Reduction of the Intermetatarsal Angle, Hallux Abductus Angle, and Tibial Sesamoid Position in the Derotational Lapidus versus the Traditional Modified Lapidus Procedure

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Statement of Purpose

The aim of this study was to make radiographic comparisons between two Lapidus Bunionectomy techniques; the wedge resection and the parallel cut with derotation of the first metatarsal.

Introduction

The metatarsal cuneiform joint has been identified as the level of deformity in a bunion, this is often termed the CORA (1). Typically during the Lapidus procedure, a flat cut is made on the metatarsal base and a laterally based wedge is taken from medial cunieform. This techinique has been described by many authors (2-11). More recently published studies confirm the existence of frontal plane deformity (12-14). This inherently makes the bunion deformity tri-plane in nature. These studies have described techniques for derotation of the metatarsal to correct the deformity in all three planes. The purpose of this article is to compare radiographic outcomes between two groups; one in which a laterally based wedge was removed from the medial cuneiform and one in which no wedge was removed and frontal plane derotation was performed. We suspect there will be similar correction of the intermetatarsal angle (IMA) and and hallux abductus angle (HAA) along with tibial sesamoid position (TSP) with derotation vs wedge resection.

Patients and Methods

After obtaining approval from our institutional review board, we reviewed records of patients who underwent a lapidus bunionectomy. A retrospective review was performed on Lapidus procedures performed by four total surgeons (DB, RB, RG, LD). Our indications for the lapidus procedure included a moderate to severe hallux valgus or hallux valgus of any degree of severity with a hypermobile first ray. Patients were excluded if they had previous bunion surgery or violation of the 1st metatarsophalangeal complex and if they had a concommitant 1st metatarsophlangeal joint arthrodesis. We identified a total of 28 derotational lapidus procedures performed on 24 patients with an average follow up of 24 months. A total of 24 wedge resection Lapidus procedures were performed on 22 patients. The intermetatarsal 1-2 angle (IMA), tibial sesamoid position (TSP), and hallux abductus angle (HAA) were measured for pre-operative weight bearing x-rays and and post-operative weight bearing x-rays at most recent follow up. The data was then analyzed by a hospital statistician. We measured percent change in the above radiographic parameters. We also secondarily analyzed age, BMI, and sex in relationship to correction.

Surgical Technique for Wedge Resection

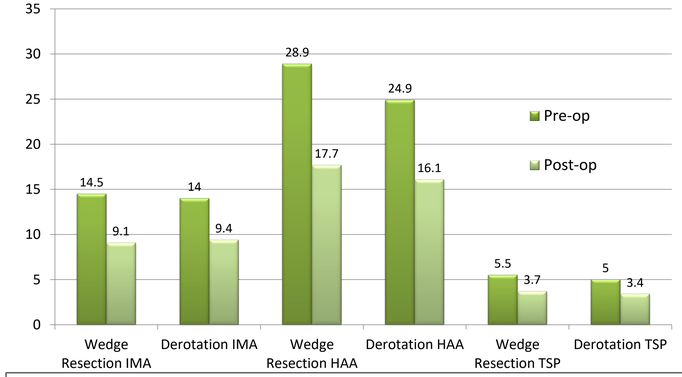
With the patient in a supine position, an ipsilateral bump was placed under hip of the operated extremity. General anesthesia and a pneumatic tourniquet was used. A linear incision was made beginning at the level of the 1st metatarsophalangeal joint and extending proximally to the 1st metatarsocuneiform joint (MCJ). Attention was then directed to the first interspace. Soft tissues were dissected in the 1st interspace a lateral release was performed. Attention was then directed to the dorsal aspect of the 1st MCJ. The tibialis anterior tendon was identified and retracted. The 1st MCJ was dissected and visualized. Soft tissues were freed from the 1st MCJ. A sagittal saw was then used in order to make a lateral wedge shaped bone excision of the distal aspect of the medial cuneiform. Next, the cartilage was then removed from the base of the 1st metatarsal using the sagittal saw perpendicular to the long axis of the bone. The 1st metatarsal was manipulated into a plantar flexed and abducted position and fixed with a kirschner wire from the dorsal aspect of the base of the 1st metatarsal into the medial cuneiform. The 1st MCJ fusion site was fixated in one of two ways; two crossing screws or one compression screw plus a locking plate. In most cases, the remaining medial eminence was resected.

