CHAPTER

31

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Lapidus Bunionectomy: First Metatarsal–Cuneiform Arthrodesis

Metatarsus primus varus and hallux abducto valgus (HAV) have been used to correct HAV since originally described by Albrecht (1) in 1911. Truslow (2) followed with a version of the procedure in 1925 that involved a wedged resection of bone from the first metatarsocuneiform joint. The procedure was later popularized by and named after Paul Lapidus. In 1930, he proposed a first metatarsal–cuneiform arthrodesis paired with arthrodesis of the second metatarsal as well as resection of the dorsomedial eminence of the first metatarsal head and distal soft tissue repositioning for metatarsus primus varus. He believed that metatarsus primus varus was the result of an underdeveloped atavistic foot type. He hypothesized that hypermobility of the first metatarsal–cuneiform joint combined with an increased first to second intermetatarsal (IM) angle caused by an oblique joint axis predisposes the foot to HAV and metatarsus primus varus. Lapidus concluded that the apex of the deformity, the first metatarsal–cuneiform joint, needed to be addressed or a "bayonet-shaped" deformity would result (3).

While many techniques have been described modifying the original Lapidus procedure, all use arthrodesis of the metatarsal–cuneiform joint (4–11). The procedure allows for triplanar correction of first metatarsal pathology, increases the biomechanical advantage of the peroneus longus, and has the ability to stabilize the medial column. The first metatarsal–cuneiform arthrodesis, while controversial, is a versatile procedure that can correct numerous pathologies.

EVALUATION/DIAGNOSIS/ FUNCTIONAL ANATOMY

Traditionally, the first metatarsal–cuneiform arthrodesis has been used to correct for a hypermobile first ray. When the first metatarsal possesses increased motion of the first metatarsal–cuneiform joint, the metatarsal elevates during gait, making the first ray unstable and unable to maintain its position against ground reaction forces throughout the gait cycle (12). Numerous attempts have been made to define hypermobility in both the sagittal and transverse planes although no standardized values exist. Clinical assessment of the first ray range of motion is still currently the most accepted method to diagnose hypermobility of the first ray. Root described normal first ray motion as equal dorsal and plantar range of motion and hypermobility as anything beyond equal motion in the sagittal plane. He placed the ankle joint and subtalar joints in neutral position and then stabilized metatarsal heads 2 to 5 with one hand and the first metatarsal head with the other hand, while taking the first metatarsal through its range of motion (13,14). Later, one thumb's breadth of dorsal motion was described as hypermobile when using Root's technique (15). Roukis et al have promoted the "dynamic Hicks test," in which the foot is tested with the hands positioned in the same manner as Root described. The hallux is then fully dorsiflexed at the first metatarsophalangeal joint, and dorsal and plantar pressures are then applied to the metatarsal head. The results of the "dynamic Hicks test" are then compared with those of Root's; they believe that true hypermobility of the first ray exists when both tests show a positive result of hypermobility (16). Radiographically, hypermobility is frequently distinguished on anteroposterior radiograph as an increased first to second IM angle with medial cortical thickening of the second metatarsal, which is believed to be due to second metatarsal overload (17). Clinically, this can be accompanied with a hyperkeratotic lesion plantar to the second metatarsal head (18). Some advocate the test for evaluation of transverse plane hypermobility, which entails wrapping an ACE wrap across the forefoot while applying moderate tightness (19,20). Radiographs with the ACE wrap applied are compared with normal weight-bearing radiographs to assess if hypermobility of the joint occurs in the transverse plane, which can be seen with a decreased IM angle with the apex of deformity at the first metatarsal–cuneiform joint. Hypermobility is frequently concomitant with a large HAV deformity, although mild to moderate cases of HAV have been treated successfully when first ray hypermobility is present (5,12,21–23). The procedure is also indicated when generalized ligamentous laxity is seen with HAV.

Juvenile HAV frequently is accompanied by hypermobility at the first metatarsal–cuneiform joint. Adolescent HAV differs from adult HAV in that a smaller dorsomedial eminence is present and less valgus rotation of the hallux occurs (24,25). If hypermobility is present and not addressed, recurrence of the deformity may result, as juvenile HAV frequently is a structural problem that can persist throughout adulthood and progress (12,22). It has been demonstrated that the angle created by the axis of the first metatarsal and the distal surface of the medial cuneiform is increased with statistical significance in Juvenile HAV, supporting that varus angulation occurs proximal to the metatarsal at the level of the first metatarsal–cuneiform joint. A positive correlation also exists between the angle created by the distal surface of the medial cuneiform and the axis of the second metatarsal and an increased IM angle (26). Lower recurrence rates have been achieved with this procedure as it addresses the deformity at its apex and eliminates first ray hypermobility (17,22,27). Juvenile HAV corrected with other procedures has been noted to have recurrence rates as high as 35% (27,28). The procedure is an excellent option for correction of Juvenile HAV as it can be performed successfully without resection of the medial eminence and distal soft tissue release (17).

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Moderate to severe HAV can be treated effectively with this procedure without the presence of hypermobility. IM angles ranging from 14 to 30 degrees on anteroposterior radiograph have been used as a baseline for the procedure (24,29). Etiology of an increased IM angle may be due to the shape of the first MC joint itself, as a positive correlation exists between the obliqueness of the joint and increased first to second IM angle (30). Surgical correction of large IM angles needs to be addressed with proximal procedures, as the long lever arm allows for a higher level degree of correction as opposed to distal procedures. The procedure has the ability to restore first metatarsophalangeal joint congruency and realign the sesamoid apparatus in addition to correction of the IM angle. The closing base wedge osteotomy (CBWO) and the modified Lapidus were compared and both procedures demonstrated significant first to second IM correction, with the Lapidus maintaining a greater degree of correction postoperatively, the CBWO losing an average of 2.55 degrees of correction and the Lapidus losing only an average of 1.08 degrees (31).

