Intraoperative Multiplanar Alignment System to Guide Triplanar Correction of Hallux Valgus Deformity

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Abstract: Hallux valgus surgery or "bunion surgery" is one of the most common surgical procedures for the foot and ankle surgeon. As we continue to gain understanding of this complex deformity, it has become clear that our understanding may be incomplete. The Lapidus procedure was described over 80 years ago and still offers many challenges. Often the choice of a Lapidus procedure is not considered due to the complexity or perceived complications. As the traditional Lapidus procedure relied on multiple freehand steps that can be fraught with error, it was often relegated to be used as a last resort. As our understanding of the hallux valgus deformity has grown it is becoming clear that the anatomic Center of Rotation of Angulation of the deformity may lie at the tarsometatarsal joint. There is also the component of the 3-dimensional nature of the deformity that may be best addressed at this anatomic Center of Rotation of Angulation. With those issues in mind, it was necessary to address the shortcomings of the traditional Lapidus procedure and progress toward more consistent, instrumented steps that could address the 3-dimensional nature of the deformity.

Level of Evidence: Level IV—Technique presentation.

Key Words: hallux valgus, triplanar, lapidus, instrumented, guidance

(*Tech Foot & Ankle* 2017;00: 000–000)

HISTORICAL PERSPECTIVE

When Paul Lapidus described his technique for arthrodesis of the firsttarsometatarsal (TMT) joint in 1934 he was building on the work of others (most notably Albrecht and Truslow).[1,2] Lapidus felt that the basis of the hallux valgus (HAV) deformity was centered at the TMT joint and was related to hypermobility.[3–5] The recommendations by Dr Lapidus at the time was to take down and prepare the first TMT joint as well as the interspace between the first and second metatarsal (MT). Correction was to address the transverse and sagittal deformities and fixate the joint in the new position.

Over the course of many decades there have been numerous modifications made on the procedure based at the first TMT joint. Some of the early modifications aimed at reducing the nonunion rates, which Lapidus noted, such as adding bone graft from the medial eminence resection and fixating the first to second MT with the kirschner wires.[6,7]

Later dissertations on the procedure began to focus on fixation of the arthrodesis. Initially this was in the form of screw osteosynthesis.[8,9] More recently with the addition of plate fixation, specifically locked constructs have been evaluated.[10–13]

In the initial publications on the Lapidus procedure, there were concerns about complications such as nonunions and malpositioning of the first ray. More recent studies have shown that the Lapidus procedure offers a safe and effective option for treatment of the HAV deformity.[14–16]

INDICATIONS AND CONTRAINDICATIONS

The Lapiplasty (Treace Medical Concepts, Ponte Vedra Beach, FL) technique may be indicated for the vast majority of HAV deformities. As the technique corrects the deformity at the Center of Rotation of Angulation in all 3 planes (coronal/frontal, transverse, and sagittal), and is adjustable to the degree of correction in those planes, nearly all HAV deformities are amenable to this type of correction. There are no limitations to this technique based on severity of the hallux valgus angle (HVA) or intermetatarsal angle. The presence (or absence) of hypermobility, or sagittal plane malalignment is not a factor in the use of this technique, and it may be used in either condition. This technique is appropriate for all ages as well. Both the adult and adolescent HAV deformities can be corrected via this approach.

The strength of this technique is the ability to reliably correct all 3 anatomic planes in HAV deformities before committing to a permanent resection of bone. This includes correcting the coronal/frontal plane MT rotation that is present in 87.3% of HAV deformities when examined by weight-bearing computed tomographic scan.[17] However, the system is adjustable to correct all deformities, from 0 rotation to maximum rotation.

One unique HAV deformity that requires special attention is the deformity secondary to metatarsus adductus. This technique may still be appropriate, and indicated in this type of deformity, however, careful attention and correction must be made to the alignment of the second and third MT. The current technique relies upon a "normal" second MT alignment in the transverse plane. Therefore correction of the second MT alignment (and often the third MT alignment) should be performed first, before using this triplane technique on the first TMT joint. Correction of the MTA deformity at the lesser MT's may be addressed using any number of osteotomies or corrective arthrodesis at the lesser TMT joint.

