
Sural nerve inferior branch, mm	7	NA	5	NA	7	NA	12	9	5	NA
Sural vein, mm	11	5	7	5	11	13	14	11	8	4
Cuboid, mm	–5	–1	1	–1	1	–2	2	–2	1	–1
Fourth metatarsal, mm	7	5	8	8	12	10	10	12	12	10
Hit cuboid	Yes	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Abbreviation: NA: Not applicable.

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Approval Statement

The study took place at the Hospital for Special Surgery and was approved by the institution's Biomechanics Department.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Mark C. Drakos, MD, is a paid consultant for Extremity Medical and Fast Form, neither of whose products is involved in this study. The authors have no other conflicts to disclose.

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