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The First Ray

THOMAS J. CHANG, DPM, GUEST EDITOR

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More than 60 years ago an anatomist, Dudley Morton, and an orthopaedic surgeon, Paul Lapidus, independently published similar theories that implicated excessive mobility of the first metatarsal in forefoot dysfunction. Morton first studied in detail the evolution of the foot leading to bipedal gait and then examined the feet of many of his students in an attempt to correlate his tentative assumptions with the presence of or lack of symptoms. Morton's analysis of forefoot dysfunction provides the foundation of modern surgical procedures that restore normal forefoot balance and function to asymptotic feet.

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THE LAPIDUS PROCEDURE

Mark H. Hofbauer, DPM, DABPS, and
Jordan P. Grossman, DPM

The purpose of this article is to present the authors' experience and clinical results when using the Lapidus procedure for the primary repair of hallux abducto valgus deformity. Many foot surgeons have used this procedure for correction of cavus deformity, flatfoot deformity, medial column instability, or as a salvage procedure for hallux abducto valgus. Many authors have described the procedure as technically difficult, biomechanically unsound, and plagued with complications. These individuals support their views with evidence that Lapidus himself abandoned the procedure. Dr. Kelikian once stated that the failure of a procedure does not always condemn the procedure. Occasionally, it is necessary to condemn the surgeon. We would like to offer our findings, our surgical technique, and our postoperative regimen using the Lapidus procedure, as a primary procedure, in the properly selected patient.

HISTORY

There is an abundance of literature on the deformity of hallux valgus. Kelikian has stated that well over 100 procedures have been described for surgical correction of this condition.[12] Arthrodesis of the first metatarsocuneiform joint has been advocated as a primary procedure for addressing hallux valgus and metatarsus primus adductus since the early 1900s.

Although Paul Lapidus has been credited for popularizing this procedure, Albrecht in 1911 was the first to initially describe a lateral closing wedge with an arthrodesis of the first met-cuneiform joint. Because his original paper was published in the Russian literature, his work wasn't acknowledged until Albrecht worked with Lapidus at The Hospital for Joint Diseases in New York.[1, 12] The first publication in the English journals occurred in 1925 when Walter

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Truslow described a biplanar first cuneiform wedge resection for arthrodesis and correction of metatarsus primus adductus.[12, 24]

By 1932 Lapidus was a junior member at the New York Hospital for Joint Diseases, under the guidance of Samuel Kleinberg. Kleinberg published his procedure experience using the first metatarsal-cuneiform arthrodesis for hallux valgus repair. His technique was virtually analogous to Albrecht's, with the addition of resection of the lateral base of the first metatarsal. He wrote "Frequently there is a shoulder or projection of the bone on the outer side of the first metatarsal or the inner side of the base of the second metatarsal, which interferes with the free motion of the first metatarsal and has to be removed."[12, 13]

Lapidus published his original article in 1934, followed by a series of publications advocating first metatarsocuneiform fusion for the deformity he noted as metatarsus primus varus. In his original paper his technique was very similar to that of Albrecht and Kleinberg, but Lapidus also roughed the adjacent aspect of the second metatarsal base to induce intermetatarsal fusion. He summarized by saying that this procedure is most useful in an "atavistic" or "weak" foot and that by addressing the deformity at the apex he felt was the metatarsal-cuneiform joint (MCJ), the first metatarsal was corrected and served as a medial buttress that helped to prevent pronation and deformity.[12, 14] In subsequent articles, Dr. Lapidus admitted that, although his procedure was useful in properly selected cases, proper patient selection was important.[15, 16]

Since Lapidus' work, arthrodesis of the metatarsocuneiform joint and its modification were published by Armstrong (1937),[2] Hue and Thyes (1938),[10] and Wissel (1952).[25] Durman, in 1957, combined first MCJ fusion with a medially based wedge osteotomy of the first metatarsal head. The resected wedge of bone was then used as medially based autogenous bone graft at the arthrodesis site.[7, 8]

Giannestras, in 1973, used a transcortical K-wire fixation between the first and second metatarsal to prevent the common complication of elevation of the first metatarsal. Additionally, he used the resected medial exostosis of the first metatarsal head as bone graft at the arthrodesis site.[4, 8] A retrospective analysis of 47 fusions in 33 patients was performed by Maguire in 1973. He concluded that this procedure had some advantages over metatarsal osteotomies and that nonunion, if it occurred, was in the region of a normal joint and was not necessarily considered a complication.[4, 17] An article by Robert Rutherford in a 1974 issue of the *Journal of the American Podiatric Association* was the first to describe the use of a compression screw for fixation at the arthrodesis site. He emphasized the need for stability to help obliviate hypermobility of the first ray.[21]

In 1976, Goldner and Gaines performed first MCJ arthrodesis as a primary procedure for severe juvenile hallux abductovalgus (HAV) deformity. They advocated the procedure when the angle between the first metatarsal and first cuneiform was greater than 30 degrees, and particularly when the first metatarsal was considerably shorter than the second.[4, 9] Butson, in 1980, published his study utilizing a procedure similar to the technique of Giannestras. He also used the resected exostosis from the first metatarsal as an autogenous graft to maintain first ray length, but immobilized the patient postoperatively for a longer period of time.[3]

The Lapidus procedure recently came back into vogue over the last eight to ten years as numerous articles have been published in orthopedic and podiatric literature. In 1987, Clark, Veith, and Hansen reported on a long-term retrospective review of 32 feet, using their modified procedure. The authors employed A.O. principles of fixation, using two-screw compression fixation across the arthrodesis site. A high recurrence rate in their patient population prompted

these authors to use dual screw fixation. In addition, a lateral and plantar wedge osteotomy at the first MCJ was performed, removing the articular surfaces and a minimal amount of bone. Iliac bone graft was interposed when clinically indicated to prevent a short first ray.[6]

Sangeorzan and Hansen reported their retrospective analysis at Harborview Medical Center in 1989. They evaluated 40 feet preoperatively and postoperatively. They also used multiscrew fixation, bone graft (autogenous) when indicated, and emphasized plantarflexion of the first ray during the procedure. They used 3.5 mm cortical screws across the first MCJ and from the first metatarsal into the second cuneiform primarily to ensure "rotational stability" of the arthrodesis site and not to induce fusion of the first and second metatarsals.[4, 23]

Two publications in the recent podiatric literature reviewed the Lapidus procedure. Saffo et al reported a 5-year retrospective analysis. They reported 54 procedures on 44 patients. The procedure they described emphasized minimal bone resection to prevent shortening, and more importantly, stressed the plantarflexion of the first metatarsal. This could be achieved by either a plantarly based wedge or plantar transposition of the first metatarsal at the first MCJ and was considered paramount to the success of the procedure. Fixation employed was primarily with K-wires or Steinman pins. Descript surgery technique and multiple interoperative pearls were discussed.[4, 22] Also, Hernandez et al in 1989 published an article explaining the proper indications and reasoning for choosing the Lapidus procedure.[11]

In 1990, Mauldin and colleagues published an intriguing modification, incorporating an inlay block of bone after achieving corrected position of the first metatarsal. A modified McBride bunionectomy is performed, followed by mobilization of the first MCJ. The first metatarsal was manipulated in a more lateral position as a 9/64 Steinmann pin was used for fixation. Finally, a medial rectangular trough was performed across the first MCJ and subsequently firmly packed with autogenous bone chips followed by the inlay cortical graft.[18]

Myerson has published two recent articles on metatarsal-cuneiform arthrodesis for hallux abducto valgus and metatarsus primus varus. In his 1990 publication he describes a procedure similarly. Myerson utilizes two-screw fixation but does not employ interpositional bone graft to prevent shortening of the first metatarsal. He advocates plantarflexion of the first metatarsal by bone resection and advises against transposing the first metatarsal plantar. This creates a step-off and increases the technical difficulty of fixation placement.[19] In 1992 Myerson et al published an article which was a long-term, retrospective study of sixty-seven procedures in 53 patients. The authors modified the previously described technique in Myerson's 1990 publication. Instead of resecting a biplanar wedge at the first MCJ, the authors removed only the lateral and plantar articular cartilage, leaving the medial aspect of the joint intact. Manipulation of the first metatarsal in the adducted and plantarward attitude was performed prior to insertion of the screw fixation. This modification allowed the metatarsal to be repositioned with little if any bone resection.[20]