The described technique is contraindicated in the case of the unhealthy first metatarsal phalangeal joint (MTPJ), or "degenerative bunion". As with other previously described HAV corrective techniques, an arthritic first MTPJ should be addressed by a first MTPJ arthrodesis.

PREOPERATIVE PLANNING

The described technique can be used in the vast majority of hallux-abducto-valgus deformities, however, a thorough clinical and radiographic examination is required for adequate preparation of any hallux-abducto-valgus corrective surgery. Key clinical examination points necessary to adequately use the current technique are similar to those of many other HAV corrections. This inspection should include the exclusion of

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The authors of this paper are paid consultants and/or royalty recipients for Treace Medical Concepts the company that manufactures the Lapiplasty System.

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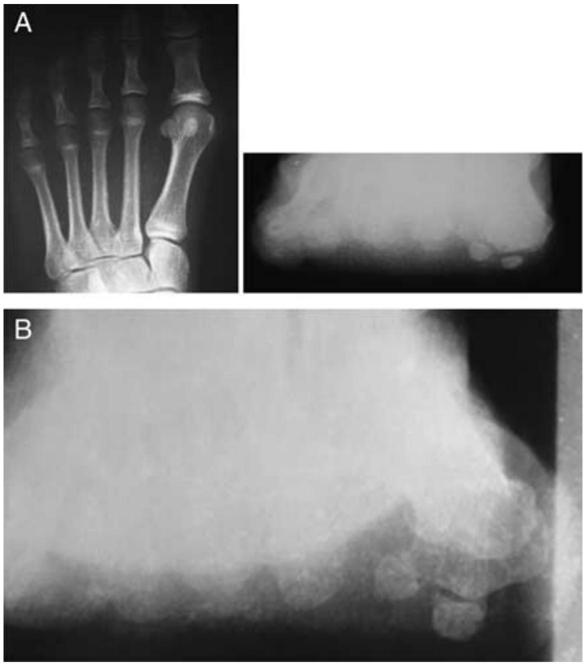

FIGURE 1. A, Axial sesamoid showing sesamoids rotated with the pronated metatarsal but not subluxed. B, Axial sesamoid with sesamoids subluxed.

equinus contracture and hindfoot malalignment. The first MTPJ should be free of arthritis, as noted above. In addition the foot should have an adequate neurovascular examination to expedite healing. Notice that this examination does not rely upon the presence of first TMT joint arthrosis, pain, or hypermobility. The presence of first MTPJ arthrofibrosis should be noted as well. This notation will predict whether or not any release of the lateral structures of the MTPJ will need to be performed as a part of the technique.

The radiographic examination requires weight-bearing x-rays of the foot. It is recommended to obtain an anterior-posterior, oblique, lateral, and axial sesamoid views. The axial sesamoid view is of utmost importance to gauge the presence of first MT coronal/frontal plane rotation (Fig. 1A). This axial sesamoid view (along with the anterior-posterior x-ray) will help assess the presence of sesamoid subluxation (Fig. 1B). Both findings (MT rotation and sesamoid position) are key in the surgical step order when using this technique. Notice the preoperative planning does not require calculation of the HVA or intermetatarsal angle.

As noted in the previous section, the described technique is not appropriate to treat the clinically or radiographically unhealthy (arthritic) first MTPJ. The other unique situation to be prepared for is the case of metatarsus adductus. The described technique can be used in the case of metatarsus adductus, but not in isolation. One should be alert to the presence of metatarsus adductus before the commencement of the procedure.

TECHNIQUE

The patient's operative extremity is marked and consent confirmed. For anesthesia, the authors preference is a regional

FIGURE 2. Dorsal incision.

