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Surgical Anatomy of the Medial Cuneiform (Cotton) Osteotomy

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Abstract

Background: The Cotton osteotomy, or dorsal-opening wedge osteotomy of the medial cuneiform (MC), is used to address medial column alignment to restore the static-triangle of support. There are many described techniques regarding the incision and osteotomy. Successful completion of the osteotomy requires knowledge of the anatomy, particularly the location of the medial dorsal cutaneous nerve (MDCN). This study describes the relationship between MDCN, tibialis anterior, extensor-hallucis-longus tendon, and ligamentous attachments to the MC. A technique to determine a safe location for the osteotomy is also described.

Methods: Twelve fresh-frozen adult foot specimens were used for this study (7 male and 5 female). The MDCN and its branches were dissected and its relationship with the MC was documented. Osteotomy tilt angle and relationship to structures around the MC were measured.

Results: MDCN traveled medially and distally over the dorsum of the MC, and a small branch to the MC was observed. The tilt angle was 80.1 $\pm$ 1.4 degrees. There was no significant difference between the distance from the distal-articular surface to the midline of the cuneiform and to the interosseous ligament ($P = .69$), or between the distance from the distal-articular surface to the second tarsometatarsal joint and to the origin of the Lisfranc ligament ($P = .12$).

Conclusions: The dorsal-medial-oblique incision effectively protected MDCN and the MC. We believe the osteotomy should be performed in the safe zone to maintain the stability of the opening wedge.

Clinical relevance: The dorsal-medial-oblique incision could reduce the risk of injury to the MDCN and the tibialis-anterior tendon.

Keywords: medial dorsal cutaneous nerve (MDCN), Cotton osteotomy, medial cuneiform, tilt angle, safe zone, dorsal open-wedge osteotomy

Introduction

A medial cuneiform plantarflexion opening wedge osteotomy, also referred to as Cotton osteotomy, is used to address medial column alignment to restore the static triangle of support of the foot. The osteotomy was originally described in 1936[3] but continues to be used as a powerful adjunct to corrective hindfoot procedures for posterior tibial tendon dysfunction or flatfoot. It can also be used to address forefoot varus as a result of congenital flatfoot, overcorrected clubfoot deformity, or tarsal coalition.[11] Scotta et al demonstrated that each millimeter of opening wedge graft inserted into the medial cuneiform gained roughly 1.9 degrees of plantarflexion of the medial column.[10]

There are many described techniques for the Cotton osteotomy.[1,2,6-8] The proper approach should be easy to expose but also avoid the medial dorsal cutaneous nerve (MDCN), medial marginal vein, and tendon injury. Several incisions have been described, including a medial, dorsomedial, or dorsal linear incision overlying the medial cuneiform. The MDCN, the larger branch of the superficial peroneal nerve, mainly innervates the medial edge of the foot and the great toe, but there are many variations in the

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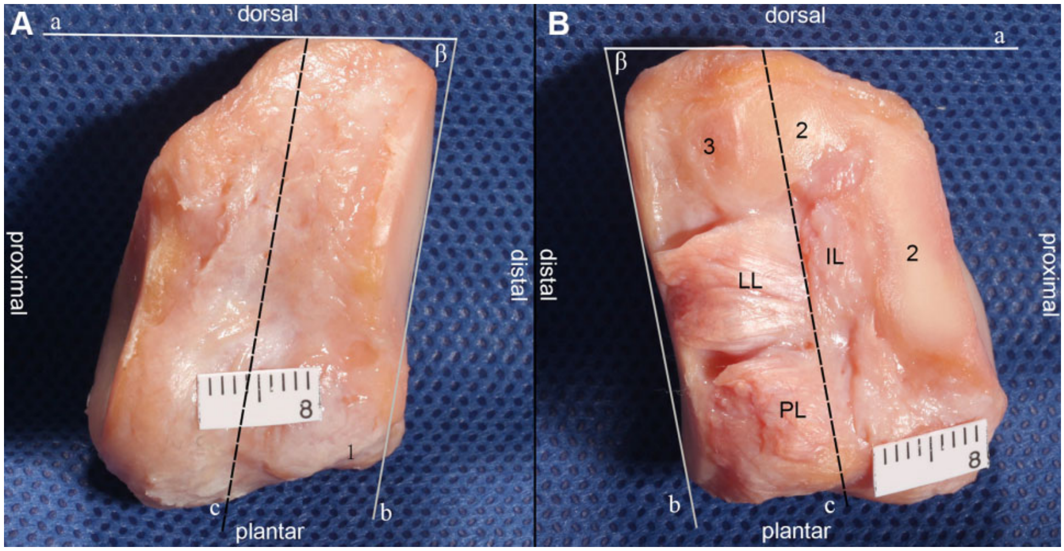