The most recent article on the lapidus arthrodesis was written by Chang and Ruch in 1994. The authors' indications were primarily for midfoot stabilization in cases of Lis Franc arthrodesis, Charcot reconstruction and medial column fusion. The technique evaluated four different forms of fixation with the use of mechanical stress apparatus. The authors concluded that a 1/3 semitubular A.O. plate placed medially with a 4.0 mm interfragmental screw directed from plantar-distal provided the greatest amount of strength when medial column stability is critical.[5]

CLINICAL PRESENTATION

Criteria to be considered when choosing the Lapidus procedure are many. The question is often asked, "Why perform a Lapidus procedure when the same can be accomplished with a base wedge osteotomy?" This is by no means true. Patient selection for Lapidus arthrodesis does not necessarily require a large intermetatarsal angle. It is not uncommon for the author to perform a Lapidus on a patient with a ten to twelve degree intermetatarsal angle. Although it is true that patients with extremely high intermetatarsal angles are well-suited to a Lapidus procedure, those with small intermetatarsal angles may also be candidates for this procedure. Hypermobility of the first ray is a primary indicator when selecting the Lapidus procedure. Hypermobility has often been questioned. How do you measure it? Is it important? Does it really exist? Vern Inman noted that with regard to first ray motion 10% of the first ray's range-of-motion is at the first metatarsal cuneiform joint and 90% is at the navicular cuneiform joint. This may be true in patients with a rectus foot; however, it has been the authors' experience through cadaveric research that as hallux abducto valgus deformity increases and the axis of motion changes, the location of motion within the first ray also increases. We have found that in patients with moderate to severe hallux abducto valgus deformity, the amount of motion within the first ray is divided equally between joints. Therefore, it is the authors' opinion that as the axis of motion of the first ray deviates with increasing deformity, so does the apex of the deformity, precisely to the metatarsal cuneiform joint. Hypermobility is not a measurable entity; however, it can be assessed clinically by loading the foot to neutral position and moving the first ray dorsally and plantarly and noting its relationship to the second ray. Any excessive deviation dorsally with regard to the second ray would constitute hypermobility.

Many patients with hallux abductus valgus deformity present with a sub second metatarsal head lesion, or metatarsalgia associated with the second metatarsal. Often these patients demonstrate hypermobility that is leading to redistribution of weight-bearing forces from the first metatarsal to the second. Despite the intermetarsal angle, this type of patient is a candidate for a Lapidus procedure. Fusion of the metatarsal cuneiform joint with the first ray plantarflexed helps to realign the first metatarsal, thereby distributing weight back to the first ray and alleviating second metatarsal symptomatology.

Patients suffering from hallux limitus or hallux rigidus that have maintained some joint articular surface are also candidates for a Lapidus procedure. Plantarflexing and shortening the first metatarsal will decompress the first MPJ, increase range of motion and alleviate symptomatology.

Other indications include splay foot deformity requiring forefoot reconstruction, metatarsus adductus repair with Berman Gartland, isolated pain at the first metatarsal cuneiform joint, or as a medial column stabilizing procedure.

RADIOGRAPHS

Evaluation of standard weightbearing radiographs are a vital part of the preoperative assessment of hallux valgus deformity. The severity of the hallux abductus angle, the intermetatarsal angle, sesamoid position, and metatarsus adductus angle should be measured prior to surgery.[19] It is also prudent to correlate the congruity of the first MPJ and relative length of the first and second metatarsals with the clinical examination. The relative elevation of the first

metatarsal to the second metatarsal on lateral radiograph may be determined by divergence of the dorsal cortices and by sagittal plane joint breaching with plantar gapping at the first metatarsocuneiform joint.[4] Hypermobility of the first ray has been suggested to be expressed radiographically as cortical hypertrophy of the second and third metatarsal shaft secondary to excessive weightbearing.[4] Degenerative joint disease and periarticular osteophytic proliferation at the first metatarsal cuneiform joint can also be reliable signs of hypermobility. Evaluation of the lateral condyle of the base of the first metatarsal should also be noted because this prominence is resected as part of the procedure. The so-called addivistic cuneiform, in the authors' experience, is a radiographic anomaly and not necessarily a true structural entity seen intraoperatively. Preoperative radiographs help determine the possible size and length of a screw that will avoid screw threads across the fusion site and avoid peripheral joint spaces proximally.

THE PROCEDURE

Regional anesthesia along with intravenous sedation is most commonly used for this procedure; however, general anesthesia may also be used. An ankle pneumatic tourniquet is routinely used. Numerous incisional approaches have been described and are dependent on the type of fixation chosen. Screw fixation is generally the choice of the author, and therefore we routinely use a long curvolinear incision, originating just proximal to the first metatarsal cuneiform joint, and extending distally across the first metatarsalphalangeal joint. It is important to begin the most proximal portion of the incision at the most extreme dorsal portion of the joint to aid in visualization when joint resection is required. A more medial incision aids in easier resection at the joint; however, the disadvantages of a medial incision include difficulty in obtaining internal fixation as well as the inability to resect the lateral base of the first metatarsal which allows for lateral displacement and will be discussed later. A two-incisional approach has also been described and also provides fine exposure; however, it is recommended to only use this incisional approach if K-wire or Steinman pin fixation is being used. The two-incisional approach combines a 3 cm incision proximally over the first metatarsal cuneiform joint dorsally and a 3 cm to 4 cm dorsal medial incision over the first metatarsal phalangeal joint.

The incision is then deepened distally at the first MPJ. The extensor hallucis brevis tendon is identified and transected. Dissection medially is not extensive unless an osteotomy is planned distally to realign the cartilage. This is not routinely done. Dissection laterally includes an extensive lateral release of the conjoint tendon of the adductor hallucis and a capsolotomy is performed at the plantar one-half of the joint capsule. An inverted "L" incision is made dorsally in the joint capsule with one arm of the "L" extending plantarly at the medial aspect of the joint but proximal to the joint.

The head of the first metatarsal is freed from soft tissue to allow for adequate resection of the dorsal medial exostosis as well as appropriate release of the sesamoid apparatus. Once this has been completed attention is directed to the proximal portion of the wound where the incision is deepened. The extensor hallucis longus tendon must be retracted laterally. If the EHB tendon is identified, it may be isolated and removed from the wound totally. The first metatarsal cuneiform joint can be identified with a 25-gauge needle. An incision is then made at the most extreme dorsal portion of the joint. Dissection proximal

and distal should be adequate enough to allow for good exposure of the joint that aids in resection. Dissection in this area medially and laterally is best obtained with a freer elevator as well as with a #15 blade. Once adequate exposure is obtained, it is recommended that the lateral base of the first metatarsal be resected from a dorsal to plantar direction. Resection of this condyle makes it much easier to displace the metatarsal laterally and obtain IM correction. It is important when resecting this condyle not to be overzealous and resect so much bone as to leave little surface for bone-to-bone apposition as well as enough bone surface for internal fixation. One must also keep in mind that when resecting this condyle, the metatarsal must be held in a rectus position to avoid resection in an oblique fashion. This mistake is easily made if the metatarsal is held in a varus or valgus attitude.

Resection of the joint begins at the metatarsal base and is made parallel and just distal to the articular cartilage. Resection of the cuneiform is then carried out, again, just proximal to the articular surface but with minimal wedging laterally to allow for IM correction (Fig. 1*A* and *B*).

Once articular surfaces have been resected, numerous fenestrations are made on each side at the fusion site with a 1.5 mm drill bit to promote osseous bleeding and fusion (Fig. 2).

