The Journal of Foot & Ankle Surgery 58 (2019) 62–65

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Structures at Risk From an Intermetatarsal Screw for Lapidus Bunionectomy: A Cadaveric Study

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ARTICLE INFO

Level of Clinical Evidence: 5

Keywords:
deep peroneal nerve
dorsalis pedis artery
hallux valgus
neurovascular bundle

ABSTRACT

The Lapidus bunionectomy is performed to treat hallux valgus. Recurrence of the deformity remains a concern. A transverse intermetatarsal screw spanning the base of the first metatarsal to the base of the second can increase stability. The neurovascular bundle is located within the proximity of this screw. In this study, we assessed the structures at risks with the use of this technique. In 10 specimens, a guide wire was placed, and a 4.0-mm cannulated screw was inserted. The neurovascular bundle was dissected and inspected for direct trauma to the neurovascular bundle, and the proximity of the screw was measured using a digital caliper. Ten cadaveric specimens were used. The dorsalis pedis artery and deep peroneal nerve were free from injury in 9 of 10 specimens. In those 9 specimens, the neurovascular bundle was located dorsal in relation to the screw. The mean distance of the screw to the neurovascular bundle was 7.1 ± 3.3 mm. The mean distance from the screw to the first tarsometatarsal joint (TMTJ) was 14.7 ± 4.3 mm. The mean distance from the screw as it entered the second metatarsal to the second TMTJ was 18.0 ± 7.2 mm. In 1 specimen, the screw was found to be traversing through the neurovascular bundle. The distance from the screw to the first TMTJ was 15.0 mm. The distance of the screw from where it entered the second metatarsal to the second TMTJ was 24.0 mm. Although the intermetatarsal screw avoided the neurovascular cases in most instances, there is some anatomic risk to the neurovascular bundle. Further study is warranted to evaluate clinical results using the intermetatarsal screw for the modified Lapidus procedure.

The surgical treatment of hallux valgus continues to progress with the advent of newly reported fixation techniques. In 1934, Paul Lapidus reported the first tarsometatarsal joint (TMTJ) arthrodesis as a means of correction of severe metatarsus primus varus in addressing hallux valgus deformity (1). The modified Lapidus procedure can provide continued deformity correction and stability of the medial column (2). Several investigators have reported on modified Lapidus techniques with different fixation methods to achieve correction without deformity recurrence or nonunion complications (2–4). The use of augmented, multipoint fixation as a means of increasing stability across the first TMTJ has been increasingly reported in the literature (2,4–6).

The use of an intermetatarsal screw, placed from the base of the first metatarsal to the base of the second metatarsal, is a modified technique for angular reduction and enhanced stability (5,7–10). Coetzee et al (7) reported on 105 feet using the first to second intermetatarsal base screw for reduction maintenance. The mean duration of postoperative follow-up was 3.7 years, with only a 0.3-degree loss of intermetatarsal reduction from the 1-year follow-up. Recently, Feilmeier et al (11) reported a reduction in transverse and coronal plane force across the first TMTJ with the placement of this additional intermetatarsal screw. The use of this screw can help maintain intermetatarsal reduction and improve union across the first TMTJ. Clinically, this can improve pain, edema, and return to functional activity.

The deep peroneal nerve is a branch of the common peroneal nerve that courses 2.9 mm lateral to the first TMTJ, deep to the extensor hallucis brevis tendon (12). The dorsalis pedis artery is the continuation of the anterior tibial artery. As this artery courses distally in the first dorsal interosseous space, it also travels plantar to connect to the dorsal and plantar arterial network (13). Thus, use of the intermetatarsal screw is not without risk, because it may lead to complications, including neurovascular injury. The purpose of this study was to assess the risk of injury

Financial Disclosure: This study was supported by Novastep.
Conflict of Interest: None reported.
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https://doi.org/10.1053/j.jfas.2018.08.010

to relevant neurovascular structures, including the dorsalis pedis artery and deep peroneal nerve, during placement of the intermetatarsal screw.

Materials and Methods

This study was conducted in a clinical skills anatomy laboratory. A total of 10 fresh-frozen adult cadaveric below-knee specimens were used. Each specimen had no obvious deformity or outward signs of previous trauma or surgery. The specimens were allowed to thaw for 24 hours before the study.

For each specimen, a 4.0-mm partially threaded cannulated intermetatarsal screw was placed percutaneously under fluoroscopy, as described previously (7,8,10). A single surgeon (C.F.H.) placed each screw. First, a guide wire was placed against the skin. The starting point was approximately 1 cm distal to the base of the metatarsal at the medial midaxial point of the metatarsal shaft as judged by the surgeon. The wire was driven toward the midaxial point in the second metatarsal shaft at a trajectory roughly parallel with the first TMTJ (Fig. 1). This requires aiming slightly dorsal from the first metatarsal starting point. The wire was driven through the far cortex of the second metatarsal. The first pass of the wire was accepted to eliminate the potential for neurovascular damage from multiple passes. A cannulated drill was passed over the guide wire, and all 4 cortices were drilled. A 4.0-mm cannulated partially threaded screw of the appropriate length was placed over the guide wire until the head was flush with the medial cortex of the first metatarsal (Figs. 2 and 3).