More recently, the procedure has been used in conjunction with other procedures as a practical option for treatment of medial column insufficiency and flatfoot deformity. Addressing the medial column for these pathologies is vital as the first metatarsal can accommodate up to 50% of the stress experienced through gait and provides a paramount role in stabilizing the medial longitudinal arch (32). It is important to note that the procedure is not advocated for primary correction of these pathologies. Morton described what has become known as a "Morton's foot" in which the first metatarsal is anatomically or functionally short, leading to rotation about the axis of the forefoot causing pronation (33–37). The goal of surgical correction of a "Morton's foot" is to stabilize the medial column and realign the parabola of the metatarsal heads to distribute weight-bearing evenly. The peroneus longus muscle gains mechanical advantage following a Lapidus procedure contributing to functional stability of the medial column, which is lost with pronation of the foot (38,39). In 2008, Avino et al performed radiographic analysis on 39 feet in which an isolated Lapidus was performed to review the effects of the arthrodesis to the medial column in the sagittal plane. Postoperatively, the mean cuneiform increase in height was 3.44 mm and Meary's angle decreased by a mean of 2.97 degrees (40). Logel et al examined the effects of calcaneocuboid arthrodesis and first metatarsal–cuneiform arthrodesis on lateral column pressure as well as radiographic correction of flatfoot deformity on 10 fresh frozen cadaver limbs. They found that with the lateral column lengthening procedure alone there was improved radiographic measurements when evaluating lateral talus–first metatarsocuneiform angle, talonavicular coverage angle, medial column height, lateral talus–calcaneal angle, and calcaneal pitch; however, increased lateral column pressures were noted. They subsequently performed a first metatarsal–cuneiform arthrodesis on the same limbs, which decreased pressure of the lateral column and the radiographic values demonstrated additional increased correction (41). This procedure has been successfully used when medial column insufficiency is present in conditions such as Charcot-Marie-Tooth and postpolio when restoration and stability of the medial column is essential to restore function of the foot (4,42).

Degenerative joint disease (DJD) of the first metatarsal–cuneiform joint can be successfully treated with arthrodesis of the joint. DJD can be the result of arthritides, trauma, and longstanding biomechanical abnormalities (11,17,43). The pain experienced with the DJD is corrected with arthrodesis of the joint.

Failed HAV procedures may also elicit the need of arthrodesis of the Lapidus procedure as it can maintain good functional results (44). If the deformity returns following initial surgical correction, hypermobility of the first metatarsal–cuneiform joint needs to be assessed as well as generalized ligamentous laxity to determine if excessive movement of the joint was etiology of recurrence. A bone graft may need to be incorporated into the joint to maintain length and restore function as the prior procedure may have shortened the first metatarsal.

Hallux limitus and metatarsal primus elevatus may also be corrected with this procedure (21,45). With intraoperative plantarflexion of the first metatarsal, decompression of the first metatarsophalangeal joint occurs, allowing for increased motion of the joint.

CRITERIA/SELECTION OF PROCEDURE/CONTRAINDICATIONS

Inclusion criteria for the Lapidus procedure for HAV and metatarsus primus varus include a pathologic hypermobile first ray, moderate to severe HAV with or without the presence of hypermobility with a first to second IM angle greater than 15 degrees, HAV with concurrent generalized ligamentous laxity, adolescent HAV (Fig. 31.1), or instability at the tarsal–metatarsal joint in the sagittal, transverse, and/or frontal plane. The procedure can be used as an adjunctive procedure for correction of pes planovalgus deformity and hallux rigidus deformity, in patients who present with a sub–second metatarsal callous/lesion, or in conditions where tarsal–metatarsal instability exists (Fig. 31.2). Arthrodesis of the first metatarsal–cuneiform joint can be performed in the presence of painful degenerative joint and for decompression of the first metatarsophalangeal joint seen with hallux limitus and metatarsus primus elevatus.

Figure 31.1 Preoperative HAV deformity. Note the valgus rotation of the great toe

Figure 31.2 Preoperative HAV deformity in a patient who experiences pain from the callous sub–second metatarsal lesion. The lesion is a direct result of the HAV deformity and the associated instability of the tarsal–metatarsal joint.

The main contraindication of the Lapidus procedure is an exceedingly short first ray due to the shortening that is inevitable with resection of the joint. When this does occur, techniques have been described that use grafts in order to facilitate and lengthen the metatarsal–tarsal complex. A relative contraindication is juveniles with HAV when the epiphyses are open; however, the procedure can be performed with open epiphyses if fixation is performed with smooth Kirschner wires (K-wires) (46). Another relative contraindication is a young, athletic person where postoperative stiffness could follow and add morbidity to their active lifestyle (47). A foot with underlying hind foot biomechanical abnormalities should not primarily be treated with a Lapidus procedure (48,49).

TECHNIQUE

An incision is made over the metatarsal–cuneiform joint approximately 4 to 6 cm in length. There is no incision at the level of the first metatarsophalangeal joint or in the IM joint space. The tarsal–metatarsal incision is deepened in the same plane using sharp and blunt dissection. All bleeders are identified and ligated as necessary. The incision is carried down exposing the metatarsal–cuneiform joint. The tarsal–metatarsal ligaments are resected using a rongeur exposing the joint. Two mini Hohman retractors are used for the soft tissue retraction and the articular cartilage of the metatarsal–cuneiform joint are resected. The initial joint resection is performed on the first metatarsal articular surface. The first metatarsal articular surface is denuded first as this is the most distal and the most unstable segment. This resection is made perpendicular to the long axis of the first metatarsal and parallel to the existing metatarsal base. There is no correction made within the first metatarsal segment, as there is no deformity in the first metatarsal of an untreated hallux valgus/metatarsal primus varus deformity: Thus, the articular joint resection needs to be kept consistent and parallel with the natural occurring anatomy. The base of the first metatarsal is concave; therefore, the amount of cartilaginous resection on the base of the first metatarsal will need to be slightly greater than the amount on the convexity of the natural occurring articular surface of the cuneiform. The corrective articular resection is made at the distal aspect of the convex-shaped cuneiform. The correction is made in the transverse plane and the frontal and sagittal planes are later corrected via reduction and appropriate positioning of the tarsal–metatarsal joint.