Figure 1. The medial cuneiform: the tilt angle and the osteotomy line. (A) The medial side; (B) the lateral side. β angle: tilt angle of the medial cuneiform; a line: dorsal surface of the medial cuneiform; b line: distal articular surface. Black dotted line: midline parallels to the b line, ideal osteotomy line. 1, the medial side of the medial cuneiform; 2, the joint surface for the middle cuneiform; 3, the joint surface for the second metatarsal. LL, Lisfranc ligament; IL, interosseous ligament; PL, plantar ligament.

MDCN.[9] Boffeli and Schnell[1] reported a modified oblique incision in order to protect the MDCN.

The description of the osteotomy location is also not consistent. The osteotomy line has been described as 2-4 mm proximal to the second tarsometatarsal joint[11] at the midportion of the medial cuneiform[4] or 1.0 cm proximal and parallel to the distal articular facet of the medial cuneiform.[6] Proper identification of the osteotomy line depends on an accurate understanding of the surrounding anatomy. This includes the medial cuneiform's relationship to the Lisfranc ligament, interosseous ligament, and the medial dorsal cutaneous nerve to the osteotomy line. To our knowledge, there are no studies describing the relationship of the osteotomy line and the origin of these ligaments. The current study measured the oblique angle of the distal articular facet of the medial cuneiform, evaluated the relationship between the osteotomy line and the origin of the Lisfranc ligament, and described the relationship between the incision and the course of the MDCN. An understanding of these relationships should allow a safe and feasible technique for the Cotton osteotomy.

Methods

Twelve fresh-frozen adult forefoot specimens were used, 8 left and 4 right, 7 male and 5 female. The average age was 62 years (range, 51-70). Institutional review board approval was obtained. None of the specimens had any obvious deformity, injury, or surgical scars. All specimens were thawed for 24 hours at room temperature prior to dissection.

The skin was removed and the MDCN and its branches were dissected carefully on the dorsal fascia. The medial marginal vein and its branches were also dissected in the same plane. After removing the superficial soft tissue overlying the medial cuneiform, the relationship of the medial cuneiform among the veins, nerve, and anterior tibialis tendon was measured. After removal of the MDCN and the superficial veins, the tibialis anterior tendon (TAT) and its insertion, extensor hallucis longus (EHL) tendon, and extensor hallucis brevis (EHB) tendon were exposed. The deep peroneal nerve and the dorsalis pedis artery were exposed through the space between the EHL and the EHB. Next, the TAT, EHL, and EHB were removed to allow the ligaments surrounding the medial cuneiform to be completely exposed.

The tilt angle of the medial cuneiform, the angle between the distal articular surface and the dorsal surface of the medial cuneiform, was measured using a protractor (Figure 1). The distances from the distal articular surface to the midline of the cuneiform (D1) and to the level of the second tarsometatarsal (TMT) joint (D2) were measured, respectively, in relationship to the upper surface of the medial cuneiform (Figure 2A).

The ligaments connected to the intermediate cuneiform were resected to expose the upper part of the intermediate cuneiform, base of the second metatarsal, lateral surface of the medial cuneiform, Lisfranc ligament, and the interosseous ligament. The distance from the distal articular surface to the central point of the origin of Lisfranc ligament (DL) and to the space between the origins of Lisfranc ligament and the interosseous ligament (DS) were measured, respectively, using an electronic digital caliper (Figure 2B).