With the screw in place, a dorsal incision was made between the first and second metatarsals. Careful dissection was carried down to identify the neurovascular bundle without disturbing its normal resting position (Fig. 4). Any violations of the dorsalis pedal artery, first dorsal metatarsal artery, or deep peroneal nerve were documented. The distance from neurovascular bundle to the nearest aspect of the screw as it entered the second metatarsal was recorded, the distance of the screw head from the first TMTJ, the distance of the screw as it entered the second metatarsal to the second TMTJ, and the location of the neurovascular bundle in relation to the screw were recorded (Table 1). The distances between the specimens without neurovascular violation and specimens with neurovascular violation were averaged (Table 2).

Results

A total of 10 specimens were used. The neurovascular bundle was free from injury in 9 of these 10 specimens. In those 9 specimens, the location of the neurovascular bundle in relation to the screw was found to be dorsal (Fig. 5). The mean distance of the screw to the neurovascular bundle was 7.1 ± 3.3 mm. The mean distance from the screw to the first TMTJ was 14.7 ± 4.3 mm, and the mean distance from the screw as

Fig. 1. Anteroposterior fluoroscopic image of the guidewire for the 4.0-mm cannulated intermetatarsal screw.

Fig. 2. Anteroposterior fluoroscopic image of final placement of the 4.0-mm cannulated intermetatarsal screw.

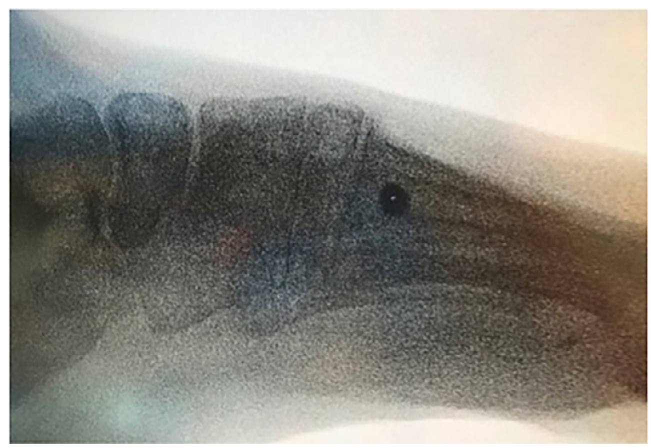

Fig. 3. Lateral fluoroscopic image of final placement of the 4.0-mm cannulated intermetatarsal screw.

Fig. 4. Dissection to expose the neurovascular bundle.

Table 1
Measurements for each specimen

Specimen	Screw to NVB (mm)	Screw to First TMTJ (mm)	Screw to Second Metatarsal Base (mm)	Violates NVB (yes/no)	Location of NVB to Screw (dorsal/ plantar)
1	12	13	24	No	Dorsal
2	5	24	26.5	No	Dorsal
3	7	13	16	No	Dorsal
4	4	17	20	No	Dorsal
5	4	17.5	20	No	Dorsal
6	7	14	16	No	Dorsal
7	5	10	15	No	Dorsal
8	13	13	2	No	Dorsal
9	7	11	23	No	Dorsal
10	0	15	24	Yes	Through

Abbreviations: NVB, neurovascular bundle; TMTJ, tarsometatarsal joint.

Table 2
Mean distances with standard deviation

Parameter	NVB Safe	NVB Violated
Number of specimens	9	1
Mean distance from screw to NVB (mm), mean ± SD	7.1 ± 3.3	0
Mean distance from screw to first TMTJ (mm), mean ± SD	14.7 ± 4.3	15.0
Mean Distance from screw to second metatarsal base (mm), mean ± SD	18.0 ± 7.2	24.0
Location of NVB to screw	Dorsal	Through

Abbreviations: NVB, neurovascular bundle; SD, standard deviation; TMTJ, tarsometatarsal joint.

it entered the second metatarsal to the second TMTJ was 18.0 ± 7.2 mm. In 1 specimen, the screw was found to be traversing through the neurovascular bundle. Thus, the distance from the screw to the neurovascular bundle was 0.0 mm. The distance from the screw to the first TMTJ was 15.0 mm, and the distance of the screw as it entered the second metatarsal to the second TMTJ was 24.0 mm.