Prior to reducing the joint into the appropriate desired position, a significant amount of time should be spent with joint preparation. The metatarsal base and distal cuneiform as well as the medial aspect of the second metatarsal base are prepared. It is imperative that the surgeon is diligent to ensure that the subchondral plate is penetrated demonstrating good bleeding at both the metatarsal and cuneiform. The medial cortex of the base of the second metatarsal is débrided with a pituitary rongeur (Fig. 31.3A). The joint preparation is extremely important in efforts to obtain a bony union and to avoid a delayed and nonunion. The recommended joint preparation techniques consist of the use of an osteotome and mallet, a 2-mm drill bit, and a bone pic (Fig. 31.3B). A substantial period of time is spent preparing this joint as this is a vital portion of the procedure to ensure good bony healing.

Next, the frontal plane is addressed. The surgeon derotates the hallux out of valgus in order to get the nail plate to be parallel with the ground. This derotation, allows for the entire hallux, sesamoid, and first metatarsal complex to be rotated from a position of valgus and into a neutral position as one unit. This rotation will be clinically evident at the tarsal–metatarsal joint as well as under fluoroscopy (Fig. 31.4). Because there is no dissection at the first metatarsophalangeal joint (medial eminence resection or sesamoidal dissection), the maintenance of the soft tissues allows the hallux, sesamoids, and metatarsal to function as one unit. The sesamoid correction can be observed under fluoroscopy at this time.

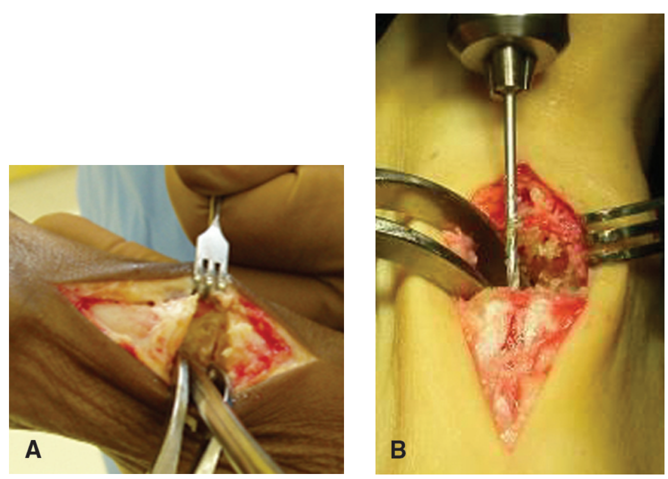

Figure 31.3 A: Intraoperative view demonstrating an incision that does not involve the first metatarsal phalangeal joint. This view also demonstrates the use of a pituitary rongeur to débride the medial aspect of the base of the second metatarsal. This area is used for additional attempt of stabilization between first and second metatarsal. **B:** Intraoperative clinical view demonstrating the use of a 2-mm drill preparing the tarsal–metatarsal joint prior to fixation.

Figure 31.4 **A:** Preoperative AP radiograph demonstrating a large IM angle with notable valgus deformity of the great toe and a significant sesamoid position with a valgus rotation. **B:** Intraoperative radiograph demonstrating the ability to correct the frontal plane pathology of the HAV deformity, following joint preparation of the tarsal–metatarsal. Please note the rotation of the hallux and that there is no soft tissue release performed at the metatarsophalangeal joint. **C:** Preoperative AP radiograph of a significant HAV deformity. Please note the valgus rotation of the hallux. **D:** Intraoperative AP radiograph reducing the frontal plane deformity, aligning the metatarsal phalangeal joint and the sesamoids without any distal soft tissue dissection.

The sagittal plane reduction technique is performed by stabilizing the hind foot, while the surgeon dorsiflexes the first metatarsophalangeal joint initiating the windless mechanism. This hind foot stability allows the surgeon to apply retrograde forces to the plantar tarsal–metatarsal joint and allows for the first metatarsal to plantarflex to a natural occurring level, parallel with the lesser metatarsals. Once the surgeon has the hallux, sesamoid, and metatarsal rotated to a neutral desirable position (frontal plane reduction), and the first metatarsal sagittal plane corrected, the surgeon can use his or her thumb against the first metatarsal to manually reduce the first intermetatarsal angle in the transverse plane. The primary surgeon must ensure that the first metatarsal is in the desired position, which is essentially rotated out of valgus, and parallel with the second metatarsal in both the transverse and sagittal planes. In many cases, a large Weber clamp may be used to assist, increase, or maintain the reduction (Fig. 31.5). When using the large Weber clamp, the surgeon must be sure not to change the sagittal plane

Figure 31.5 Intraoperative radiograph in a case in which a large Weber clamp was used for reduction of a large IM angle.

relationship between the first and lesser metatarsals. Next a 1.6- or 2-inch smooth K-wire is used to stabilize the reduction and position. The first K-wire is positioned from the central proximal one-third of the first metatarsal into the cuneiform. Because of appropriate positioning of the tarsal–metatarsal joint, it is not unusual to see dorsal gapping at the tarsal–metatarsal joint. Subsequently, while maintaining position in all three planes a second K-wire is inserted into the medial first metatarsal head and into the lesser metatarsals; this serves to prevent derotation in the frontal plane and maintains reduction in the transverse plane. If the surgeon feels a need to obtain more correction in the frontal plane, the K-wire can be inserted into the first metatarsal medial and lateral cortex with the K-wire in the direction of inferior medial to superior lateral. Once the K-wire penetrates the far cortex of the first metatarsal, the K-wire can be used as a rotation device and rotate the metatarsal into more of a neutral position and insert the K-wire into the lesser metatarsal to stabilize the position. The position is checked both clinically as well as under fluoroscopy to confirm acceptable alignment.