Intermetatarsal angle correction is then performed with the goal of correction to zero degrees. The entire first metatarsal is then displaced plantarly on the cuneiform to achieve plantarflexion. The fusion site is then temporarily fixated with two distally threaded guide wires that are used with the Synthes 4.0 mm cannulated screw set. The first guide wire is placed dorsally in the base of the first metatarsal approximately 1.5 cm distal to the fusion site. The guide wire is then directed from distal to proximal and slightly plantar with attention being paid not to deviate laterally, but instead to attempt to purchase solid bone in the medial portion of the medial cuneiform. The second guide wire is then placed from the medial aspect of the base of the first metatarsal approximately 1.5 cm distal to the fusion site and angled from distal medial to proximal lateral into the medial cuneiform and avoiding the intermediate cuneiform. Once the temporary guide wires are in place, each is countersunk and corresponding 4.0 mm cannulated Synthes self-tapping, self-drilling screws are placed across the fusion site (Fig. 3*A* and *B*). Intraoperative radiographs or fluoroscopy is obtained to evaluate screw placement. Once it has been determined that no screw threads are crossing the fusion site and that screw length is satisfactory, the guide wires are removed.

Closure of the wound is then carried out in layers with capsulorrhaphy work done at the first metatarsal phalangeal level. A compressive dressing of the Jones type or unnaboot application is achieved and the foot is then placed in a posterior splint.

There are a number of intraoperative decisions that are made that help to determine a successful result. When performing this procedure on children with a growth plate present, .062 Kirshner wires or 5/64 Steinmann pin fixations may be substituted for screw fixation, providing excellent results.

Much debate has been given to the advantage of curettage technique of the joint compared to resection to avoid shortening of the metatarsal. It has been the authors' experience that shortening of the first metatarsal postoperatively is irrelevant, so long as the entire metatarsal has been plantarflexed. Second metatarsal head lesions and metatarsalgia are a result of metatarsus primus elevatus and not necessarily first ray shortening. Resection of the joint allows for easier

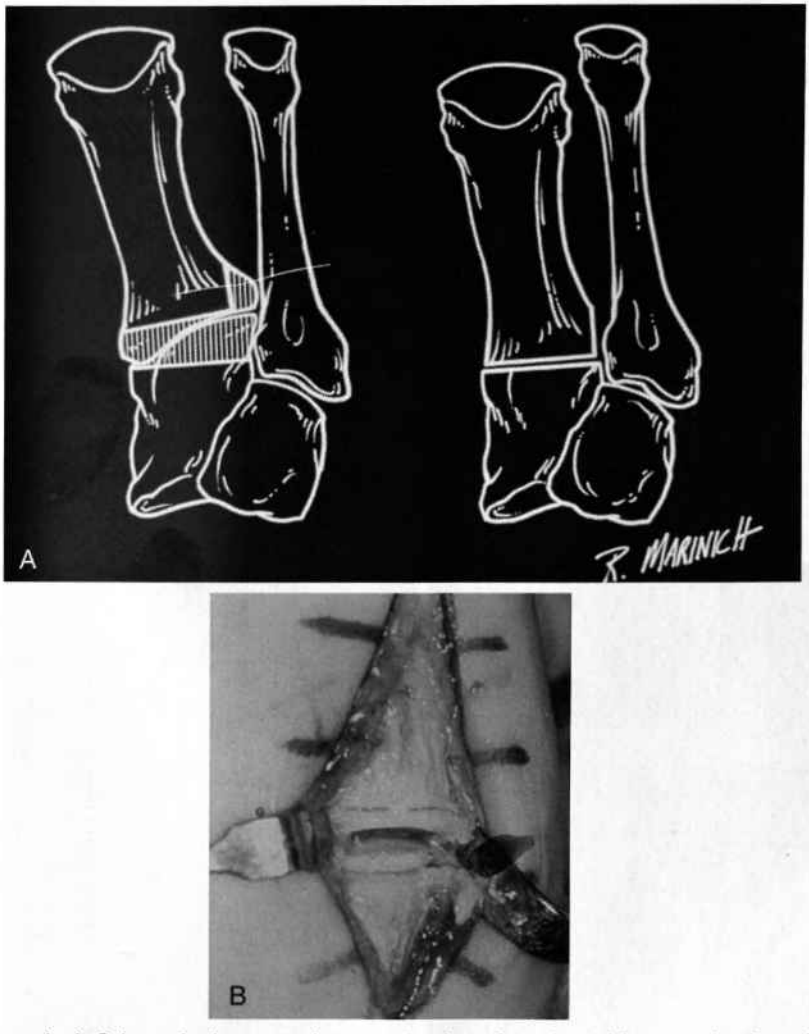


Figure 1. *A,* Schematic demonstrating resection base lateral condyle, resection base first metatarsal, and resection distal cuneiform with wedge for IM correction. (Courtesy of Dr. Alan Catanzanti.) *B,* Intraoperative of schematic.



Figure 2. Intraoperative demonstrating 1.5 mm drill fenestrations.



Figure 3. AP *(A)* and lateral *(B)* radiographs demonstrating proper positioning of two 4.0 mm cancellous screws. Note plantarflexed position of first metatarsal on lateral view.

reduction of the intermetatarsal angle and provides more surface area for bony apposition when plantarflexing the metatarsal on the cuneiform.

Bone grafting should be reserved for cases that have failed due to nonunion or malalignment and require filling of a void or reestablishment of length to the medial column. Bone grafting is generally not indicated when the Lapidus is an initial primary procedure.

Inherent to the procedure is the ability to correct deformity in three planes. One advantage over other procedures is the ability to correct metatarsus primus varus or valgus in the frontal plane. Often the central crista at the head of the first metatarsal is deviated in the frontal plane, and when the sesamoids are realigned, they do not function properly within their sesamoidal groove because of this crista rotation. The Lapidus procedure also allows for rotation of the entire metatarsal to correct this problem.

POSTOPERATIVE COURSE

Control of edema, immobilization and nonweightbearing is started immediately post operation. The patient is maintained in a compressive dressing with a posterior splint and three-point nonweightbearing with crutches or walker. At 1 week the dressing is changed, wound examined, and again placed in a compressive-type dressing with splintage. The dressing is changed after the 2nd postoperative week, at which time the stitches are removed. A below-the-knee cast is then applied and nonweightbearing with crutches is continued. First metatarsal phalangeal joint range of motion exercises are started at home beginning the second postoperative week. The patient is then seen during the sixth to eighth postoperative week at which time the cast is removed, radiographs obtained and clinical assessment is made. Partial weightbearing in a surgical shoe with an unnaboot compression dressing is started if clinical and radiographic signs indicate. Radiographic union may not be evident for months. Clinical evaluation is most important, assessing pain and stability. If 1 week of partial weightbearing is well-tolerated, progression to full weightbearing in a jogging shoe is begun.

Serial radiographs are needed only if bone graft has been used or if some type of complication needs monitoring. In the case of bone grafting, nonweightbearing should be maintained until bony union is evident and clinical signs and symptoms correlate with healing.

Edema of the midfoot, rearfoot, or ankle is a frequent finding at 8 to 12 weeks postoperatively in the Lapidus patient. Control of this edema is by means of antiembolic compression stockings and oral steroid therapy. The patient should be informed that this transient edema resolves uneventfully.

Radiographs obtained following return to weightbearing may demonstrate some metatarsus primus elevatus on a lateral view. It has been the authors' experience that this temporary condition is due in part to weakening of the peroneous longus tendon following resection of the metatarsal cuneiform joint. This condition generally will resolve itself over time with increased activity and eventual strengthening of the peroneal tendon. Occasionally, physical therapy directed at strengthening of this tendon may be indicated. Stiffness of the first metatarsal phalangeal joint is usually not encountered because the plantarflexed and shortened position of the first metatarsal acts to decompress the joint. A number of authors have stated that long-term follow-up of these patients may demonstrate proximal midfoot and rearfoot joint pathology; however, there is

no literature to support this claim and the authors have not witnessed this phenomenon.