Surgical technique for parallel cute with frontal plane derotation

With the patient in a supine position, an ipsilateral bump was placed under hip of the operated extremity. General anesthesia and a pneumatic tourniquet was used. A linear incision was made at the dorsomedial aspect of the 1st metatarsocuneiform joint (MCJ). Joint preparation consists of a takedown of articular cartilage with cuts made parallel to the joint surface. Fenestration of the subchondral bone was performed. Attention was then directed to reduction of the bunion deformity in the sagittal, transverse and frontal planes. The hallux was dorsiflexed and the first ray is plantar flexed to reduce the deformity in the sagittal plane. Next, a varus rotation force was applied to the hallux to de-rotate the first metatarsal in the frontal plane in a varus direction and into a neutral position. Following the reduction, the great toe should maintain a neutral position. Last, a medial to lateral force was placed on the first metatarsal head to reduce the transverse plane. Temporary fixation was achieved using two Kirschner wires before rigid internal fixation is placed. Once adequate reduction was noted clinically and fluoroscopically, a partially-threaded cannulated screw was inserted creating compression across the 1st MCJ. The screw was placed from centrally on the dorsal metatarsal and directed to the plantar medial portion of the medial cuneiform. A locking plate was then placed spanning the 1st MC fusion site.

Patient Demographics

	Wedge Resection N=22	Derotation N=24
Age	45.8	42
Females	20	18
Males	2	6
BMI	28.8	27.3



There was no statistically significant difference in the pre-operative IMA, HAA, and TSP (P-values were 0.63, 0.12, and 0.23, respectively).
There was no statistical significance in post-operative IMA, HAA, and TSP (p-values were 0.68, 0.37, and 0.51 respectively).

Percent Change in:	Wedge Resection	Derotation	p-value
IMA	-0.346	-0.289	0.36
HAA	-0.352	-0.258	0.33
TSP	-0.333	-0.293	0.57

Discussion

With recent literature confirming the presence of the frontal plane component of the bunion deformity, the surgical approach to the Lapidus procedure has shifted. Mizuno first described a detorsional osteotomy in 1956. DiDomenico then described the procedural approach to multiplanar bunion correction using the hallux to drive derotation of the valgus metatarsal by way of ligamentotaxis (12). Dayton went on to describe first MPJ joint alignment with a derotational Lapidus. He found a decrease in PASA and HAA with minimal or no soft tissue balancing and no distal osteotomy (1). He stated that the medial eminence or bump actually represents the dorsal medial surface of the head of the first metatarsal that is brought into prominence by rotation through eversion and the degree of first metatarsal pronation has a linear relationship to the amount of medial deviation of the first metatarsal. Dayton went on the further explain that when comparing the sesamoids on axial radiographs with their AP counterpart, the sesamoids are still found in their anatomic positions despite their appearance of lateral translocation on the AP radiograph.

There are several advantages to derotation versus wedge resection. Not only does derotation of the metatarsal contribute to deformity correction, it also gives the surgeon greater bone to bone contact and surface area for placing fixation across the 1st metatarsal-cuneiform joint. Pre-operatively the deformity (HAV) of the metatarsal is rotated in a pathologic position of valgus. Because of the pathologic position, the metatarsal base is rotated in valgus. Subsequently, the inferior broad base of the most proximal portion of the metatarsal is situated dorsal laterally and is not in contact with the medial cuneiform. With derotation of the metatarsal, this portion of the metatarsal base is now in contact with the medial cuneiform providing a larger bone-to-bone contact area. By performing anatomic joint resection and then rotating the first metatarsal in the frontal plane out of valgus and into neutral position, this optimizes the bone-bone surface area, while providing the surgeon a larger target area to place fixation and increased contact for fusion. This technique should simultaneously decrease the medial eminence appreciated with all HAV deformities. Some surgeons suggest plantarflexing the metatarsal by sliding the metatarsal plantar- again this decreases the bone surface area.

One must also examine the effects of derotating in terms of stress and strain. Stress to an area is calculated by dividing force by area ($\sigma = \frac{F}{A}$). Having the metatarsal derotated provides a larger area therefore dividing the force by larger number resulting in decreased stress to the area. Inversely, the load the construct can withstand is calculated by multiplying stress and area ($F = \sigma A$). Again, the larger the area, the more force that the area can withstand. A larger surface area allows for dispersion of ground reactive forces hence not concentrating force in one area. When the metatarsal is in a derotated position there is a transition from the metatarsal to the cuneiform in which there is a non-uniform cross sectional area. This results in varying stress and strain from the metatarsal to the cuneiform. Further, stiffness is dependent on area. Stiffness (k) is how a material resists deformation in response to an applied force. It is found by multiplying the area (A) times the Young's modulus (E) of bone and dividing that by the length ($k = \frac{AE}{L}$). It is advantageous to have uniform stiffness across the fusion site .