The recommended fixation techniques consist of interfragmentary compression of three solid cortical screws or an interfragmentary compression of solid cortical screw along with a medial based locking plate. Regardless of the construct, the first screw is the most important screw; this is often referred to as the "homerun screw" (50) (Fig. 31.6). This screw should be a solid long cortical screw with preference size of a 3.5 or 4 mm. A trough is created into the middorsal side of the first metatarsal approximately in the proximal one-third of the metatarsal (51). The first drill is either 4 mm for a 4-mm cortical screw or 3.5 mm for a 3.5-mm cortical screw and is drilled into the first metatarsal and stopped at the cuneiform. The next drill is either 2.9 mm for the 4-mm cortical screw or 2.5 mm for the 3.5-mm cortical screw and drilled into the cuneiform. The drill is aimed for the inferior, medial aspect of the cuneiform (based on the shape of the cuneiform, the largest cross section of bone is in the medial cuneiform). This screw should have a bicortical purchase; this screw provides interfragmentary compression and leverage. The interfragmentary compression will create an excellent reduction at the base of the tarsal–metatarsal joint most often leaving some dorsal gapping of the tarsal–metatarsal joint.

When a three-screw construct is desired, the next screw is inserted from the medial proximal one-third of the first metatarsal under the first screw with the respective drill sizes for a 3.5-mm or a 4-mm cortical screw. The initial drill is the oversized drill through the first metatarsal, and the second drill is the undersized drill into the second and or possibly the lesser metatarsals in order to obtain an excellent screw purchase. Often times a washer will be applied with this screw, which provides greater reduction of the IM angle. The third screw is placed from the most proximal dorsal position of the cuneiform aiming into the medial proximal first metatarsal. This screw also should be as long as possible for obtaining leverage (52). The construct should be checked under fluoroscopy to confirm adequate reduction (Fig. 31.7).

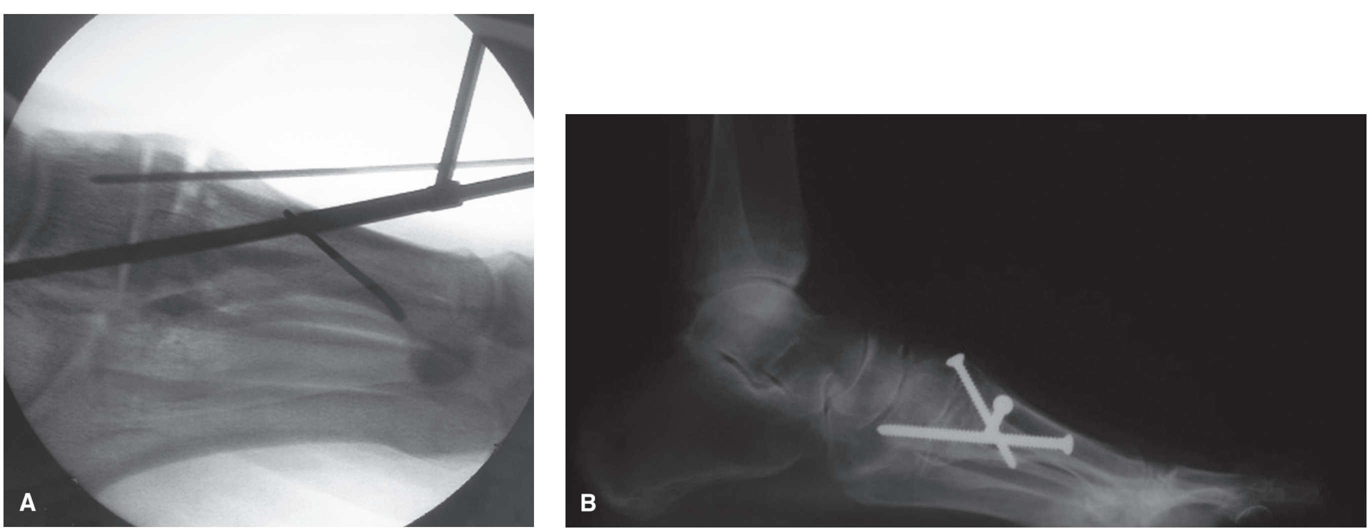

Figure 31.6 **A:** An intraoperative view demonstrating the drilling of the "homerun screw" from proximal one-third to one-half the metatarsal into and exiting the most medial, inferior cortex of the medial cuneiform. **B:** The homerun screw is long with a bicortical purchase and is almost parallel to the ground providing a "beam effect."

Figure 31.7 Postoperative AP radiograph demonstrating the “three solid cortical screw technique” with restoration of anatomical alignment.

When a locking plate is used in conjunction with an interfragmentary compression screw the plate is applied to the medial first metatarsal–cuneiform joint. Following the insertion of the homerun screw, the initial screws are placed proximal in the medial cuneiform of the plate in combination of locking and nonlocking screws. The distal screws are placed into the metatarsal with a combination of locking and nonlocking screws (Figs. 31.8 and 31.9). Similar to the three-screw technique, an interfragmentary compression screw can be applied in the plate from medial to lateral into the second and/or lesser metatarsals. This interfragmentary compression allows the surgeon to reduce the IM angle well as the plate essentially becomes an excellent reduction tool acting similar to a large washer. The construct should be checked under fluoroscopy to confirm adequate reduction.

Attention is directed to the lateral aspect of the calcaneus where a small stab incision is made in the resting skin line that is posteroinferior to the sural nerve and the peroneal nerves. A Freer elevator is inserted in the incision, freeing the periosteum medially and laterally, exposing the lateral wall of the calcaneus. A 3.5-mm drill was used to penetrate the lateral cortex. With this done, a curette is inserted into the calcaneus, allowing for harvesting of cancellous bone from the lateral aspect of the calcaneus (53).

