

# New Techniques and Alternative Fixation for the Lapidus Arthrodesis

Nathan J. Young, DPM, AACFAS, AAFAS<sup>a,b</sup>,  
Charles M. Zelen, DPM, FACFAS, FACFAOM<sup>a,b,\*</sup>

## KEYWORDS

- Lapidus procedure • First metatarsocuneiform arthrodesis
- Polyaxial and monoaxial locking plates • Mini TightRope • External fixation
- Arthroscopy

## KEY POINTS

- Arthrodesis of the first metatarsocuneiform joint is a powerful procedure to be used in the correction of various pathologic conditions of the first ray.
- Because of its history of high rates of nonunion, many surgeons are reluctant to perform this procedure.
- Newer devices, especially the advent of locking plate technology slightly more than a decade ago, have allowed surgeons to confidently fixate the joint and help reconstruct the first ray with a lower rate of nonunion.
- Other innovative techniques and technology, such as arthroscopic fusion of the joint and the use of exceptionally strong sutures to decrease and fixate the intermetatarsal space, are still in their infancy; their long-term results remain to be seen.

## INTRODUCTION

Fusion of the first metatarsocuneiform (MTC) joint was first described by Albrecht in 1911<sup>1</sup> but was popularized by Lapidus<sup>2</sup> in 1934. In his report, Lapidus described fixation of the fusion using a number zero chromic catgut suture and allowed immediate postoperative ambulation in a leather-soled shoe.<sup>2</sup> He abandoned the procedure for a time because of the lack of adequate internal fixation.<sup>3</sup> Since Lapidus' time, numerous fixation methods have been advocated, including staples, Kirschner wires (k wires), lag screws, plates, and, more recently, external fixation or locking plates.<sup>4</sup>

<sup>a</sup> Foot and Ankle Associates of Southwest Virginia, 1802 Braeburn Drive, Suite M120, Salem, VA 24153, USA; <sup>b</sup> Professional Education and Research Institute, 222 Walnut Avenue, Roanoke, VA 24016, USA

\* Corresponding author. Foot and Ankle Associates of Southwest Virginia, 1802 Braeburn Drive, Suite M120, Salem, VA 24153, USA.

E-mail address: cmzelen@periedu.com

Regardless of the fixation method, one of the potential complications when performing this procedure is nonunion of the arthrodesis.<sup>5</sup> Before advancements in rigid internal fixation, nonunion rates for the Lapidus procedure approached 25%.<sup>6</sup> As a result, many surgeons were hesitant to perform the procedure.<sup>7</sup> After advancements in screw technology, published data suggested the nonunion rate to be between 3.3% and 12.0%.<sup>4,8,9</sup> Patel and colleagues<sup>9</sup> found the nonunion rate of the Lapidus procedure to be 5.3% in 227 feet retrospectively analyzed. Interestingly, in a systematic review of the literature, Donnenwerth and colleagues<sup>5</sup> evaluated published research of nearly 600 feet that had first MTC joint curettage with 2 crossed compression screws and also found the nonunion rate to be 5.3%.

Some surgeons have limited their use of the Lapidus procedure because of the risk of nonunion. Blitz<sup>6</sup> argues that nonunions exist even in the best hands and therefore, they should not be considered a complication but rather "an expected outcome in a low percentage of cases."<sup>6</sup> The Lapidus, however, remains one of the most powerful procedures in the correction of common foot pathologies, including metatarsus primus varus associated with hallux abducto valgus (HAV), first ray hypermobility, arthrosis of the first MTC joint, recurrent HAV, stabilization of the medial column, a long first metatarsal, and HAV associated with ligamentous laxity.<sup>4,8,10,11</sup>

In his report, Lapidus<sup>2</sup> described fixation of the fusion using a number zero chromic catgut suture and allowed immediate postoperative ambulation in a leather-soled shoe. He abandoned the procedure for a time because of the lack of adequate internal fixation.<sup>3</sup> Modern principles of bone fixation developed in 1958 by the Swiss association Arbeitsgemeinschaft fuer Osteosynthesefragen, or AO, have improved the success rate and include anatomic reduction, rigid internal fixation, atraumatic technique on the soft tissues and bone, and early pain-free range of motion. With the advent of AO fixation, biomechanical studies have shown that the stainless steel screws are 4 times stronger and are 12 times more stable than suture fixation.<sup>12</sup> As such, suture or wire fixation of the Lapidus arthrodesis is no longer considered.