Statistical Analysis

All continuous variables are reported as means ± SDs. Normal distribution in continuous variables were verified with

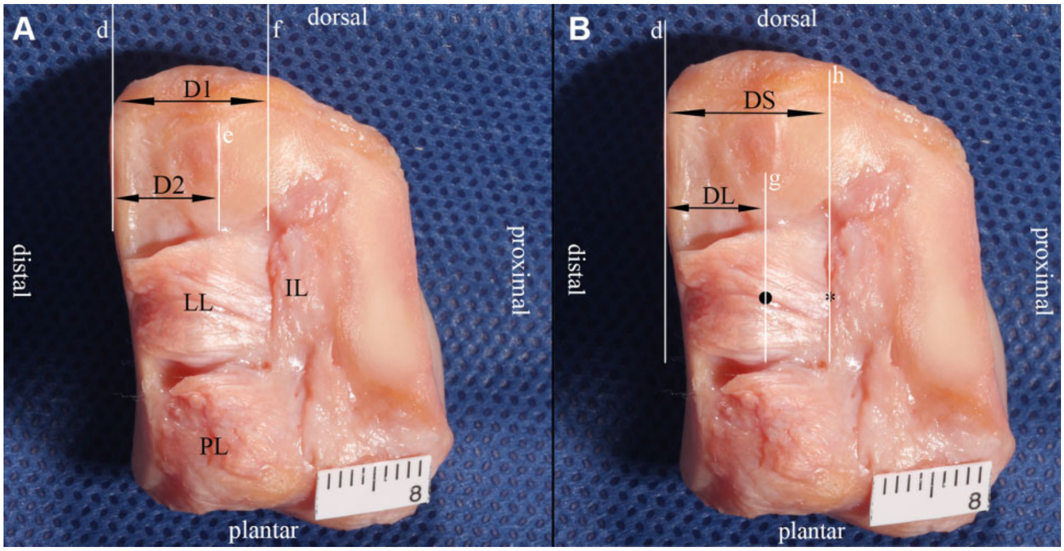

Figure 2. The medial cuneiform. (A) Schematic diagram of D1 and D2; (B) schematic diagram of DL and DS. D1, distance between the distal articular surface and the midline; D2, distance between the distal articular surface and the level of the second tarsometatarsal joint; DL, distance between the distal articular surface and the central point of the origin of Lisfranc ligament; DS, distance between the distal articular surface and the space between the origin of Lisfranc ligament and the interosseous ligament. d line: distal articular surface; e line: level of the second tarsometatarsal joint; f line: midline of the medial cuneiform; g line: central line of the origin of Lisfranc ligament; h line: space between the Lisfranc ligament and the interosseous ligament. LL, Lisfranc ligament; IL, interosseous ligament; PL, plantar ligament. Black circle: the central point of the origin of Lisfranc ligament; black asterisk: the space between the origin of Lisfranc ligament and the interosseous ligament.

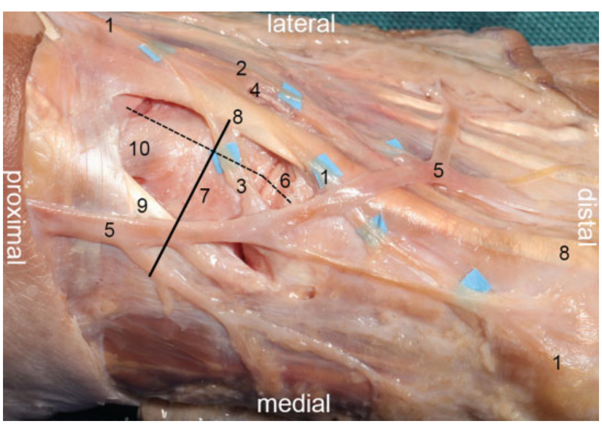

Figure 3. The superficial nerve and vein. 1, MDCN; 2, communicating branch between the MDCN and the deep peroneal nerve; 3, branch of the MDCN to the medial side of the medial cuneiform; 4, deep peroneal nerve; 5, medial marginal vein; 6, base of the first metatarsal; 7, medial cuneiform; 8, extensor hallucis longus; 9, tibialis anterior tendon; 10, dorsal cuneonavicular ligament. Dotted black line: the skin incision; solid black line: the osteotomy line. MDCN, medial dorsal cutaneous nerve.

the Kolmogorov-Smirnov test. Student *t* test was performed for continuous variables, depending on the normality of the data distribution. An alpha level less than 0.05 was considered significant. Statistical analyses were carried out by an independent biomedical statistician using SPSS software (version 18.0; IBM Corp, Armonk, NY).

Results

The MDCN traveled distally from the midportion of the ankle joint to the medial side of the midfoot, over the dorsal surface of the intermediate medial cuneiform and medial cuneiform, then turned to the medial side of the first metatarsal through the upper third of the first tarsometatarsal joint, traveled distally and terminated in the dorsal and medial side of the great toe. The MDCN had a thin branch to the medial side of the medial cuneiform (Figure 3).