The dorsal gap of the tarsal–metatarsal is packed tightly with autogenous bone graft and serves as a shear strain–relieved bone graft (52,54). The construct is checked under fluoroscopy and the wound is closed with typical deep and skin wound sutures.

The postoperative course is dictated by the construct. It has been the experience of the authors to keep patients with the three solid cortical screw technique non-weight-bearing in a below the knee cast for 2 weeks, followed by 4 to 6 weeks of full weight-bearing in a protective fracture boot with a sound AO construct (55). The authors are encouraged with the results and believe that in the future it may be possible to allow for immediate full weight-bearing in a protective fracture boot. When utilizing a interfragmentary compression screw along with a medial locking plate, it has been the experience of the authors to allow immediate and full weight-bearing in a protective fracture boot.

PEARLS, TIPS, PITFALLS

During clinical assessment, it is important to assess mobility of the first metatarsocuneiform joint in the sagittal, frontal, and transverse planes. While sagittal plane range of motion

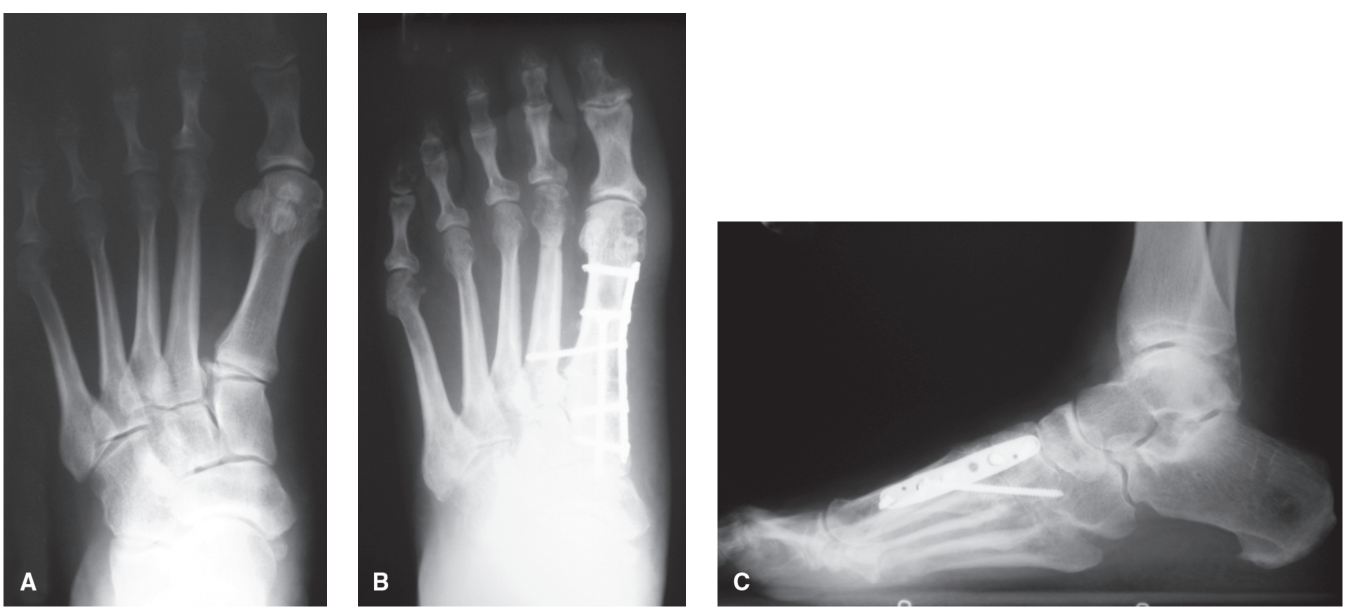

Figure 31.8 **A:** Preoperative radiograph with a HAV deformity. **B,C:** Postoperative radiographs demonstrating the use of an interfragmentary screw with a locking plate. Please note the restoration of anatomical alignment.

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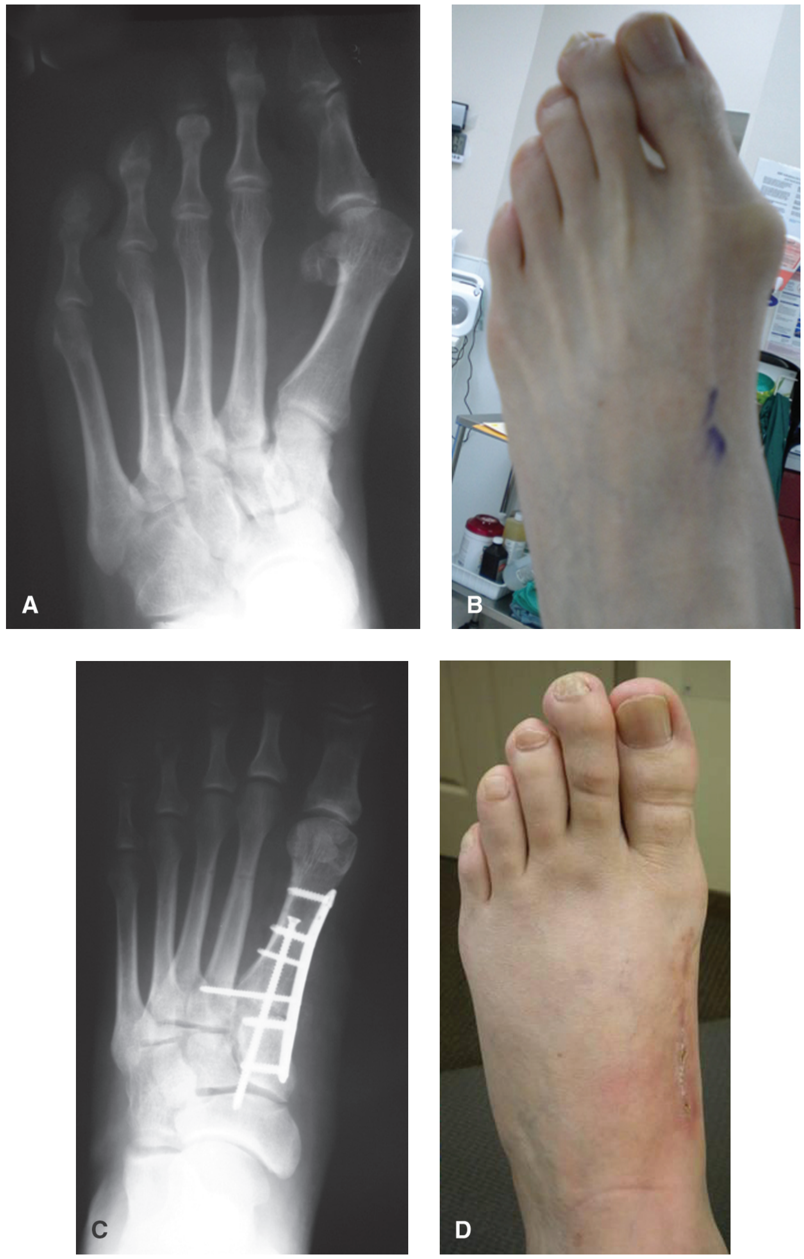