RESULTS

The best evidence to support the long-term success of the Lapidus procedure comes from a study done by Saffo et al at our institution in 1989. A 5-year analysis of the Lapidus procedure was performed, and 44 patients comprising 54 procedures were evaluated. The average age was 45 years, ranging from 13 to 64. Minimum follow-up consisted of 1 year with a maximum follow-up of 5 years. Eighty-four percent of the patients studied believed that the surgery adequately addressed their complaint. Eighty-two percent of the patients rated the surgery as excellent or good. Most patients who were unsatisfied were primarily unhappy with concomitant procedures, not with the Lapidus itself.

Clinical results of the study revealed that 14% of the patients developed subsecond metatarsal head lesions, four percent of which were symptomatic. Four percent of the patients had pseudoarthrosis/nonunion of the arthrodesis site; however, none of these were symptomatic. Evaluation of the subtalar and midtarsal joints revealed no evidence of increased range of motion, pain, or signs of degenerative changes.

The intermetatarsal angle was routinely reduced to zero degrees and the metatarsal declination angle of the first metatarsal was shown to increase by an average of 2 degrees. Average first metatarsal shortening was 6mm; however, as demonstrated earlier, this shortening appeared irrelevant with regard to lesser metatarsal symptomatology.[22]

It is the authors' experience that the technical difficulty and morbidity that has been often associated with the Lapidus procedure can be avoided if judicious preoperative planning and comprehensive postoperative follow-up are achieved.

Hypermobility has been a highlight throughout this chapter and is a common finding in patients selected for this procedure. We have found that hypermobility and laxity of other joints of the foot in these patients are commonplace. Although no studies are published to substantiate the use of orthotic devices in patients with hallux valgus, it has been the authors' experience that these patients are prime candidates and respond well to orthotics postoperatively. To date, the authors have witnessed no recurrent HAV deformities in patients undergoing the Lapidus procedure.

Other authors have reported similar results. Maguire in 1973 reported on 33 patients undergoing a total of 47 Lapidus procedures. Good to excellent results in 80% of the patients were demonstrated. Maguire also found that nonunions were asymptomatic and not necessarily a complication. He also reported the cosmetic results were very good.[17]

Butson reported on 119 procedures in 78 patients with a follow-up of 2 to 16 years. Good to excellent results were demonstrated in 92% of cases with zero incidence of nonunions.[3] Sangeorzan and Hansen in 1989 reviewed 32 patients undergoing 40 operations. A 90% union of the arthrodesis site was reported, and 80% of the procedures were reported as successful.[23]

Myerson in 1992 reported 67 Lapidus procedures in 53 patients. At 28 months follow-up, 77% of patients had total alleviation of symptomatology, 15% were partially relieved, and 8% were not relieved with regard to comfort, pain, cosmesis, and shoewear following surgery. Seven nonunions were reported, one of which was symptomatic.[20]

The literature has supported the use of the Lapidus procedure as a primary procedure for the repair of the hallux valgus deformity. Good to excellent results have been consistently reported. The authors concur with these findings and have concluded that in the properly selected patient, consistent clinical results can be obtained utilizing the Lapidus procedure for primary repair of hallux valgus deformity.

CONCLUSION

The Lapidus procedure has been used at our institution for many years as a primary procedure for the repair of hallux abducto valgus deformity and has provided excellent results.

Indications range from mild to severe intermetatarsal angles, hypermobility of the first ray with or without pain at the metatarsal cuneiform joint, and patients with sub second metatarsal head lesions or metatarsalgia. Other indications include hallux limitus or hallux rigidus, combined forefoot deformities requiring first ray stabilization including splay foot, and metatarsus adductus.

Successful results are dependent on proper patient selection, appropriate and aggressive intraoperative techniques, properly used rigid fixation techniques, and a well-monitored postoperative regimen.

Complications can occur including mal- or nonunion, pseudoarthrosis, under- or overcorrection of the intermetatarsal angle, failure of fixation devices, and sesamoiditis due to excessive plantarflexion of the first metatarsal. All of these are common complications with any hallux valgus repair. These complications are more amenable to repair following Lapidus fusion compared with other metatarsal osteotomy failures, such as the base wedge osteotomy. Technical difficulties with the Lapidus procedure are primarily encountered with resection of the joint due to extensive, plantar, soft-tissue adherence. With proper dissection and exposure this difficulty can be minimized and should not be considered as a negative factor influencing selection of this procedure.

Long-term results of large numbers of patients that have had first metatarsal cuneiform joint arthrodesis have demonstrated excellent results with recurrence of deformity practically nonexistent. The authors believe that the Lapidus is an excellent procedure for the primary repair of hallux abductus valgus deformity and provides excellent long-term results.

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Number Sixteen



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12

The Author's Bunion Operation From 1931 to 1959

PAUL W. LAPIDUS, M.D.*

The author's bunion operation was first performed at the Hospital for Joint Diseases on April 8, 1931, and thus far has stood the test of time; it is still being done successfully. The details of it were published as a preliminary communication in February, 1934.

The purpose of this chapter is to describe our present-day approach to the bunion problem. Since the earliest days of his orthopaedic practice, the author has been aware of the frequent association of the metatarsus varus primus with bunions. What he was *not* aware of at that time was the fact that the same observation was made by anthropologists long before orthopaedic surgeons thought of it. Already in 1882, Lebouccq pointed out that the divergence of the first metatarsal was due to the extreme angle made by the plane of the distal articular facet of the first cuneiform bone with the

* New York, N. Y.

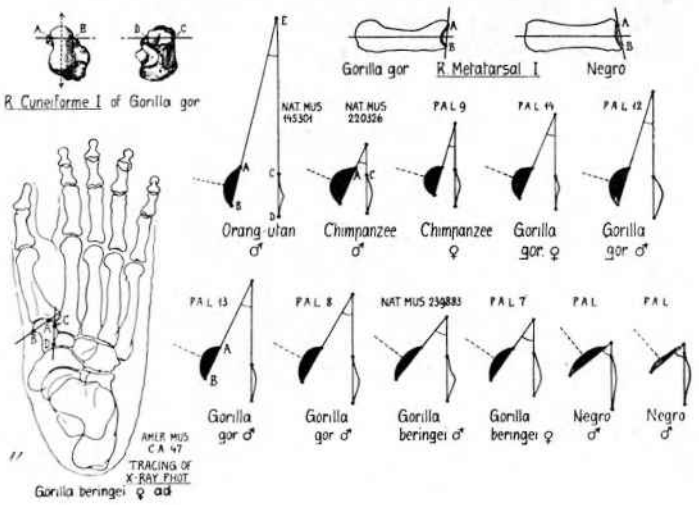


FIG. 1. Tracing of the roentgenogram of the skinned foot of an adult female mountain gorilla (beringei) showing the location of the section through the joint of the hallux and the first cuneiform. Figures on the right are accurate copies of these sections through the first cuneiform bones of various higher primates. Line A-B represents a section through the center of the first cuneiform-metatarsal joint in the plane roughly parallel to the sole of the foot. Line C-D is drawn through the middle of the joint between the first and the second cuneiforms and was found always to have practically the same direction as the morphologic axis at the foot. The angle B-E-D (see orangutan) determines the medial slant of the plane of the first cuneiform-metatarsal joint. The greater this angle the less the slant and, likewise, the divergence of the first metatarsal. According to Schultz, in man this angle is 56 to 50°; in the terrestrial gorilla beringei it is 39 to 35°; in the arboreal Gorilla gorilla it is 30 to 18°; and in monkeys it is 24 to 13°. The black semicircle represents the shape of the first cuneiform-metatarsal joint, which is more ball-and-socketlike in movable hallux of the lower primates and becomes flattened in higher primate and especially in man, with the loss of mobility of the first metatarsal. (Reprinted from Human Biology, vol. 2, no. 3 [chapter entitled "The Skeleton of the Trunk and Limbs of Higher Primates," by Adolph H. Schultz] by permission of the Wayne State University Press)