Although suture fixation may have been abandoned as a technique for fixation of the fusion, it still may be considered to maintain and reduce the intermetatarsal angle during a Lapidus. Arthrex offers the Mini TightRope (Arthrex, Naples, FL), which is a No. 2 FiberWire suture with 2 stainless steel buttons. This suture is a novel way to help correct the intermetatarsal angle. The Mini TightRope device is to be used as an adjunct fixation device in the Lapidus procedure. There have been several case studies by foot and ankle surgeons describing this use. Hasselman and colleagues<sup>13</sup> has submitted the results of this procedure for publication in 40 patients. He experienced no nonunions or malunions, no recurrence of the deformity, and he reports that the correction from the procedure is not lost over time. His technique inserts the Mini TightRope proximally through the base of the first metatarsal and into the base of the second metatarsal. This placement holds the correction during the application of the plate and screw. The Mini TightRope can also be inserted distally in the neck of the first metatarsal and secured to the second metatarsal to correct and maintain the transverse plane stability and to augment the correction of the plate and screws. Potential disadvantages may include delayed or nonunion of the fusion caused by increased tension on the medial aspect of the arthrodesis, fracture of the second metatarsal, and hallux varus. These complications can lead to significant added expense. Therefore, more studies evaluating the long-term results are needed to determine the true long-term efficacy of this type of fixation.

For many years, the gold standard in fixation of the Lapidus was by placing 2 crossing screws through the first MTC joint as made popular by Sangeorzan and Hansen<sup>14</sup> in 1989. Some investigators prefer the insertion of an additional screw

through the first metatarsal and into the intermediate cuneiform and/or from the medial cuneiform into the intermediate cuneiform. Biomechanical research has yielded controversial results. Gruber and colleagues<sup>8</sup> found that crossing screws alone were equivalent in terms of rigidity compared with crossing screws with a dorsomedial plate. Cohen and colleagues<sup>15</sup> also found that crossing screws were stronger and provided increased rigidity when compared with a dorsal H-plate without any interfragmentary screws.<sup>15</sup> Klos and colleagues,<sup>16</sup> however, performed a biomechanical study and found that a dorsomedial locking plate with an adjunct compression screw was, in fact, superior to crossing screws. Clinically, plating with a single screw or crossing screws seems to offer superior results with increased rates of fusion and/or earlier return to weight bearing when compared with crossing screws alone.<sup>4,7,11,17,18</sup> Some investigators recommend plantar interfragmentary lag screw insertion combined with plating systems. This technique provides compression across the tension side of the joint.<sup>10,11</sup> Research has yielded good results thus far; however, it is technically more demanding and more time consuming.

Because of the notoriously high rate of complications including nonunion following the Lapidus procedures, innovators have designed plates specifically for this purpose. Newer-generation plating devices seek to provide excellent conformity to the local anatomy; allow for ease of placement of locking and nonlocking screws; provide rigidity and stability; and, in some instances, provide compression. Over the last few years, it has become more commonplace for foot and ankle surgeon to use locking plates for the Lapidus procedure primarily.<sup>19</sup> Examples of newer-generation Lapidus plates include the VariAx plate (Stryker, Mahwah, NJ); CP Anchorage plate (Stryker, Mahwah, NJ) (**Figs. 1 and 2**); Contours LPS (Orthofix, Lewisville, TX); FPS Lapidus plate (Osteomed, Addison, TX); Ascension Orthopedics Lapidus plate (Ascension Orthopedics, Austin, TX); Arthrex Lapidus plate (Arthrex, Naples, FL); Darco LPS plate (Wright Medical Technology, Inc, Arlington, TN); Aptus plate (Medartis, Basel, Switzerland) (**Fig. 3**); Depuy Alps plate (Biomet, Warsaw, IN); Accumed Forefoot locking plate (Accumed, Hillsboro, OR) (**Fig. 4**); and the Synthes First TMT fusion plate (Synthes, West Chester, PA).