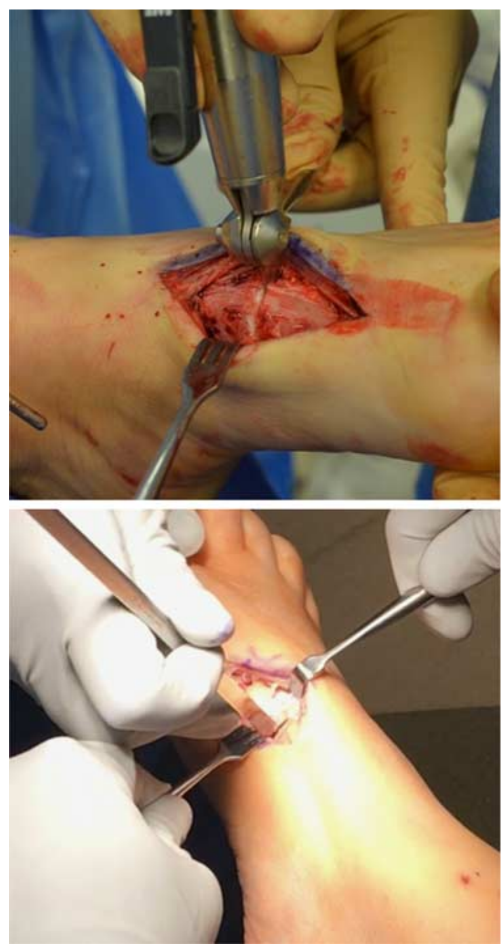

FIGURE 3. TMT arsometatarsal release (showing both the saw and osteotome options).

FIGURE 4. Fulcrum.

extremity nerve block performed by the anesthesia team. Once the nerve block has been completed, the patient is taken to the operative suite. The patient is placed on a radiolucent operating room table. A tourniquet is applied to the operative limb, and the limb is prepped and draped in the usual manner for the operative procedure. The leg is exsanguinated and the tourniquet inflated to the appropriate pressure.

The initial incision is made over the dorsal aspect of the first TMT joint, just medial to the extensor hallucis longus tendon (Fig. 2). It is essential to keep the incision dorsal for this technique to allow the guidance system to work properly. The incision is developed until the dorsal aspect of the first TMT joint is exposed staying medial to the extensor hallucis longus. At this time the entire dorsal and medial aspect of the joint are subperiosteally dissected.

Next the joint is released to allow for rotation if a frontal plane deformity is noted preoperatively. The joint can be released plantarly using a combination of oscillating saw and/or osteotome. (Fig. 3). A hemostat is the utilized to open a small space at the proximal aspect of the first and second MT interspace. The fulcrum device is then placed into the interspace of the proximal first and second MT (Fig. 4).

At this time the mobility of the the first MTPJ needs to be evaluated. If it is found to be stiff or ankylosed then a small webspace incision is made and the tight lateral structures are gradually released until the joint is mobilized. It is important to note that you should avoid opening the medial capsule of the first MTPJ at this time, as destabilizing the medial structures will not allow the system to correct all 3 planes of the deformity properly.

Once the fulcrum has been placed, a positioner device is ready to be applied. A small stab incision is made over the second MT ~1.5 to 2.0 cm distal from the first TMT joint. The positioner is then applied distal to the fulcrum and the joint (Fig. 5). The medial aspect of the positioner should be applied to the plantar medial ridge on the first MT. The lateral portion of the positioner is placed over the lateral cortex of the second MT.

At this time the correction of the HAV deformity can be corrected in all 3 planes. Once the correction has been dialed into a satisfactory position, it can be confirmed on fluoroscopy. A kirschner wire can be utilized to temporarily stabilize the corrected position with a pin placed through a cannulation in the positioner.

A joint seeker is then introduced dorsally in the first TMT joint. This provides both a placement guide for the cutting guide as well as assuring that the the cuts are made correctly in the sagittal plane to prevent dorsiflexion of the first ray. The cutting guide is then placed and temporarily fixed in place (Fig. 6). It is recommended at this point to take an image with the c-arm to confirm the alignment of the cutting guide. Once the position has been confirmed, a final pin can be introduced to

FIGURE 5. Positioner (to assist with reduction).