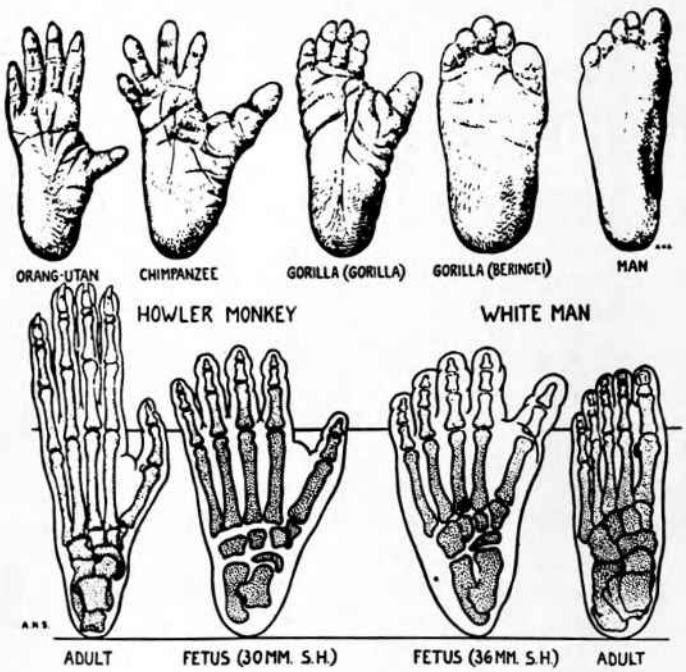


FIG. 2. Note the shortening of the hallucial ray from man to orangutan and also the increased divergence of the big toe in prehensile foot of lower primates as compared with man (upper row). The difference between the big toe in gorilla beringei and that of the Gorilla gorilla is most interesting. Although they are very closely related, the first spends a great deal of time walking on the ground; therefore, his big toe resembles very closely that of man, while the hallux of the prevailingly arboreal Gorilla gorilla still retains simian features and is more like that of the chimpanzee. In the lower row is a semidiagrammatic drawing of feet of fetal and adult man, and howling monkey, showing ontogenetic reduction of the lesser digits in adult man and their increase in a grown-up monkey. Also note that the hallucial elements are almost similar in both embryos, but the first ray of the adult man becomes stouter and loses its divergence while the reverse growth changes take place in the monkey's foot. Distance from heel to second metatarsophalangeal joint is same absolute length in all 4 drawings. (Schultz, A. H.: Quart. Rev. Biol. 1:465)

long axis of the foot. This angle approaches that found in the prehensile arboreal foot of the primates (Fig. 1). In 1927, Straus, an anthropologist, who probably never saw a patient with bunions, stated:

> In the adult human, the long axis of the basal phalanx of the hallux is not, as a rule, in line with the long axis of the first metatarsal. The phalangeal portion is bent toward the other digits. Adduction of the hallucial phalanges is the rule for all human development, being quite as marked in the fetus as in the adult. This condition cannot be ascribed to wearing boots, for it is general among the lower primates and was present in a howler fetus as well. In man it persists most likely as a relic of the days when the foot was a grasping organ and the hallux was bent as a hook toward the other toes.

Figure 2 (Schultz, 1926) illustrates the trend of ontogenetic development of the foot in the howling monkey and man, and also shows the changes of the big toe as it gradually lost its prehensile functions from ape to man.

Figure 1 (Schultz, 1930) shows the changes of the first cuneiformometatarsal joint, also from ape to man. The two cardinal features are (1) diminution of medial slant of the first cuneiformometatarsal joint and, consequently, also of the medial divergence of the first metatarsal, and (2) the flattening of the first cuneiformometatarsal articulation, which is more ball-and-socket-like in the mobile hallux of the lower primates.

The following table (Straus, 1927) brings out the fact that the varus of the first metatarsal, measured by the angle between the long axes of the first and the second metatarsals, is more marked in the human embryo, being 32.0° in an eight-week human fetus, and diminishes to 6.2° in an adult

ANGLE (APPROXIMATE) BETWEEN LONG AXES OF METATARSI I AND II DURING GROWTH OF MAN AND HOWLING MONKEY AND IN SOME OTHER PRIMATES

AGE	AVERAGE IN DEGREES	RANGE OF VARIATION IN DEGREES
Man		
8th week fetus	32.0	
3rd mo. fetuses	18.7	14.0–30.0
4th mo. fetuses	11.1	3.5–14.0
5–6 mo. fetuses	10.1	6.5–15.5
7–8 mo. fetuses	6.1	3.0– 9.5
9th mo. fetuses	8.9	3.0–19.5
Newborn	5.8	4.0– 8.0
Juvenile	5.0	2.0– 8.0
Adult	6.2	3.0– 9.0
Anthropoid Apes		
Orangutan, adult	46.2	42.0–49.5
Chimpanzee, juvenile	42.0	
Chimpanzee, adult	39.0	
Gorilla, juvenile	25.0	18.0–30.0
Gorilla, adult	25.0	20.0–30.0
Hylobates, adult	17.5	11.0–33.0
New World Monkeys		
Alouatta, fetus 111 mm., C.R.	55.0	
Alouatta, newborn	40.0	
Alouatta, adult	23.0	

Note gradual ontogenetic diminution of hallucial divergence in man from 32.0° in the 8th month fetus to 6.2° in adult. Anthropoids have a much greater angle, which reaches an average of 46.2° in prevailingly arboreal orang-utan. It is interesting to note the diminution of divergence with growth also in Alouatta (howling monkey) (Straus, W. L., Jr.: Contrib. Embryol., No. 101, **19**:119)

man. In other words, the hallux of the human embryo has simian features that gradually are lost with growth.

The above-quoted anthropologic works seem to support the postulations made by the author in his preliminary report in 1934, that the bunion is more prone to develop in an "atavistic" foot with metatarsus varus primus. This type of foot apparently became arrested in its ontogenetic development and retained some features normally present in the human embryo and in the adult foot of the lower primates. It may be considered as a reversion to a primitive state, presenting "congenital potential predisposition toward hallux valgus formation, and thus the often observed hereditary predisposition toward this deformity can be readily understood" (Lapidus, 1934). When harelip and cleft palate are repaired, or an operation for undescended testicle is performed both being typical examples of an arrest of ontogenetic development, the surgeon attempts to complete the process that normally takes place during natural growth. By the same token, if the persistence of the metatarsus varus primus, together with hypermobility and the apelike shape of the first cuneiformometatarsal joint, allowing excessive tibial abduction of the first metatarsal in an adult man, is accepted as an arrest of development and is one of the main predisposing factors for bunion formation in a great number of patients, it is only logical to conclude that surgical repair should also consist of correction of metatarsus varus primus. If the divergence of the first metatarsal in an adult is explained as a failure of nature to complete its normal cycle of growth, then it is up to the surgeon to complete what nature failed to do, similar to harelip, cleft palate or undescended testicle.

The idea that the metatarsus varus primus is a primary factor with subsequent formation of hallux valgus is not a new one. It has been advanced by a number of orthopaedic surgeons, as can be seem from Figure 3 (after Timmer), a schematic illustration of some of the numerous operative procedures devised for correction of the bunion. Once more the author wishes to repeat that, except for the details of the operation, he does not claim priority or originality. Quite a few surgeons in the past and a number of them today approached this problem in somewhat similar manner, attempting to correct the metatarsus varus primus.