Fixation via plating technology achieves stability in different ways, depending on whether the plate is locking or nonlocking. Nonlocking plates work by compressing the plate to bone causing static friction. Similarly, locking plates limit forces at the fracture or fusion site by acting as a single beam. This single-beam construct gives increased strength and stiffness when compared with its nonlocking plate counterparts. Because the construct acts as a single unit, it requires very high forces before screw toggle or failure occurs. Because of its increased stability these types of plates provide, they should be especially considered in the high-risk fusion.<sup>20-23</sup>

One disadvantage of earlier-generation locking plate systems was that they were fixed-angle, or monoaxial, systems. Occasionally, this led to difficulty during screw insertion because of the blocking of the lag screw or other hardware. In addition, with the unique contour of the first MTC joint, screws could also be placed in a less-than-optimal position because you are constrained to only one angle for insertion. Many newer-generation locking plate systems are polyaxial, which gives the surgeon the possibility to insert the screws at a different angle, thus allowing increased freedom anywhere from 10° to 15° from the center of the screw hole in any direction. Most polyaxial locking plates have holes that can accept either a locking or a nonlocking screw. The usage of a nonlocking screw in the hybrid plate provides better conformity of the plate against the bone because this nonlocking construct is able to bring the plate and the bone into close apposition. Using a mixture of nonlocking and locking screws also maintains a lower overall cost.



**Fig. 1.** Preoperative radiographs of severe bunion deformity as well as second hammertoe and elongated partially dislocated second metatarsophalangeal joint. Postoperative radiographs of the Anchorage CP plate with excellent fusion of the first metatarsal cuneiform joint, reduction of the bunion deformity, and correction of the hammertoe and second metatarsal phalangeal joint pathology.

The use of external fixation in Lapidus procedures is also a viable option. External fixation offers the ability to bear weight immediately after surgery; there is no retained internal hardware when the fixator is removed; and, when performed correctly, a predictable fusion is usually obtained.<sup>24</sup> A powerful indication for external fixation is in the case of revision Lapidus fusion because of infected hardware or osteomyelitis to provide an effective means for septic fusion.

Wang and Riley<sup>24</sup> presented 102 patients who had a Lapidus procedure with external fixation. They found that the average time to unassisted full weight bearing was 13.1 days; the average time to fusion was 5.3 weeks, with removal of the fixator at 5.5 weeks postoperatively. They had no incidences of delayed union or nonunion. They had one case of pin track irritation/infection, which resolved with appropriate pin care and antibiotics.<sup>24</sup> Although this study provided a complication and healing rate that is rather unparalleled in the literature, Treadwell's<sup>25</sup> series provided a more realistic rate of complications often seen with external fixation-related midfoot fusions. Treadwell<sup>25</sup> evaluated a series of 16 proximal metatarsal procedures using a rail external fixator, 11 of which were Lapidus procedures and 5 of which were base wedge osteotomies. He reported significant complications, including 10 out of 16 pin tract infections, 5 which required isolated pin removal and another 2 required removal of the entire frame because of the severity of infection. Seven patients developed hardware loosening. Two patients required long-term intravenous antibiotic therapy. Two of the 11 Lapidus procedures went on to nonunion.<sup>25</sup> However, Van Gompel and Dei<sup>26</sup> warned that it is difficult to make any conclusive statements



**Fig. 2.** Postoperative radiographs of the Anchorage CP plate with excellent fusion of the first metatarsal cuneiform joint, reduction of the bunion deformity, and correction of the hammertoe and elongated second metatarsal. Postoperative radiographs of the Anchorage CP plate with excellent fusion of the first metatarsal cuneiform joint, reduction of the bunion deformity, and correction of the hammertoe and second metatarsal phalangeal joint pathology.

about the use of external fixation in the Lapidus procedure and recommended further study with larger patient populations.

Another possible technique for Lapidus arthrodesis in the foot and ankle surgeon's armamentarium is the arthroscopic Lapidus. The arthroscopic technique may allow better visualization of the plantar and lateral side of the joint. It may allow easier and more thorough removal of the articular cartilage without needing to take the subchondral bone, which may help eliminate excessive shortening of the first ray. It may also provide better cosmesis and less scar formation, less postoperative wound pain, and less risk of infection.<sup>27</sup>