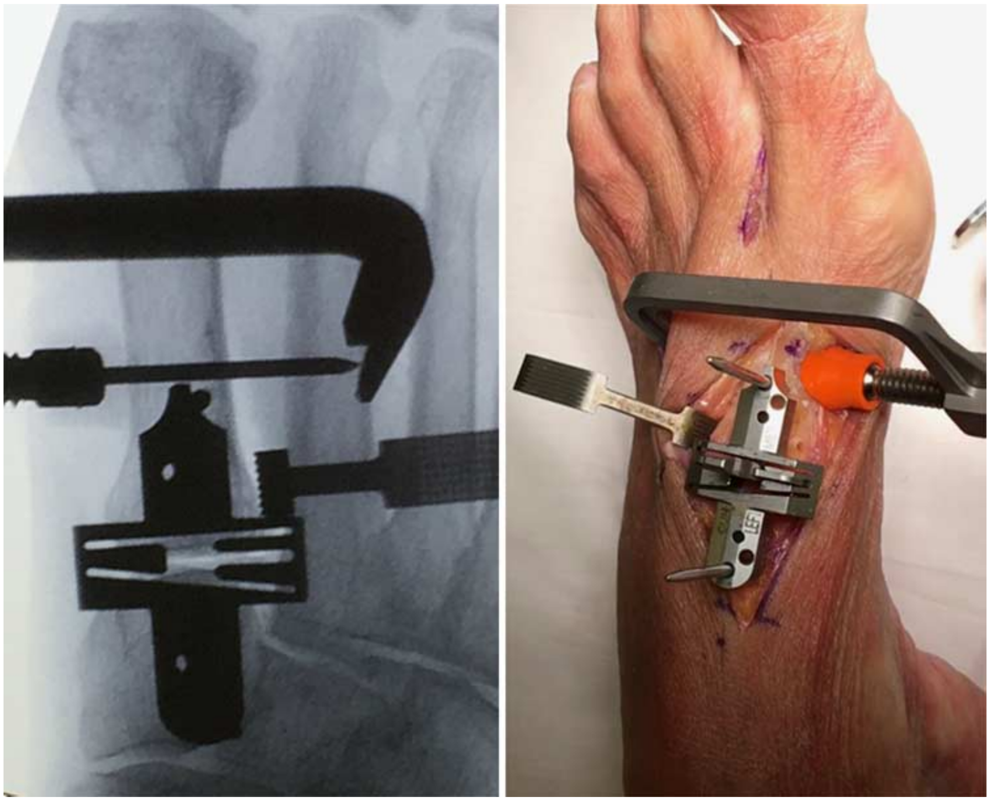

FIGURE 6. Cut guide.

secure the cutting jig in position. The joint seeker is then removed and the cuts on the base of the MT and cuneiform can be completed.

The cut bone is then removed usually with a combination of osteotome and rongeur. Once all of the cut bone has been removed, the joint is prepared for arthrodesis. A drill bit is used

FIGURE 7. Olive compression wires holding correction.

to fenestrate the joint surfaces. At this time the pin placed through the positioner will need to be removed.

Once the temporary holding pin in the positioner has been removed, the joint is axially compressed and held in the corrected position of choice and precompressed with the terminally threaded olive wire (Fig. 7). A second-threaded olive can be placed as well based on surgeon preference. It is recommended at this time to remove or release the positioner and check the correction with fluoroscopy.

If the position is satisfactory, then final fixation can be applied. The current technique utilizes a biplanar miniplate construct that offers stability and allows for physiologic micromotion to promote healing as described by Perren.[18]

The initial plate is applied straight dorsal across the first TMT joint. Once the plate is positioned, it is temporarily held in position with plate tacks placed in one hole on either side of the joint. With the plate held in position the other open holes are drilled in preparation for screw placement. The drill guides are then removed and the locking screws placed. At this time the plate tacks can be removed and drill guides and the final 2 locking screws are applied to the plate construct.