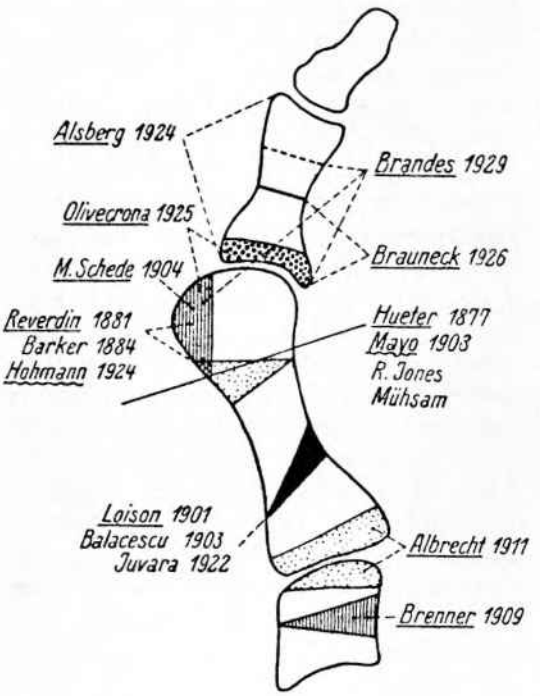


FIG. 3. Schematic drawing of various operative procedures devised for correction of bunion. The name of the author and the year of description of the operation are indicated. (Timmer, H.: Die Behandlung des Hallux valgus, Leipzig, Barth)

As already stated, the degree of divergence of the first metatarsal away (tibialward) from the second depends upon the shape and the range of motion in the first metatarsocuneiform joint. The long axis of the first metatarsal forms an obtuse angle, open tibialward, with the long axis of the first cuneiform; the apex of this angle is at the first cuneiformometatarsal joint.

Osteotomy to correct an angulation deformity of any long bone is performed usually at the apex of the angulation, and not distally or proximally to it; otherwise, a bayonet-shaped deformity is produced. An ankylosed knee joint with genu valgum or with flexion deformity is best corrected by an osteotomy placed right through the former line of the joint and not over the femur or the tibia. Therefore, it is the author's preference to correct the metatarsus varus primus at the first cuneiformometatarsal joint; numerous and variable osteotomies of the first metatarsal shaft, and particularly so over its distal part, never have seemed to the author to be mechanically sound (Fig. 3).

Furthermore, any osteotomies require adequate and prolonged immobilization to prevent displacement of fragments and to ensure their firm bony union. This, again, makes them undesirable. In another group of operative technics, attempt is made to utilize soft tissues (muscles, tendons or fascia) to approximate the first metatarsal head to the second and, thus, to correct the metatarsus varus primus. For a number of years it has been our preoperative routine in bunion cases to take dorsiplantar roentgenograms of the foot tightly bandaged across the metatarsal heads in addition to other routine exposures. We learned that in some cases we were unable to approximate closely the first and the second metatarsal heads, with some persistence of metatarsus varus primus even on tight bandaging. This was obviously due to a fixed tibial abduction contracture at the first cuneiformometatarsal joint. Consequently, is it reasonable to expect a small intrinsic muscle of the foot, as, for instance, the abductor hallucis, when it is transplanted onto the first metatarsal neck, to adduct the first metatarsal fibularward, and especially when there is fixed tibial abduction contracture present in the joint? Fascial or tendinous transplants anchored to the metatarsal necks to correct their spreading, advocated by some surgeons today, have also been tried by the author (1933) but were abandoned in favor of the bony fusion of the first metatarsocuneiform joint with creation of a bone bridging the first and the second metatarsal bases. Of course, it goes without saying that when correction of the first metatarsus varus is indicated, it is always combined with the correction of the valgus deformity of the big toe itself. In the latter procedure, not only do we depend on passive re-establishment

of balance between (tibial) abduction and (fibular) adduction of the big toe, but also we utilize the abductor hallucis muscle to supply the active power to maintain the big toe in proper alignment with the first metatarsal, as will be described below (Fig. 4).

Another group of operative technics consist of resection of the first metatarsophalangeal joint itself. The old Mayo-Küttner resection of the first metatarsal head never appealed to the author, and he is even more convinced now than he was in 1934 that "any operation creating shortening of the first metatarsal, or of the big toe, is emphatically condemned as unphysiological, and causing static and dynamic disturbance of the foot."

The resection of the base of the proximal phalanx according to the Keller-Brandes procedure has gained some popularity recently, mainly because of its simplicity and allegedly short postoperative disability. However, not infrequently after this procedure the big toe becomes a short, dangling appendage held above the ground, and the important "shove-off" function of the big toe may be lost permanently. Consequently, if one wishes to obtain as close as possible restoration of normal anatomic and physiologic relations, one cannot accept the Keller-Brandes operation.

INDICATION FOR OPERATION

Bunions are very common, especially in females, who, using their feet primarily for sex appeal, locomotor function being given only secondary consideration, succumb to the dictates of fashion and develop the deformity. The poorly fitting, narrow woman's shoe with a high heel is a factor in developing the malformation in a foot, which most of the time possesses a congenital and often hereditary predisposition toward bunion formation. In this respect, the shoe may be compared with a developing solution that only brings out the picture in a previously exposed photographic film.

We have operated upon a large number of female feet. Only a few male patients have sought surgical correction. A large percentage of bunion feet give very little, if any, discomfort, and can be treated adequately with properly fitted shoes. On the other hand, even mild bunions, especially in females, may produce a great many complaints, especially while "breaking in" a new shoe.

In addition to actual functional disturbances and disability, quite a few patients request the operation for cosmetic reasons. As a rule, we limit our surgical correction to selected cases in which functional and cosmetic consideration seem to warrant it. Therefore, although for the past many years we have operated upon a large number of patients, they represent only a small percentage of extremely numerous patients with bunions treated conservatively. Furthermore, if surgical procedure is undertaken, we do not attempt to correct the metatarsus varus primus as frequently as we did originally. We must admit that with the accumulation of larger experience through many years, we have become more conservative and in a number of cases have limited our procedure to correction of the hallux valgus alone. It has been our observation that after satisfactory correction of hallux valgus, using our modification of the Silver procedure, the varus of the first metatarsal may diminish simultaneously, provided that there is adequate mobility of the first cuneiformometatarsal joint to allow the approximation of the first and the second metatarsal heads. This mobility is estimated on roentgenograms with tight bandaging across the metatarsal heads, as already described. It has been our impression that in spite of the fact that metatarsus varus primus may be the main factor, hallux valgus developing subsequently, in a number of cases successful correction and maintenance of this correction of the big toe deformity are more important and often may be performed alone. On the other hand, additional correction of the first metatarsus varus, when it is

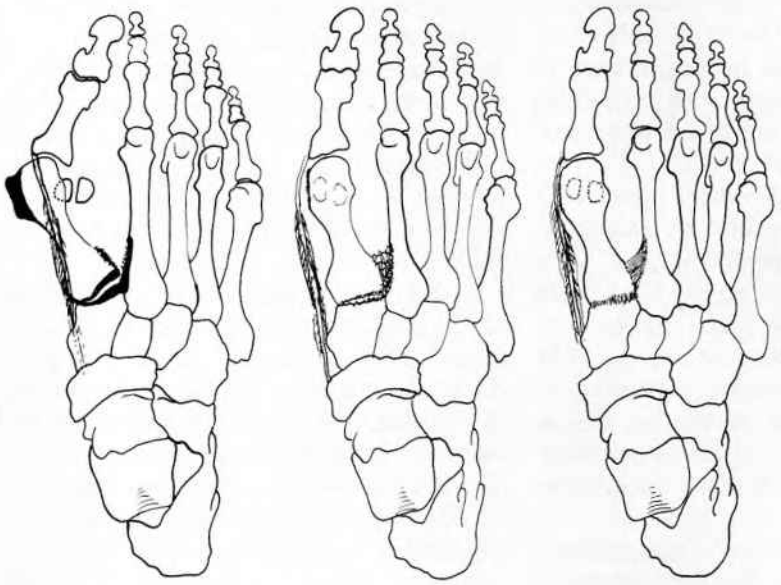


FIG. 4. Operative technic. (Lapidus, P. W.: Surg. Gynec. & Obst. 58:183.) Note the plantar displacement of the abductor hallucis in bunions and its action as a plantar flexor. It is relocated along the medial aspect of the first metatarsal, and its *abduction* action is re-established.

pronounced, with first and second metatarsals forming an angle of 10° to 12° or more, may ensure better results in the long run.