Lui and colleagues<sup>28</sup> described their technique for primary arthrodesis of the first MTC joint in *Arthroscopy* in 2005. The instrumentation that they recommend is a 2.7-mm, 30° arthroscope, a small periosteal elevator, an arthroscopic osteotome, and an arthroscopic awl. A 21-gauge needle is inserted into the joint and it is inflated with 2 to 3 mL of sterile normal saline. Two arthroscopy ports are then made plantar medially and dorsomedial to the joint. After visualization of the joint using the arthroscope, the articular cartilage is denuded using the osteotome and periosteal elevator leaving the subchondral bone intact. Arthroscopic awls are then used to perform microfracture to the subchondral bone. After reduction of the intermetatarsal angle and with some mild plantar flexion, a 4.0-mm cannulated screw is inserted in a



**Fig. 3.** Polyaxial locking plate used here for neutralization allows for angular insertion of the screws based on position surgeon assesses as most appropriate. Herbert headless screws are used for joint compression and metatarsal-intercuneiform stability.



**Fig. 4.** Mono axial locking plate used for neutralization and headless Herbert screws for joint compression. Also note the Akin osteotomy fixated with resorbable screw fixation.

lag-screw fashion from proximal dorsal to distal plantar to compress the joint. A second 4.0-mm positioning screw is inserted from the base of the first metatarsal to the base of the second metatarsal, which is subsequently removed at 12 weeks. Patients are kept non-weight bearing for an extended period of time, up to 12 weeks with this procedure. Arthroscopy of the first MTC joint may provide an effective minimally invasive means of the Lapidus procedure.

Lui and colleagues and Lui<sup>27,28</sup> reported single case studies of the arthroscopic technique. They described a case of primary arthrodesis using arthroscopy and also a case of revision arthrodesis using arthroscopy. Michels and colleagues<sup>29</sup> performed arthroscopic Lapidus fusion on 5 patients and reported that the hallux valgus angle improved by 25.6°, the intermetatarsal angle improved by 10.6°, and shortening of the first ray was limited to 2.7 mm. They had fusion in all 5 patients. Lui and colleagues<sup>28</sup> recommend that this technique only be used by surgeons who are familiar with small joint arthroscopy because of the high degree of technical demand.

Bone healing across a fracture or an osteotomy typically takes 6 to 8 weeks to achieve in a healthy individual. Because the Lapidus procedure has a high risk of non-unions, many surgeons will limit their patients to a strict non-weight-bearing protocol during this time period.<sup>5</sup> Prolonged non-weight bearing can have deleterious effects for patients, such as disuse osteopenia, muscle atrophy, weight gain, deep vein thrombosis, and pulmonary embolism.<sup>30</sup> After periods of prolonged non-weight bearing, it is vital to gradually increase patients' weight-bearing activities to prevent injury secondary to the bone and muscle atrophy. It is also essential to provide proper prophylaxis with an anticoagulant during the early non-weight-bearing period to help prevent deep vein thrombosis and pulmonary embolism.

Because of the disadvantages of prolonged non-weight bearing, there is a growing amount of research that advocates earlier weight bearing after a Lapidus fusion. Some investigators recommend weight bearing at 2 weeks postoperatively once the surgical wounds have healed.<sup>5-7</sup> Others recommend near-immediate weight bearing.<sup>17</sup> When considering early weight bearing, it is vital to consider multiple factors, including the patients' age, activity level, smoking status, usage of nonsteroidal antiinflammatory drugs, obesity, and whether they are neuropathic or not.<sup>6</sup> Sangeorzan and Hansen<sup>14</sup> promoted early weight bearing and found 92% union rate. Sorenson and colleagues<sup>7</sup> applied locking plates for a Lapidus fusion and allowed weight bearing at 2 weeks and had 100% union. Saxena and colleagues<sup>11</sup> found no difference in fusion rates between crossing screws and locking plates for Lapidus fusion but did find that the locking-plate group ambulated at 4 weeks instead of 6 weeks in the crossing-screw group. Basile and colleagues<sup>17</sup> allowed immediate postoperative partial weight bearing by fusing the first MTC joint with crossing screws and also inserting a stabilizing percutaneous k wire and compared the results with their control group who had crossing screws only and were non-weight bearing for 6 weeks in 41 patients. Neither group had nonunions or malunions. Although very little research exists on the definitive length of non-weight bearing after a Lapidus, existing research may indicate that with newer plating options and in selected individuals, earlier weight bearing may be appropriate.

#### **AUTHORS' SURGICAL TECHNIQUE FOR LAPIDUS ARTHRODESIS**

With the patient placed on the operating table in the supine position, a well-padded pneumatic calf tourniquet is placed on the operative extremity. If needed, an ipsilateral hip bump is placed to help adduct the extremity.