At this time a choice of either a second straight plate can be applied medially across the first TMT joint, 90 degrees to the dorsal plate, or a specially designed anatomic plantar-medial based plate can be applied. As with the dorsal plate, the second plate is held with 2 plate tacks and then secured in sequence with the 4 locked screws (Fig. 8).

Once the biplanar plate construct has been applied the surgeon does have the option of adding a screw from the first to the second MT if there is suspicion of intercuneiform instability or they would like additional stabilization of the construct.

Once the first TMT joint has been stabilized, the surgeon can direct their attention to the first MTPJ. If needed a medial based incision is used to access the joint. The decision to address the distal medial joint is based on clinical evaluation of the first MTP (MTPJ after the correction proximally has been completed. Usually it is noted that there is significant capsular thickening that may require thinning. It is also not uncommon to find a dorsal ridge on the first MT head that may also require removal. This is not usually a formal Silver type procedure or capsular plication.

Once any additional procedures have been completed, the wounds are copiously irrigated and closed in the standard manner. The patient is placed into a sterile dressing and either a stiffened postoperative shoe or low walking boot based on preference.

Weight bearing may be started at the preference of the surgeon. The authors' are currently allowing immediate protected postoperative weight bearing in a protected boot or stiffened postoperative shoe with crutches or walker. Protection is maintained for ~6 weeks based on radiographic and clinical progression.

RESULTS

Although published long-term outcomes are not yet available, the early results reviewed over the past 15 months show promise for this instrumented technique of bunion correction. We believe that there are many benefits to restoring the triplane position of the first ray back to its normal alignment. One component of realignment that should be highlighted is the effect that restoration of frontal plane alignment has on the function of the first MTPJ and the windlass mechanism of the medial column. A decrease in first MTPJ range of motion (ROM) has been reported by surgeons evaluating motion after

FIGURE 8. Plates (demonstrating both biplanar and plantar options).

osteotomy procedures. Jones et al[19] performed a cadaveric study that confirmed loss of 22.6 degrees of dorsiflexion and only 0.6 degrees of plantarflexion following proximal MT osteotomy and distal soft tissue reconstruction. They hypothesized this selective loss of dorsiflexion is secondary to nonisometric capsular repair or tight intrinsic musculature, but could not correlate loss of motion with amount of IM or HVA correction. They did not take into account frontal plane rotation or sesamoid position. In performing proximal MT osteotomies, no frontal plane correction is performed; it is possible that the lack of corrected rotation leaves the MTPJ out of normal functional alignment and explains the failure to increase first MTPJ ROM. Further, it is possible that the distal soft tissue reconstruction actually displaced the sesamoids from their grooves on the MT, leading to a loss of dorsiflexion. If frontal plane rotation is not addressed, at best, decreased first MTPJ ROM may persist as the sesamoids bind during dorsiflexion and at worst, displaced sesamoids may lead to a loss of dorsiflexion. Ebert et al[20] presented a poster presentation in which they performed a cadaveric experimental study to better understand the impact that frontal plane rotation of the first MT has on first MTPJ ROM. They noted a statistically significant relationship between frontal plane rotation and the first MTPJ ROM in a simulated first TMTJ arthrodesis positioned in 10 degree increments of increasing valgus position of the first MT. As they increased the valgus position (pronation) of the first MT there was a resulting decrease in the first MTPJ ROM. Though they did not propose a reason for the decrease in MTPJ ROM, the work of Mortier and colleagues[21] lends some insight into the mechanism. They discuss the "drive belt" effect that the occurs as the first MT pronates in the frontal plane and the sesamoid apparatus rotates along with it. The sesamoids no longer slide normally in their grooves and the sagittal plane hallux movement is restricted, replaced by a transverse pull, displacing the hallux laterally. This biomechanical concept can then be extended to provide a potential explanation for the fact the if the frontal plane malposition of the first MT is not addressed with the bunion correction, there may still be reduction of joint movement because of the tethering of the soft tissues that occur as the first MTPJ is not fully restored to its anatomic position and thus lead to joint degeneration over time.