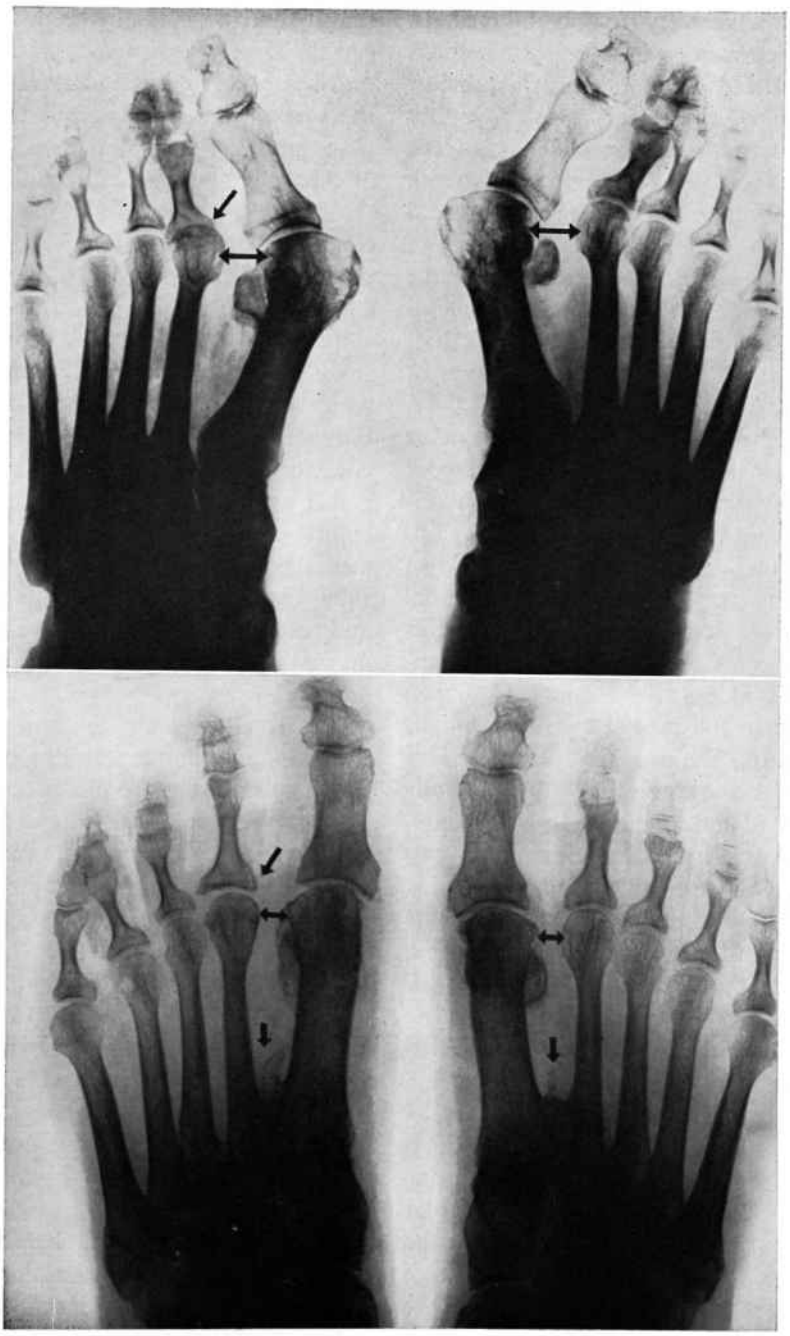
A survey of end-results of various operative procedures for correction of hallux valgus performed at the Hospital for Joint Diseases during 10 years (1931-1940) has seemed to indicate that better results were observed when metatarsus varus primus also was corrected.

We have operated upon a considerable number of patients under local anesthesia when we limited ourselves to correction of the hallux valgus alone. There is no need for a tourniquet in this procedure, which also requires less time to perform, and the postoperative recovery may be a few days shorter. On the other hand, when correction of metatarsus varus is undertaken, a tourniquet is used, and, therefore, general anesthesia is required. The decision, of course, should depend on the judgment and the personal experience of the surgeon, as well as on the condition and the requirements of each patient. If the patient is not too old and is robust, and is willing to invest an extra week or two in anticipation of a somewhat better eventual result, and if the surgeon is quite confident in his hospital facilities and is fully familiar with the foot, the combination of both procedures may be indicated. Otherwise, mere correction of hallux valgus alone will be a preferable and a safer undertaking, and may also give a very satisfactory final result.

OPERATIVE TECHNIC

The present operative technic remains essentially the same as described originally in 1934 (Fig. 4). If the correction of metatarsus varus primus is planned, the operation is performed under general anesthesia. An Esmarch rubber bandage is first applied from the toes up to the lower quarter of the leg, where it is bandaged tightly over a towel and is used as a tourniquet.

The operation over the big toe joint is performed first. A straight longitudinal incision about 3½ to 4 inches (9-10 cm.) long is made along the medial aspect of the big toe and the first metatarsal. The subcutaneous veins are ligated. The medial cutaneous nerve frequently seen in the wound is identified and retracted. The bursa over the bunion is opened, and further dissection is carried proximally in the same plane, as the



FIGS. 5 to 8, 3 cases (L.K., B.K. & A.S.) following correction of metatarsus varus primus in hallux valgus. (L.K. and A.S. also had bilateral second hammertoe operations; in Case A.S., the second toes also overlapped the big [see Fig. 7, *top*]). FIG. 5, L.K. (*Top*) Before operation. (*Bottom*) About 6 years after operation.

tissues here have very few blood vessels. The fascia covering the abductor hallucis muscle is incised longitudinally just below the insertion of this fascia along the first metatarsal shaft. A muscular belly of the abductor hallucis pops out into the wound. Its loose connection with the first metatarsal shaft may be separated by blunt dissection. As a rule, in nearly all bunions the abductor hallucis is found displaced plantarly, blending with the medial belly of the flexor hallucis brevis and acting as a plantar flexor of the big toe rather than its abductor (Fig. 4). These muscles are separated from each other also mostly by blunt dissection. The slender tendon of the abductor hallucis is then followed distally and separated from the capsule of the metatarsophalangeal joint down to its insertion onto the base of the proximal phalanx, care being taken not to sever this tendon or to open the joint capsule. The tendon is retracted plantarly, and a U-shaped flap is made in the medial capsule, with its base attached to the proximal phalanx. This flap usually is about ¾ inch (2 cm.) long and ⅜ inch (1 cm.) wide at its distal base, tapering proximally to the neck of the first metatarsal. The capsular flap is reflected distally, care being taken to dissect it from the medial aspect of the first metatarsal head, preserving its full thickness. Usually a small artery is cut over the metatarsal neck. The joint now is opened by reflecting the flap distally. The neck of the metatarsal is exposed. The "sagittal groove," so well described by Haines and McDougall (1954), is noted. It runs in dorsoplantar direction, separating the normal lateral cartilaginous articular surface that remains in contact with the laterally subluxated proximal phalanx from the fibrously degenerated cartilage of the medial part of the head. This groove often is quite deep in marked cases of bunion and is reddish, containing denuded rough bone. The "bunion" itself is represented usually by the dorsomedial prominence of the first metatarsal head. This prominence is shaved off so that the medial, the dorsal and, to a certain extent, the medioplantar flare-up of the first metatarsal head is removed. Now the medial part of the head is in the same plane and is the continuation of the cortex of the neck and the shaft of the metatarsal. Occasionally there is a dorsal prominence over the first metatarsal head, which likewise has to be shaved off. Small wood-carving chisels obtainable in any hardware store in a set, together with a sharpening stone, have been used by the author for many years and are indispensable, particularly for resection of the first metatarsocuneiform joint. They are sterilized, together with the stone, and sharpened just before the operation. When resecting the medial part of the first metatarsal head, care should be taken to preserve its round shape, and especially its part covered with the normal cartilage, without excising too much bone.