A dorsomedial skin incision is made from 1 cm proximal to the first MTC joint and extended to the level of the hallux interphalangeal joint. Attention is first directed to the metatarsal head. The medial eminence is resected and a lateral release is performed if indicated. Next, with attention directed proximally, a longitudinal incision is made at the first MTC joint to expose the joint. Next, the first MTC joint surfaces are carefully resected with a triangular cut made on the cuneiform with more bone taken laterally than medially to reduce the intermetatarsal angle, and a straight cut is made over the metatarsal. The medial aspect of the second metatarsal is denuded; if needed, a small section of bone is taken from the lateral aspect of the first metatarsal, which allows for lateral translation of the first metatarsal and further deformity correction. Finally, some plantar flexion of the first metatarsal is created to compensate for the shortening of the ray. Fenestrating the joint surface with a 1.5-mm drill is recommended after bone resection to obtain further bleeding channels for healing.

Once the joint surfaces are prepared and the deformity reduced, one guidewire is directed from the dorsal aspect of the base of the first metatarsal into the plantar aspect of the medial cuneiform through the MTC joint. Another guidewire is inserted from the plantar medial aspect of the base of the first metatarsal and directed proximally and laterally into the intermediate cuneiform. Headless compression screws are then inserted. Positioning is confirmed using intraoperative fluoroscopy. After insertion of the compression screws, a dorsomedial locking plate is then applied.

The wounds are closed in anatomic layers, and a dry sterile dressing is applied. A well-padded posterior splint is applied. At the 2-week follow-up, the sutures are removed and a short leg fiberglass cast is applied for an additional 4 weeks. Light weight bearing is permitted after the second week.

### ***Case Presentation***

This patient is a 21-year-old woman who presented after a recent failed Lapidus arthrodesis. She underwent surgery 3 months before and had gapping and pain at the first MTC joint. Her past medical history was significant for smoking, and her social history significant for being a single mother with a small child. The initial treating physician related she was weight bearing immediately postoperatively because of caring for her young child, which was thought to be the cause of the joint distraction. Her treating doctor offered her a bone stimulator; but because of the significant joint distraction appreciated on radiograph, she opted for surgery and was referred to the authors for revision.

On physical examination, her neurovascular status was intact and normal. She did have some swelling around the surgical site. She had specific pinpoint pain and discomfort over the first MTC joint. She otherwise had good range of motion and muscle strength. Radiographs show crossing headless compression screws and a distracted nonunion of the right first MTC joint (**Figs. 5 and 6**).

The surgery was performed removing the original hardware, and there was a clear nonunion across the joint. The joint was re-resected to good bleeding bone, and the joint surfaces were fenestrated. Headless compression screws were then used to compress the fusion site and to slightly plantar flex the first ray to accommodate the shortening from the resected bone. Vitos Bone Graft Substitute (Stryker, Mahwah, NJ) with bone marrow aspirate was inserted into the osteotomy to enhance healing. A 4.5-mm Herbert compression screw was placed to compress the joint surfaces. A polyaxial Variax H-plate (Stryker, Mahwah, NJ) was then placed. The plate provided substantial rigidity and neutralization across the fusion site (**Figs. 7 and 8**).



**Fig. 5.** Preoperative radiographs show diastasis at the first metatarsal-cuneiform joint with complete nonunion.

The patient was kept non-weight bearing for a total of 6 weeks initially in a splint and then in a fiberglass cast. She was then progressed to a Controlled Ankle Motion boot (CAM boot) and was in tennis shoes at 8 weeks. At nearly 12 months postoperative, she remains very pleased with the correction of her deformity and has no pain. Radiographs reveal solid bony union at the first MTC joint (see **Figs. 7 and 8**). The original surgeon may have considered the history of smoking and her small child she had to care for; thus, had a locking plate been used primarily in this case, the early weight bearing that led to joint distraction may never have occurred.

#### CLINICAL RESULTS IN THE LITERATURE

Most of the recent publications regarding the Lapidus procedure seem to be directed toward locking plate technology. Clearly, locking plates offer a very stable construct that can decrease the risk of nonunions.