Figure 31.9 **A,B:** Preoperative radiograph and clinical photo of a patient with HAV deformity. **C,D:** Postoperative radiograph and clinical photo of the patient with the use of an interfragmental compression screw and a medial based locking plate. The correction can be seen in all three planes.

is typically tested, transverse and frontal plane motion is often overlooked. The use of the first ray splay test is a relevant method to determine if transverse plane hypermobility needs to be addressed. The foot is positioned with the subtalar joint and midtarsal joint in neutral, and direct transverse plane pressure is applied with the thumb and index finger to the first and second metatarsal heads. If hypermobility is demonstrated, with the addition of fixation between the first and second metatarsals, a first metatarsal base–second metatarsal base arthrodesis may be advocated (56). Unfortunately, to the best of the author's knowledge, there is no known preoperative frontal plane motion stress test. Intraoperatively, the authors have been able to demonstrate the dynamic changes in the frontal plane of the first metatarsophalangeal joint. Once the ligamentous structures of the tarsal–metatarsal joint is free of soft tissue attachments, rotation of the first metatarsal from a valgus position in the direction of varus and into a neutral position can demonstrate the frontal plane motion associated with the pathological hallux valgus deformity.

While performing the procedure, it is vital that the entire plantar ledge of the metatarsal base and medial cuneiform are removed in entirety. If a plantar ledge remains following the osteotomy, correction will be impeded as proper placement and compression across the arthrodesis site will not be achieved. A transverse capsulotomy has also been advocated at the joint to decrease periosteal stripping (45).

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Bone grafting has been heavily used in this procedure both for maintenance of length of the first ray as well as to aid in arthrodesis to prevent delayed and nonunions. Historically, cancellous bone harvested percutaneously from the calcaneus, tricortical grafts from the iliac crest as well as the medial eminence from the first metatarsal head have been successfully used as grafting material (6,7,57,58). If grafting is not performed, the surgeon should consider plantarflexing the metatarsal to accommodate for the shortening; however, caution is advised as it has been reported that a 3-mm wedge resection results in approximately 1 cm of plantarflexion (4,59).

Concomitant deformities and biomechanical abnormalities need to be addressed when performing this procedure, such as equinus (48). If other deformities are not corrected biomechanical compensations may occur that hinder the primary surgical correction (60). Early protective weight-bearing status starting at 2 weeks postoperatively has been successful when 3 points of fixation or locking plates are used (55,61,62). The authors advocate the use of a homerun screw, a fully threaded cortical screw inserted with AO standard lag technique oriented from dorsal distal to proximal plantar from the first metatarsal base to the medial cuneiform (52). The second screw, a fully threaded 4-mm cortical screw, is then inserted with AO standard lag technique perpendicular to the homerun screw, which is driven into the base of the second metatarsal to increase reduction of the first to second IM angle. The third screw, another 4-mm fully threaded cortical screw, is inserted with standard AO lag technique oriented across the first metatarsal–cuneiform joint from proximal dorsal lateral to distal plantar lateral and should cross with the homerun screw. The authors allow for early postoperative weight-bearing at 2 weeks when using this technique. This early weight-bearing may decrease incidence of deep venous thrombosis, decrease morbidity to the patient, and improve function following the surgical procedure.

In order to achieve a favorable outcome, the surgeon must spend most of his or her time obtaining good anatomical alignment, joint preparation as well as creating a rigid construct with good fixation.

COMPLICATIONS

Significant shortening of the first metatarsal can be a complication of the Lapidus procedure. Shortening of the first metatarsal can lead to transfer lesions plantar to the second metatarsal head as well as decreased hallux purchase. Current grafting techniques and proper positioning of the metatarsal during arthrodesis have made this a less common encountered complication.

Delayed unions and nonunions should be noted as complications, with delayed unions occurring more frequently in literature (63). Nonunions have had a reported incidence of up to 12% following first metatarsal–cuneiform arthrodesis (29). Grafting of the prepared joint surface and advanced internal fixation techniques of 3-point fixation and locking plates have significantly decreased the rate of delayed unions and nonunions. Nonunions have been reduced to reports of 0% (7).

Malunions associated with the procedure can be avoided with intraoperative radiographs to establish correct positioning in all three planes of motion. A malunion in an elevatus position of the first ray may give rise to a dorsal bunion, decreased range of motion, and decreased purchase of the first ray, which could lead to transfer metatarsalgia (17). Likewise, care must be taken to not plantarflex the first ray as sesamoiditis could result. Overcorrection and undercorrection are also encountered.