The dorsal vein and artery and the deep peroneal nerve were found under the space between the EHL and EHB. If the incision was performed through the dorsal approach in the space between the EHL and EHB, the MDCN, the deep peroneal nerve, and the dorsal pedis artery would have been easily damaged. It was also difficult to expose the dorsomedial side of the medial cuneiform and perform the fixation of the osteotomy.

During a dorsomedial approach, the incision was located over the dorsomedial side of the medial cuneiform, between the TAT and EHL, parallel to the EHL and about 0.5 to 1 cm medial to the EHL. We believe the incision should incline toward the sole when it crossed the first TMT (Figure 3). The MDCN, the deep peroneal nerve, and the dorsalis pedis artery were protected when the EHL was retracted dorsolaterally. The thin branch of the MDCN to the medial cuneiform had to be cut, which should have little effect on the local sensation. This would help to expose the dorsal and dorsomedial side of the medial cuneiform clearly, while allowing the osteotomy and fixation to be performed easily.

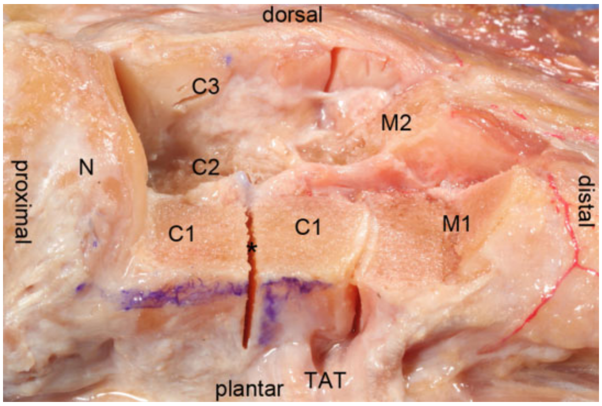

Figure 4. The relation between the osteotomy line and Lisfranc ligament, interosseous ligament, the insertion of the anterior tibialis tendon (TAT). N, navicular; C1, medial cuneiform; C2, intermediate cuneiform; C3, lateral ligament; M1, the first metatarsus; M2, second metatarsus. Black asterisk: the osteotomy line through the midline of the medial cuneiform.

Table 1. Measurements of the Medial Cuneiform.

Case Number	D1 (mm)	D2 (mm)	DL (mm)	DS (mm)
1	12.9	10.3	7.5	11.4
2	14.5	12.9	7.6	11.2
3	14.6	10.6	6.5	13.4
4	15.8	10.7	9.6	13.9
5	14.4	9.8	6.9	14.3
6	11.0	6.6	8.1	12.1
7	13.3	8.5	10.2	14.9
8	14.0	9.1	9.1	14.8
9	13.7	11.4	10.2	14.3
10	15.7	9.4	10.6	15.5
11	14.2	10.1	12.5	15.1
12	11.3	9.5	6.6	11.3
Mean ± SD	13.8 ± 1.5	9.9 ± 1.6	8.8 ± 1.9	13.5 ± 1.6

Abbreviations: D1, distance between the distal articular line of the medial and intermediate cuneiform; D2, distance between the distal articular line and the central line of the medial cuneiform; DL, distance between the distal articular line and the central point of Lisfranc ligament; DS, distance between the distal articular line and the central point of the space between the Lisfranc ligament and the interosseous ligament.

The ligaments around the medial cuneiform were as follows: (1) scaphoid ligament (dorsal, medial), (2) ligaments among the cuneiforms (dorsal, interosseous, plantar), and (3) ligaments connected to the base of the second metatarsal (dorsal ligament, Lisfranc ligament). The TAT and peroneal longus tendon inserted at the distal plantar part of the cuneiform. The TAT was close to the medial surface of the medial cuneiform and inserted onto the medial cuneiform and the base of the first metatarsal. This position would expose the TAT to the saw blade when performing an osteotomy. Therefore, as the osteotomy line would be moved closer to the distal articular surface, there would be a greater risk that the origin of the Lisfranc ligament and the insertion of TAT would be damaged. At the distal articular surface, it would be almost unavoidable to damage the origin of the Lisfranc ligament and insertion of TAT.

The angle between the distal articular surface and the dorsal edge of the cuneiform was 80.1 ± 1.4 degrees. If the osteotomy was taken at this angle to be parallel to the distal articular surface, then the bone would be uniform length on the plantar and dorsal surface. Additionally, the osteotomy line would pass through the space between the Lisfranc ligament and the interosseous ligament laterally and proximal to the insertion of the TAT medially and avoid injuring these structures (Figure 4).