Locking plates provide a very rigid construct, which lends itself to good bone healing. In a series of 128 (144 feet), Wilde and colleagues<sup>31</sup> evaluated the Lapidus



**Fig. 6.** Preoperative radiographs show diastasis at the first metatarsal-cuneiform joint with complete nonunion.



**Fig. 7.** A 12-month postoperative radiograph from the revision Lapidus shows good union across the joint. Note the slight plantar flexion of the first ray to accommodate for the shortening of the ray.

procedure using polyaxial locking plates and found a union rate of 98.6%. Sorensen and colleagues<sup>7</sup> had a 100% rate of union with interfragmentary screw and dorsomedial locking plate fixation. They also found that full weight bearing with ambulation was possible at 2 weeks postoperatively.<sup>7</sup> DeVries and colleagues<sup>4</sup> performed a Lapidus on 143 patients using either crossing screws or a dorsomedial locking plate with no interfragmentary compression. They found a union rate of 89.4% for the crossed-screw group and 98.5% for the locking-plate group. They also found that the locking plate was bearing full weight at 7.8 weeks instead of 8.8 weeks.<sup>4</sup> Saxena and colleagues<sup>11</sup> performed the Lapidus procedure on 40 patients with either crossing lag screws or a plantar lag screw with locking plate fixation. They found no significant difference in the rate of nonunions between the two groups; however, they did find that the locking-plate group was able to bear weight at 4 weeks as opposed to 6 weeks in the crossing-screw group.<sup>11</sup>



**Fig. 8.** A 12-month postoperative radiograph from the revision Lapidus shows good union across the joint. Note the slight plantar flexion of the first ray to accommodate for the shortening of the ray.

## SUMMARY

Arthrodesis of the first MTC joint is a powerful and durable procedure to help correct moderate to severe hallux valgus and/or first ray hypermobility. However, painful nonunion remains a notoriously high potential outcome, between 3.3% and 12.0%. Although some investigators may advocate early weight bearing when using crossing lag screws and locking plates, the authors think that larger prospective and randomized clinical research needs to be conducted to determine the length of non-weight bearing after a Lapidus procedure. Because of the costs and risks associated with revision surgery, it may be more beneficial to use locking plates with lag screws and to keep patients non-weight bearing for a minimum of at least 2 weeks. Research regarding locking plates seems very promising, and data so far show lower rates of nonunion. External fixation for Lapidus may provide excellent fixation and allow earlier weight bearing, but care for and complications of the external device may be a concern to surgeons and patients. Innovative fixation techniques, such as the Mini TightRope or arthroscopic fusion, are quite new but have very little published data supporting their use. Regardless of the fixation, proper joint preparation and good compression are fundamental in attempting to avoid a failed first MTC fusion.

## REFERENCES

1. Albrecht GH. The pathology and treatment of hallux valgus (Russian). *Russk Vrach* 1911;10:14–9.
2. Lapidus PW. The operative correction of the metatarsus varus primus in hallux valgus. *Surg Gynecol Obstet* 1934;58:183–91.
3. Hansen ST Jr. Hallux valgus surgery. Morton and Lapidus were right! *Clin Podiatr Med Surg* 1996;13:347–54.
4. DeVries JG, Granata JD, Hyer CF. Fixation of first tarsometatarsal arthrodesis: a retrospective comparative cohort of two techniques. *Foot Ankle Int* 2011;32(2):158–62.
5. Donnenwerth MP, Borkosky SL, Abicht BP, et al. Rate of nonunion after first metatarsal-cuneiform arthrodesis using joint curettage and two crossed compression screw fixation: a systematic review. *J Foot Ankle Surg* 2011;50(6):707–9.
6. Blitz NM. Early weightbearing of the Lapidus bunionectomy: is it feasible? *Clin Podiatr Med Surg* 2012;29:367–81.
7. Sorensen MD, Berlet GC, Hyer CF. Results of Lapidus arthrodesis and locked plating with early weight bearing. *Foot Ankle Spec* 2009;2(5):227–33.
8. Gruber F, Sinkov VS, Bae SY, et al. Crossed screws versus dorsomedial locking plate with compression screws for first metatarsocuneiform arthrodesis: a cadaver study. *Foot Ankle Int* 2008;29(9):927–30.
9. Patel S, Ford LA, Etcheverry J, et al. Modified Lapidus arthrodesis: rate of nonunion in 227 cases. *J Foot Ankle Surg* 2004;43(1):37–42.
10. Cottom JM. Fixation of the Lapidus arthrodesis with a plantar interfragmentary screw and medial low profile locking plate. *J Foot Ankle Surg* 2012;51(4):517–22.
11. Saxena A, Nguyen A, Nelson E. Lapidus bunionectomy: early evaluation of crossed lag screws versus locking plate with plantar lag screw. *J Foot Ankle Surg* 2009;48(2):170–9.
12. Calder JD, Holligdale JP, Pearse MF. Screw versus suture fixation of Mitchell's osteotomy: a prospective, randomised study. *J Bone Joint Surg Br* 1999;81(4):621–4.
13. Hasselman CT. Success story: Lapidus plate. Mini TightRope Lapidus technique. Distal extremities orthopedic update, spring 2012. *Arthrex newsletter*. Accessed October 8, 2012.