Our study found no statistically significant difference between the wedge resection technique and derotation technique. Although there was not a statistical significance in the radiographic data, the wedge resection group appeared to have had slightly better correction of deformity. Interestingly, we were able to achieve hallux abductus angle correction without invading the 1st metatarsal-phalangeal joint. This could mean less post-operative pain, stiffness, and faster recovery. This reduces the likelihood of over-resection of the medial eminence and associated complications of invading the 1st metatarsal phalangeal joint such as hallux varus and tibial sesamoid subluxation.

We were limited in our retrospective design, small sample size, as well as not having a single surgeon for all procedures. Additional research needs to be done in comparing these two techniques. A single surgeon prospective study would be of higher quality. A larger sample size may yield statistically significant differences. Pre-operative and post-operative sesamoid axial views would also provide better insight into the amount of frontal plane correction. Furthermore, other variable should be explored such as subjective pain scores, functional scores, nonunion rates, etc.

In conclusion, our technique for the Lapidus bunionectomy allows the surgeon to achieve reduction of the IMA, HAA, and TSP with derotation of the metatarsal without violation of the 1st metatarsal phalangeal joint. This derotation maximizes the surface area at the metatarsal-cuneiform complex. It also allows for increased contact area for fusion and a greater surface area when placing fixation.. Additionally, the stress to the fusion site is decreased and the load the construct can withstand is increased.

References

1. Dayton, Paul, et al. Relationship of frontal plane rotation of first metatarsal to proximal articular set angle and hallux alignment in patients undergoing tarsometatarsal arthrodesis for hallux abducto valgus: a case series and critical review of the literature. The Journal of Foot and Ankle Surgery 52.3: 348-354, 2013.
2. Scranton, Pierce E., J. Chris Coetzee, and Dominic Carreira. Arthrodesis of the first metatarsocuneiform joint: a comparative study of fixation methods. Foot & ankle international 30.4:341-345, 2009.
3. Coetzee, J. Chris, and Daren Wickum. The Lapidus procedure: a prospective cohort outcome study. Foot & ankle international 25.8:526-531, 2004.
4. Ellington, J. Kent, et al. The use of the Lapidus procedure for recurrent hallux valgus. Foot & ankle international 32.7:674-680, 2011.
5. Kopp, Franz J., et al. The modified Lapidus procedure for hallux valgus: a clinical and radiographic analysis. Foot & ankle international 26.11:913-917, 2005.
6. Bednarz, Paul A., and Arthur Manoli. Modified Lapidus procedure for the treatment of hypermobile hallux valgus. Foot & ankle international 21.10:816-821, 2000.
7. Sangeorzan, Bruce J., and Sigvard T. Hansen Jr. Modified Lapidus procedure for hallux valgus. Foot & ankle 9.6:262-266, 1989.
8. Baravarian, Babak, Gary B. Briskin, and Patrick Burns. Lapidus bunionectomy: arthrodesis of the first metatarsocuneiform joint. Clinics in podiatric medicine and surgery 21.1:97-11, 2004.
9. Wang, James C., and Brendan M. Riley. A new fixation technique for the Lapidus bunionectomy. Journal of the American Podiatric Medical Association 95.4:405-409, 2005.
10. Saxena, Amol, Aidan Nguyen, and Elise Nelsen. Lapidus bunionectomy: early evaluation of crossed lag screws versus locking plate with plantar lag screw. The Journal of foot and ankle surgery 48.2:170-179, 2009.
11. Dayton, Paul, Merrell Kaawe, and Mindi Fellmeier. Is our current paradigm for evaluation and management of the bunion deformity flawed? A discussion of procedure philosophy relative to anatomy. The Journal of Foot and Ankle Surgery 54.1:102-111, 2015.
12. DiDomenico, Lawrence A., et al. Correction of frontal plane rotation of sesamoid apparatus during the Lapidus procedure: a novel approach. The Journal of Foot and Ankle Surgery 53.2:248-251, 2014.
13. Klemola, T., et al. First Tarsometatarsal Joint Derotational Arthrodesis for Flexible Hallux Valgus: Results from Follow-Up of 3–8 Years. Scandinavian Journal of Surgery 106.4:325-331, 2017.
14. Dayton, Paul, et al. Relationship of frontal plane rotation of first metatarsal to proximal articular set angle and hallux alignment in patients undergoing tarsometatarsal arthrodesis for hallux abducto valgus: a case series and critical review of the literature. The Journal of Foot and Ankle Surgery 52.3:348-354, 2013