The distance from the distal articular surface to the (1) midline of the medial cuneiform (D1), (2) level of the second TMT (D2), (3) central point of the origin of Lisfranc ligament (DL), and (4) space between the origin of Lisfranc ligament and the interosseous ligament (DS) are shown in the Table 1. D1 was 13.8 ± 1.5 mm, DS was 13.5 ± 1.6 mm, and there was no significant difference between D1 and DS ($P = .69$). We observed that the midline of the medial cuneiform passed through the ligament space.

The DL was 8.8 ± 1.9 mm, and D2 was 9.9 ± 1.6 mm. Although the difference between D2 and DL was about 1.2 mm, there was no significant difference between D2 and DL ($P = .12$). It could reduce the damage to the Lisfranc ligament if the osteotomy line was located proximal to the level of the second TMT.

The difference between D1 and D2 was 3.9 mm; an osteotomy line in this zone would pass through the ligament space, and avoid the origin of the Lisfranc ligament (Figure 5). This area was a safe zone for the Cotton osteotomy. Additionally, the bones on both sides of the osteotomy line would be large enough for correction and plate fixation.

Discussion

There are several incisions that have been described for a Cotton osteotomy, including a medial, dorsomedial, and dorsal linear incision overlying the medial cuneiform. McCormick et al[7] described a dorsal longitudinal incision over the level of the medial cuneiform and the base of the first metatarsal, and the EHL is retracted medially while the EHB is retracted laterally. Hirose[4] also advised that the EHL be retracted medially to allow the dorsal portion of the medial cuneiform to be exposed easily. Careful dissection and retraction may protect the dorsal pedis artery and the deep peroneal nerve, but it is very difficult to protect the MDCN using this approach. This study showed that the MDCN, a larger branch of the superficial peroneal nerve, passed the ankle joint and reached the dorsum of the foot where the MDCN travels medially and distally across the intermediate cuneiform and the medial cuneiform before turning to the medial side of the first metatarsal through the upper third of the first tarsometatarsal joint. There was also a small branch to the medial side of the medial cuneiform. The MDCN also

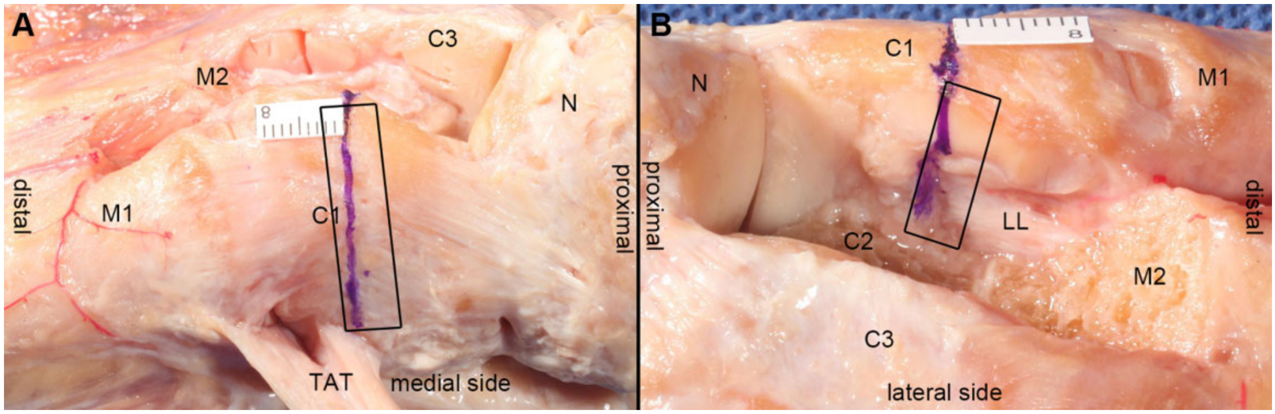

Figure 5. The safe zone for Cotton osteotomy. N, navicular; C1, medial cuneiform; C2, intermediate cuneiform; C3, lateral ligament; M1, the first metatarsus; M2, second metatarsus; TAT, anterior tibialis tendon. Black frame: the safe zone for Cotton osteotomy.

communicates with the saphenous nerve and the deep peroneal nerve.