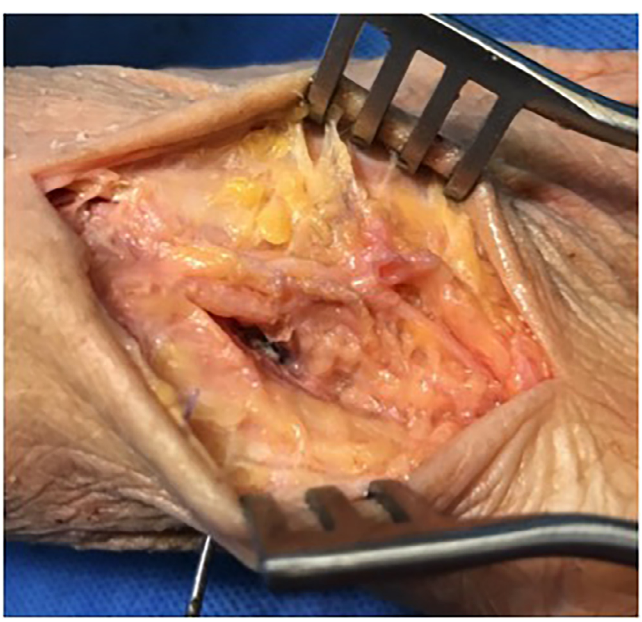

Fig. 5. Visualization of the intermetatarsal screw entering the second metatarsal and its spatial orientation in relation to the neurovascular bundle, which lies dorsal.

Discussion

Intermetatarsal screw fixation between the first and second metatarsal is a technique to increase the construct stability when performing a first tarsometatarsal arthrodesis. Instability has been recognized as a potential cause for failure in maintaining satisfactory hallux valgus correction. Fleming et al (14) reported a 73.68% incidence of intercuneiform instability after standard first tarsometatarsal arthrodesis in their study of 38 feet. They proposed the addition of the intermetatarsal screw as a way to prevent this instability (14).

The ability of the intermetatarsal screw to prevent sagittal and coronal deformity after the first tarsometatarsal arthrodesis was evaluated in a cadaveric study by Feilmeier et al (11), who observed the change in intermetatarsal angle with stress testing of 3 different constructs. The intermetatarsal screw demonstrated the greatest stability compared with screws from the first metatarsal into the intermediate cuneiform or from the medial cuneiform to the intermediate cuneiform (11).

The deep peroneal nerve is a mixed sensorimotor nerve that supplies motor innervation to the extensor hallucis brevis and extensor digitorum brevis muscle bellies in addition to cutaneous sensation in the first webspace (12). The lateral terminal branch supplies the extensor hallucis brevis and then terminates deep to the extensor digitorum brevis muscle. The medial terminal branch travels with the dorsal pedal artery into the first webspace before dividing into dorsal digital nerves and supplying the first metatarsophalangeal joint. The dorsalis pedis artery is a continuation of the anterior tibial artery. It passes under the inferior extensor retinaculum and beneath the extensor hallucis brevis muscle. At the first metatarsal interspace, it gives off the first dorsal metatarsal artery and dives to connect to the plantar arch (13).

The goal of this study was to address the risk to the neurovascular bundle with the intermetatarsal screw technique. We were unable to find a definable, anatomic safe zone. It appeared that placing the screw approximately 18 mm distal to the second TMTJ was safe and avoided neurovascular injury. In the sole instance of neurovascular injury, the screw was 24 mm distal from the second TMTJ as it entered the second metatarsal. This finding correlates with our understanding of the neurovascular anatomy. As the dorsalis pedis artery courses distally away from the second TMTJ, the artery begins to dive from dorsal to plantar, thus making it more likely to be in the zone of injury of the intermetatarsal screw. This would suggest that the trajectory of the intermetatarsal screw, with care taken to place the screw closer to the second TMTJ, is an important consideration.

There are several limitations in this small study. These were cadaveric specimens with no significant intermetatarsal deformity that may differ from the anatomy found in the clinical setting of hallux valgus with an increased intermetatarsal angle. Although we took care to prevent disturbance of the natural resting position of the nerve and artery during dissection, it is possible the native anatomy was altered before we obtained measurements. The screw position was slightly different in each specimen. We used a single surgeon placing the screw using fluoroscopy to most closely replicate a real-world intraoperative technique.

In conclusion, we found that the intermetatarsal screw can be a safe form of fixation in Lapidus bunionectomy. Anatomic risk to the neurovascular bundle does exist; however, our findings suggest that when the screw enters the second metatarsal 18 mm distal to the second TMTJ, it is able to avoid the neurovascular bundle. This area does correlate anatomically with the first metatarsal proximal metaphysis or approximately 1 to 1.5 cm distal to the first TMTJ. Further clinical study is needed to evaluate for neurovascular effects from screw placement that are not evident in a cadaveric study. However, the results of this study will give surgeons greater knowledge of the relevant anatomy when placing an intermetatarsal screw for stability of the first tarsometatarsal arthrodesis, as well as assurance that safe placement is possible with the described technique.

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