14. Sangeorzan BJ, Hansen ST. Modified Lapidus procedure for hallux valgus. *Foot Ankle* 1989;9(6):262–6.
15. Cohen DA, Parks BG, Schon LC. Screw fixation compared to H-locking plate fixation for first metatarsocuneiform arthrodesis: a biomechanical study. *Foot Ankle Int* 2005;26(11):984–9.
16. Klos K, Gueorguiev B, Mückley T, et al. Stability of medial locking plate and compression screw versus two crossed screws for Lapidus arthrodesis. *Foot Ankle Int* 2010;31(2):158–63.
17. Basile P, Cook EA, Cook JJ. Immediate weight bearing following modified Lapidus arthrodesis. *J Foot Ankle Surg* 2010;49(5):459–64.
18. Scranton PE, Coetzee JC, Carreira D. Arthrodesis of the first metatarsocuneiform joint: a comparative study of fixation methods. *Foot Ankle Int* 2009;30(4):341–5.
19. Grassia T. "Surgeons prefer polyaxial locking plate for hallux valgus." *Orthopaedics Today Europe* 2011, Issue 5. Online.
20. Haidukewych GJ. Innovations in locking plate technology. *J Am Acad Orthop Surg* 2004;12(4):205–12.
21. Haidukewych GJ, Ricci W. Locked plating in orthopaedic trauma: a clinical update. *J Am Acad Orthop Surg* 2008;16(6):347–55.
22. Königshausen M, Kübler L, Godry H, et al. Clinical outcome and complications using a polyaxial locking plate in the treatment of displaced proximal humerus fractures. A reliable system? *Injury* 2012;43(2):223–31.
23. Voigt C, Geisler A, Hepp P, et al. Are polyaxially locked screws advantageous in the plate osteosynthesis of proximal humeral fractures in the elderly? A prospective randomized clinical observational study. *J Orthop Trauma* 2011;25(10):596–602.
24. Wang JC, Riley BM. A new fixation technique for the Lapidus bunionectomy. *J Am Podiatr Med Assoc* 2005;95(4):405–9.
25. Treadwell JR. Rail external fixation for stabilization of closing base wedge osteotomies and Lapidus procedures: a retrospective analysis of sixteen cases. *J Foot Ankle Surg* 2005;44(6):429–36.
26. Van Gompel JR, Dei RL. Rail external fixation for stabilization of closing base wedge osteotomies and Lapidus procedures: a retrospective analysis of sixteen cases. *J Foot Ankle Surg* 2006;45(3):192–3.
27. Lui TH. Symptomatic first metatarsocuneiform nonunion revised by arthroscopic Lapidus technique. *J Foot Ankle Surg* 2012;51(5):656–9.
28. Lui TH, Chan KB, Ng S. Arthroscopic Lapidus arthrodesis. *Arthroscopy* 2005; 21(12):1516.e1–4.
29. Michels F, Guillo S, de Lavigne C, et al. The arthroscopic Lapidus procedure. *Foot Ankle Surg* 2011;17(1):25–8.
30. Kadous A, Abdelgawad AA, Kanlic E. Deep venous thrombosis and pulmonary embolism after surgical treatment of ankle fractures: a case report and review of literature. *J Foot Ankle Surg* 2012;51:457–63.
31. Wilde E, Schulz AP, Heinrichs G, et al. Retrospective analysis of hallux valgus therapy by Lapidus arthrodesis with polyaxial locking plates. Poster session presented at: 12th EFORT Congress 2011, Copenhagen, Denmark, June 1–4.