Boffeli and Schnell[1] described an oblique dorsal medial incision in order to minimize the risk of trauma to the MDCN. This study showed that an incision located between the EHL and the TAT, parallel to the EHL with the distal part angled to the sole after crossing the first MTP joint, would be helpful to protect the MDCN. Exposure of the medial cuneiform through the space between the EHL and TAT would also allow the deep peroneal nerve and dorsal pedis artery to be left uninjured and retracted laterally with the EHL and deep soft tissue. This approach exposed the dorsal margin of the medial cuneiform clearly, and an osteotomy could be performed accurately and hardware could be placed easily to stabilize the open-wedge osteotomy. The incision would also expose the medial side of the cuneiform and allow the TAT to be easily separated from the bone and reduce the damage to the TAT. However, the thin branch to the medial cuneiform had to be cut, which would cause only a minor effect on the local sensation.

In addition to the approach, several techniques for the direction of the osteotomy have been described. Yarmel et al[11] located the osteotomy line proximally 2 to 4 mm to the second tarsometatarsal joint. Boffeli and Schnell[1,2] placed the guidewire near the lateral cortex at the mid-medial cuneiform location, parallel to the first tarsometatarsal joint and just proximal to the second TMT joint. Hirose described a transverse osteotomy from the dorsal to plantar direction through the midportion of the medial cuneiform at the level of the second tarsometatarsal joint.[4] Peterson also located the osteotomy in the dorsal, central aspect of the medial cuneiform with the assistance of lateral intraoperative fluoroscopy.[8] Lynch created the osteotomy line 1.0 cm proximal and parallel to the distal articular facet of the medial cuneiform.[6]

According to the result of the current study, the distance between the distal articular surface of the medial cuneiform and the level of the second TMT joint was 9.9 ± 1.6 mm. The midline of the medial cuneiform was consistent with the gap between the Lisfranc ligament and the interosseous ligament. The zone between the level of the second TMT joint and the midline of the medial cuneiform is the "safe zone" for Cotton osteotomy. There would be adequate bone on both sides of the medial cuneiform if the osteotomy line was located in this zone. There was enough bone stock to allow a wedge bone graft or other wedge implants to be placed in the osteotomy and allow the medial cuneiform to be fixed on either side of the osteotomy. Because of the presence of the intermediate cuneiform, the implants cannot protrude laterally.

The osteotomy line might involve some of the origin of Lisfranc ligament, but we do not believe it would reduce the stability of the Lisfranc ligament. The osteotomy line was proximal to the insertion of the TAT, but if the osteotomy was taken distally, then the TAT could be damaged. The medial cuneiform is well vascularized from the deep and superficial medial plantar artery, and an osteotomy in the midportion would maintain the blood supply of the medial cuneiform and promote healing of the opening wedge.[5]

The medial cuneiform has an irregular rhomboid shape, resulting in the distal articular surface to be oblique that leads to the angle between the distal articular surface and the dorsal edge of the medial cuneiform to be 80.1 ± 1.4 degrees. The osteotomy line should maintain this relationship and be parallel to the distal articular surface. If the osteotomy is not made parallel to the distal articular surface, then the distal bone block could result in an inverted triangle and be prone to fracture when the osteotomy is opened. A vertical osteotomy may also damage the Lisfranc ligament and the insertion of TAT. The distal thin bone that results from a vertical cut could also lead to reduced stability of the opening wedge and could delay bone healing.

Limitations

Because of the limited cadaver specimens, and differences in body/foot size in terms of the dimension of the medial cuneiform and size of the ligaments, there was variability in measurements that we may not have been able to account for. The study was a single-center study, and the results need to be further tested during surgery.

Conclusion

We believe the dorsal medial oblique incision, parallel to the EHL and about 0.5 to 1 cm medial, could not only effectively protect the MDCN, the deep peroneal nerve, and the dorsal pedis vessel, but also clearly expose the dorsal edge and the medial side of the medial cuneiform. The safe zone, between the level of the 2nd TMT space and the midportion of the medial cuneiform, could reduce damage to the Lisfranc ligament and the TAT. There would be enough bone on both sides to maintain the stability of the opening wedge and allow fixation with screws and plate. An osteotomy line, parallel to the distal articular surface, could ensure that the dorsal part was symmetric with the plantar part of the bone and minimize the risk of weakening the Lisfranc ligament and anterior tibialis tendon.

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Declaration of Conflicting Interests

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