It is apparent from these studies, that having the first ray positioned in a neutrally rotated position and positioning the sesamoids and muscular and tendinous units purely in the sagittal plane, can restore the normal functional MTPJ alignment and consequently preserves MTPJ ROM. On the basis of extensive study of the first ray anatomy we believe restoring or maintaining neutral frontal plane rotation prevents binding of the sesamoids and joint surfaces during first MTPJ ROM. The normal motion of the first MTPJ requires dorsal sliding of the hallux with a concurrent plantarflexion of the MT when it moves in the sagittal plane. Frontal plane malposition of the MT and hallux unit disrupt this normal ginglymoarthrodial mechanism. This concept is corroborated by Rush et al[22] who showed an improvement of first MTPJ ROM after correction of HAV deformity through a TMT fusion in a

FIGURE 9. The sesamoid position from rotated to corrected.

cadaver model. They suggested that the windlass mechanism is more efficient when the first MT, sesamoids, and the hallux are properly aligned with the orientation of the plantar aponeurosis. Further indication of abnormal first ray mechanics associated with HAV was reported by Koller and colleagues.[23] They measured decreased loading under the hallux and increased loading under the lateral MTs in patients with HAV and sesamoid subluxation. Looking at this data and the previously cited works we speculate that this abnormal pressure phenomenon resulted from the alteration of the normal windlass mechanism compromising the plantar flexion effect on the first MT and therefore decreasing the loading at the first MTPJ and increasing lateral loading.

Further study will be needed to clarify both the outcomes and the mechanical effects found after triplane anatomic restoration of the first ray. We speculate that accurate triplane correction will restore a more normal kinematic and kinetic function to the first ray and that this will lead to improved patient reported long-term outcomes. We are currently collecting data to present our early and midterm results from multiple surgeons at multiple centers. Comparison of the alignment following triplane correction with the radiographic and clinical results we are used to encountering after osteotomy will need to be assesed. (Figs. 9, 10).

Complications

It is appreciated that this technique attempts to minimize complications and enhances reproducibility. That said, there are key components that need to be identified for the overall success of this procedure.

A complication of this procedure would be a technical error addressing any medial capsular work before rotation is used. If the medial capsule is released early it will cause dissociation of the sesamoid complex and cause issues with correction. The medial sesamoid complex must be intact to allow for proper rotation and sesamoid alignment.

Sagittal plane alignment is critical for overall success. Lateral radiographs must be taken intraoperatively to ensure optimal alignment during the procedure. Proper sagittal alignment is essential to decrease the chance of transfer issues to the second MT. There are clinical pearls that are utilized to enhance this outcome.

Sesamoid alignment is another key factor for repair and long-term success.[24] If preoperative axials demonstrate sesamoid subluxation then a minimal lateral release is performed. If at the end of the procedure they are not lined up sufficiently then a more aggressive release is performed and/or recheck of enough varus rotation of the MT. This is to prevent malpositioning of the sesamoid complex to decrease the chance of recurrence.

FIGURE 10. Both the derotated metatarsal and realigned sesamoids.

Although nonunion and delayed union are possibilities; the incidence of this is rare due to the enhancement of “biological” healing provided by the biplanar plating system.

Shortening of the first ray segment is usually a concern for the Lapidus procedure. It has been frequently observed that the restoration of the length is maintained by the “correct then cut” technique currently described. Minimal bone is removed to allow well coaptation of osseous surfaces.

Future of the Technique

As with any newer technique, improvements and modifications are a normal and expected part of the progression. The current triplanar guidance and correction system is no different. However, more important than the actual system is the dedicated focus to continue to research, investigate and push our understanding of the mechanics of the HAV deformity and seek to truly uncover a more complete understanding of the pathogenesis.

The understanding of the HAV deformity as a 3-dimensional issue is in its infancy. There will be additional energy focused on deepening our knowledge of this issue as well as striving to innovate solutions that will continue to improve outcomes.

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