Although the authors do not advocate it for this procedure, if a traditional lateral first metatarsal interspace release is performed, hallux varus is a possible complication. This is a complication that can accompany any procedure that uses the lateral release.

Hardware failure can result from improper placement and/or unsuitable techniques. In cases of hardware failure, subsequent surgery to remove the hardware is performed.

Neuritis, while uncommon, can be encountered with the close proximity of the medial dorsal cutaneous nerve to the surgical site. Depending upon dissection techniques and incision planning, the saphenous nerve may be involved as well as the deep peroneal nerve of the first interspace (17,27,46). Cases of complex regional pain syndrome status past surgery have been reported (63).

REFERENCES

1. Albrecht GH. The pathology and treatment of hallux valgus (Russian). *Russk Vrach* 1911;10:14–19.
2. Truslow W. Metatarsus primus varus or hallux valgus. *J Bone Joint Surg* 1925;7:98–108.
3. Lapidus PW. Operative correction of the metatarsus varus primus in hallux valgus. *J Surg Gynecol Obstet* 1930;58:183–191.
4. Chang T, Ruch J. Lapidus arthrodesis A different perspective. *J Am Podiatr Med Assoc* 1994;6:281–288.
5. Hofbauer M, Grossman J. The Lapidus procedure. Clin Podiatr Med Surg 1996;3:485–496.
6. Sangeorzan B, Hansen S. Modified Lapidus procedure for hallux valgus. *Foot Ankle* 1989;6:262–266.
7. Butson ARC. A modification of the Lapidus operation for hallux valgus. *J Bone Joint Surg* 1980;62B:350–352.
8. Bacardi BE, Boysen TJ. Considerations for the Lapidus operation. *J Foot Surg* 1986;25:138.
9. Hernandez A, Hernandez PA. Lapidus: when and why?. *Clin Podiatr Med Surg* 1989;6:197.
10. Mauldin DM, Sanders M, Whitmer WW. Correction of hallux valgus with metatarsocuneiform stabilization. *Foot Ankle* 1990;11:57
11. Myerson M. Metatarsocuneiform arthrodesis for treatment of hallux valgus and metatarsus primus varus. *Orthopedics* 1990;13:1050.
12. Neylon T, Johnson B, Laroche R. Use of the Lapidus bunionectomy in first ray insufficiency. *Clin Podiatr Med Surg* 2001;2:365–375.
13. Root ML, Orien WP, Weed JH. Muscle function of the foot during locomotion. In: Root ML, O'Rien WOP, Weed JH, eds. *Clinical biomechanics*, vol 2. Los Angeles, CA: Clinical Biomechanics Corporation, 1977.
14. Root ML, Orien WP, Weed JH, et al. Technique for the examination of the first ray. In: Root SA, ed. *Biomechanical examination of the foot*, vol 1. Los Angeles, CA: Clinical Biomechanics, 1971:80–87.
15. Bednarz PA, Manoli A. Modified Lapidus procedure for the treatment of hypermobile hallux valgus. *Foot Ankle* Int 2000;10:816–821.
16. Roukis TS, Landsman AS. Hypermobility of the first ray: a critical review of the literature. *J Foot Ankle Surg* 2003;6:377–390.
17. Myerson M, Allon S, McGarvey W. Metatarsocuneiform arthrodesis for management of hallux valgus and metatarsus primus varus. *Foot Ankle* 1992;13:107–115.
18. Klaue K, Hansen ST, Masquelet AC. Clinical, quantitative assessment of first tarsometatarsal mobility in the sagittal plane and its relation to hallux valgus deformity. *Foot Ankle Int* 1994;15:9–13.
19. Lapidus PW. The author's bunion operation from 1931 to 1959. *Clin Orthop* 1960;16:119–135.
20. Romash MM, Fugate D, Yanklowit B. Passive motion of the first metatarsal cuneiform joint: Preoperative assessment. *Foot Ankle* 1990;10:293–299.
21. Catanzariti AR, Mendecino RW, Lee MS, et al. The modified Lapidus arthrodesis: a retrospective analysis. *J Foot Ankle Surg* 1999;38:322–332.
22. Grace D, Delmonte R, Catanzariti AR, et al. Modified Lapidus arthrodesis for adolescent hallux abducto valgus. *J Foot Ankle Surg* 1999;38:8–13.
23. Rutherford RL. The misuse of the Lapidus procedure [letter]. *J Foot Ankle Surg* 1997;36:74–76.
24. Goldner JL, Gaines R. Adult and juvenile hallux valgus: analysis and treatment. *Orthop Clin* 1976;7:863–887.
25. Piggot H. The natural history of hallux valgus in adolescent and early adult life. *J Bone Joint Surg Br* 1960;42-B:749–760.
26. Vyas S, Conduah A, Vyas N, et al. The role of the first metatarsocuneiform joint in juvenile hallux valgus. *J Pediatr Orthop* B 2010;5:399–402.
27. Clarke HR, Veith RG, Hansen ST. Adolescent bunions treated by the modified Lapidus procedure. *Bull Hosp Jt Dis Orthop Inst* 1987;47:109–122.
28. Scranton PE, Zuckerman JD. Bunion surgery in adolescents: results of surgical treatment. *J Pediatr Orthop* 1984;4:39–43.
29. Saffo G, Desnoyers R, Wooster M, et al. First metatarsocuneiform joint arthrodesis: a five year retrospective analysis. *J Foot Surg* 1989;5:459–465.
30. McCrea J, Lichty T. The first metatarsocuneiform articulation and its relationship to metatarsus primus adductus. *J Am Podiatr Assoc* 1979;12:700–706.

31. Haas Z. Maintenance of correction of first metatarsal closing base wedge osteotomies versus modified Lapidus arthrodesis for moderate to severe hallux valgus deformity. *J Foot Ankle* Surg 2007;5:358–365.
32. Cooper A, Clifford P, Parikh V, et al. Instability of the first metatarsal-cuneiform joint: diagnosis and discussion of an independent pain generator in the foot. *Foot Ankle Int* 2009;10:928–932.
33. Morton DJ. Evolution of the longitudinal arch of the human foot. *J Bone Joint Surg* 1924;6:56–90.
34. Morton DJ. Hypermobility of the first metatarsal bone. Bone Joint Surg 1928;10:187–196.
35. Morton DJ. Structural factors in static disorders of the foot. *Am Surg* 1930;9:315–328.
36. Morton DJ. *The human foot: Its evolution, physiology and functional disorders*. New York, NY: Columbia University Press, 1935.
37. Morton DJ. Metatarsus atavicus, the identification of a distinctive type of foot disorder. *J Bone Joint Surg* 1927;9:531–544.
38. Catanzariti AR. First metatarsocuneiform joint arthrodesis. In: Marcinko DE, ed. *Comprehensive textbook of hallux abducto valgus reconstruction*. St. Louis, MO: Mosby-Yearbook, 1992
39. Bierman RA, Christensen JC, Johnson CH. Biomechanics of the first ray. Part III. Consequences of Lapidus arthrodesis on peroneus longus function: a three-dimensional kinematic analysis in a cadaver model. *J Foot Ankle Surg* 2001;3:125–131.
40. Avino A, Patel S, Hamilton G, et al. The effect of the Lapidus arthrodesis on the medial longitudinal arch: A radiographic review. *J Foot Ankle Surg* 2008;6:510–514.
41. Logel KJ, Parks BG, Schon L. Calcaneocuboid distraction arthrodesis and first metatarsocuneiform arthrodesis for correction of acquired flatfoot deformity in a cadaver model. *Foot Ankle Int* 2007;4:435–440.
42. Frankel J, Larsen D. The misuse of the Lapidus procedure: re-evaluation of the preoperative criteria. *J Foot Ankle Surg* 1996;4:355–361.
43. Catanzariti AR. Modified medial column arthrodesis. *J Foot Ankle Surg* 1993;2:180–188.
44. Coetzee JC, Resig SG, Kuskowski M, et al. The Lapidus procedure as salvage after failed surgical treatment of hallux valgus. Surgical technique. *J Bone Joint Surg Am* 2004;86-A:30–36.
45. Mote GA, Yarmel D, Treaster A. First metatarsal-cuneiform arthrodesis for the treatment of first ray pathology: a technical guide. *J Foot Ankle Surg* 2009;5:593–601.
46. Catanzariti AR, Blitch EL. Metatarsal cuneiform procedures. In: Banks AS, Downey MS, Martin DE, et al., eds. *McGlamry's comprehensive textbook of foot and ankle surgery*, 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2001:544–556.
47. Coughlin MJ, Mann RA. Hallux valgus. In: Coughlin MJ, Mann RA, Saltzman CL, eds. *Surgery of the foot and ankle*, 8th ed. Philadelphia, PA: Mosby Elsevier, 2007:183–362.
48. Barvarian B, Briskin GB, Burns P. Lapidus bunionectomy: arthrodesis of the first metatarsocuneiform joint. *Clin Podiatr Med Surg* 2004;21:97–111.
49. Fuhrmann RA. Arthrodesis of the first tarsometatarsal joint for correction of the advanced splayfoot accompanied by a hallux valgus. *Oper Orthop Traumat* 2005;2:195–210.
50. Hansen ST, MD, oral communication.
51. Manoli A, Hansen ST. Screw hole preparation in foot surgery. *Foot Ankle Int* 1990;11: 105–106.
52. Hansen ST, ed. *Functional reconstruction of the foot and ankle*, 1st ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2000.
53. DiDomenico LA, Haro AA. Percutaneous harvest of calcaneal bone graft. *J Foot Ankle Surg* 2006;2:131–133.
54. Perren SM. Physical and biological aspects of fracture healing with special reference to internal fixation. *Clin Orthop Relat Res* 1979;(138):175–196.
55. Blitz NM, Lee T, Williams K, et. al. Early weight bearing after modified Lapidus arthrodesis: a multicenter review of 80 cases. *J Foot Ankle Surg* 2010;49:357–362.
56. Weber AK, Hatch DJ, Jensen JL. Use of the first ray splay test to assess transverse plane instability before first metatarsocuneiform fusion. *J Foot Ankle Surg* 2004;4:278–282.
57. Giannestras N. In: Giannestras N, ed. *Foot disorders: medical and surgical management*. Philadelphia, PA: Lea & Febiger, 1973.
58. Ruch JA, Chang TJ. Relative strengths and efficacy of fixation techniques in osteotomies and arthrodesis of the first metatarsal. In: Ruch JA, Vickers NS, eds. *Reconstructive surgery of the foot and leg-update 1992*. Tucker, GA: Podiatry Institute, Inc, 1992:233–235.
59. Thompson IM, Bohay DR, Anderson JG. Fusion rate of first tarsometatarsal arthrodesis in the modified Lapidus procedure and flatfoot reconstruction. *Foot Ankle Int* 2005;698–703.
60. DiDomenico LA, Adams HB, Garchar D. Gastrocnemius recession for the treatment of gastrocnemius recession. *J Am Podiatr Med Assoc* 2005;95(4):410–413.
61. Basile P, Cook EA, Cook JJ. Immediate weight bearing following modified Lapidus arthrodesis. *J Foot Ankle Surg* 2010;49:459–464.
62. Sorensen MD, Hyer CF, Berler GC. Results of Lapidus and locked plating with early weight bearing. *Foot Ankle Spec* 2009;2:227–233.
63. Rink-Brune O. Lapidus arthrodesis for management of hallux valgus—a retrospective review of 106 cases. *J Foot Ankle Surg* 2004;43(5):290–295.