We usually replace the capsular flap and the skin and palpate through them to be sure that no bony prominences are left.

The subcutaneous tenotomy and capsulotomy then are performed over the fibular aspect of the first metatarsophalangeal joint from a dorsal approach, while the big toe is forced gently into varus (10°-15°) position. A stout sharp tenotome should be used for this, and it should be inserted to hug the bone and the joint closely, as the blood vessels and nerves pass more superficially to bone in surrounding soft tissues. The medial tongue-shaped flap of the capsule is sutured to the tendon of the abductor hallucis longus with considerable tension, several No. 00 chromic stitches being used. The plantar and the dorsal capsular wounds are also closed. At the same time the abductor hallucis belly, together with its tendon, is shifted dorsally, running now along the medial aspect of the first metatarsal instead of plantarly to it, and its action as an "abductor" (tibialward) instead of a plantar flexor of the big toe now is re-estab-

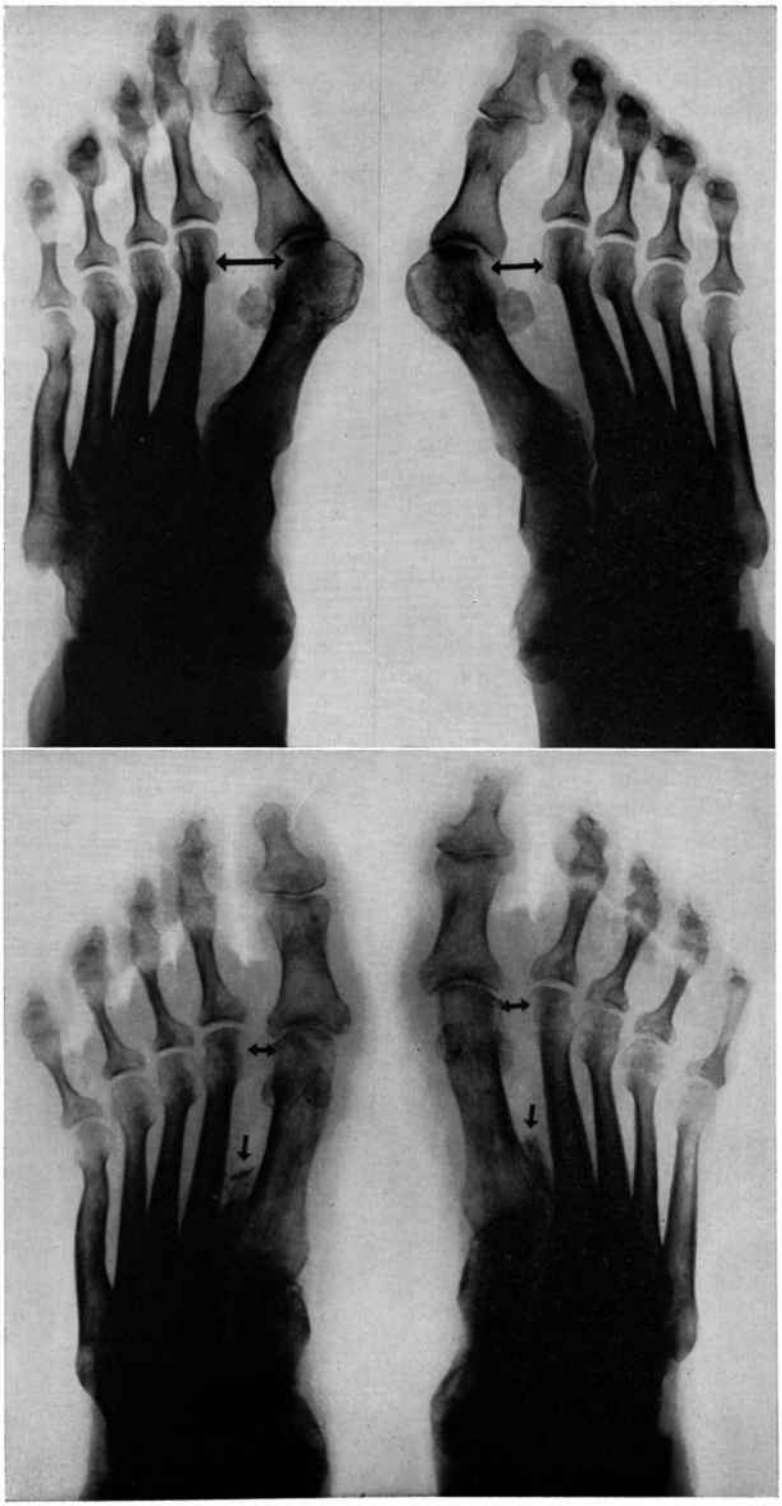


FIG. 6, B.K. (*Top*) Before operation. (*Bottom*) About 6 months after operation.

lished (Fig. 4). The closing of the capsule should be performed carefully and judiciously. All capsular slack produced by resection of the medial part of the head should be removed, but at the same time the capsule should not be sutured too tightly as later to cause limitation of motion of the big toe; a good balance between abduction and adduction and dorsal and plantar flexion should be created. As a rule, the big toe in hallux valgus is in internal rotation, so that both big toenails face each other. This also should be corrected. In ordinary cases no removal of the bursa is ever attempted unless suppurative bursitis is present. In a few of our patients, there was communication of the infected bursa with the joint. In these cases, after thorough débridement of the infected tissue, we were able also to perform the bunion operation with primary union of the wound and used antibiotics postoperatively. Occasionally there is communication of the bursa with the joint also in cases without infection. In one case there was a very extensive deposition of uric acid in the bursa, and the joint surfaces were canary yellow, all impregnated with uric acid crystals. Perfect primary healing was also obtained in this 69-year-old man. The skin is closed without suturing the subcutaneous structures. If the procedure is carried out adequately, the big toe remains well corrected without any external support.

As already stated, in a number of our cases we were able to obtain very satisfactory and lasting results after this procedure alone. If, however, the correction of the metatarsus varus primus is indicated, it is carried out as a second step following completion of the operation on the big toe. A longitudinal incision about 3½ inches (9 cm.) is made along the dorsum of the first metatarsal and the first cuneiform. The first cuneiformometatarsal joint is exposed by retracting the tendon of the extensor hallucis longus medially and that of the extensor hallucis brevis laterally. The cutaneous nerve branches are identified and protected. The V-shaped space between the first and the second metatarsal bases is exposed by dissection, hugging the first metatarsal closely. The perforating plantar branches of the dorsalis pedis vessels are retracted distally and fibularward with the soft tissues when exposing the second metatarsal base. Occasionally the veins are ruptured, but we have never had any complications from that.

The cortex from the adjacent surfaces of the base of the first and the second metatarsals is removed, leaving the bone chips in situ. The first cuneiformometatarsal joint is opened on its dorsal aspect. The adjacent cartilaginous articular surfaces of the first metatarsal and the first cuneiform are shaved off. Here a small wood-carving chisel about 5 inches (13 cm.) long and about ⅜ inch (about 1 cm.) wide, is indispensable! We learned that no real wedge resection was necessary, that mere shaving off of the articular cartilage down to subchondral bone was not only enough but also essential in order to produce close linear coaptation of the resected joint surfaces and ensure prompt "primary union" of the bones.

One has to become familiar with this bean-shaped joint, which measures almost 1⅛ inches (2.9 cm.) in dorsoplantar direction, and approximately ½ inch (1.3 cm.) from side to side in its widest dimension. It also faces plantarward and medially (Fig. 1). The articular facet of the first metatarsal is slightly concave, while that of the first cuneiform is correspondingly convexed in sagittal plane. There is also a similar concavity of the first metatarsal and convexity of the first cuneiform in the horizontal plane. A snug fitting and close approximation of the resected surfaces should be obtained. A hole is then made with a shoemaker's awl

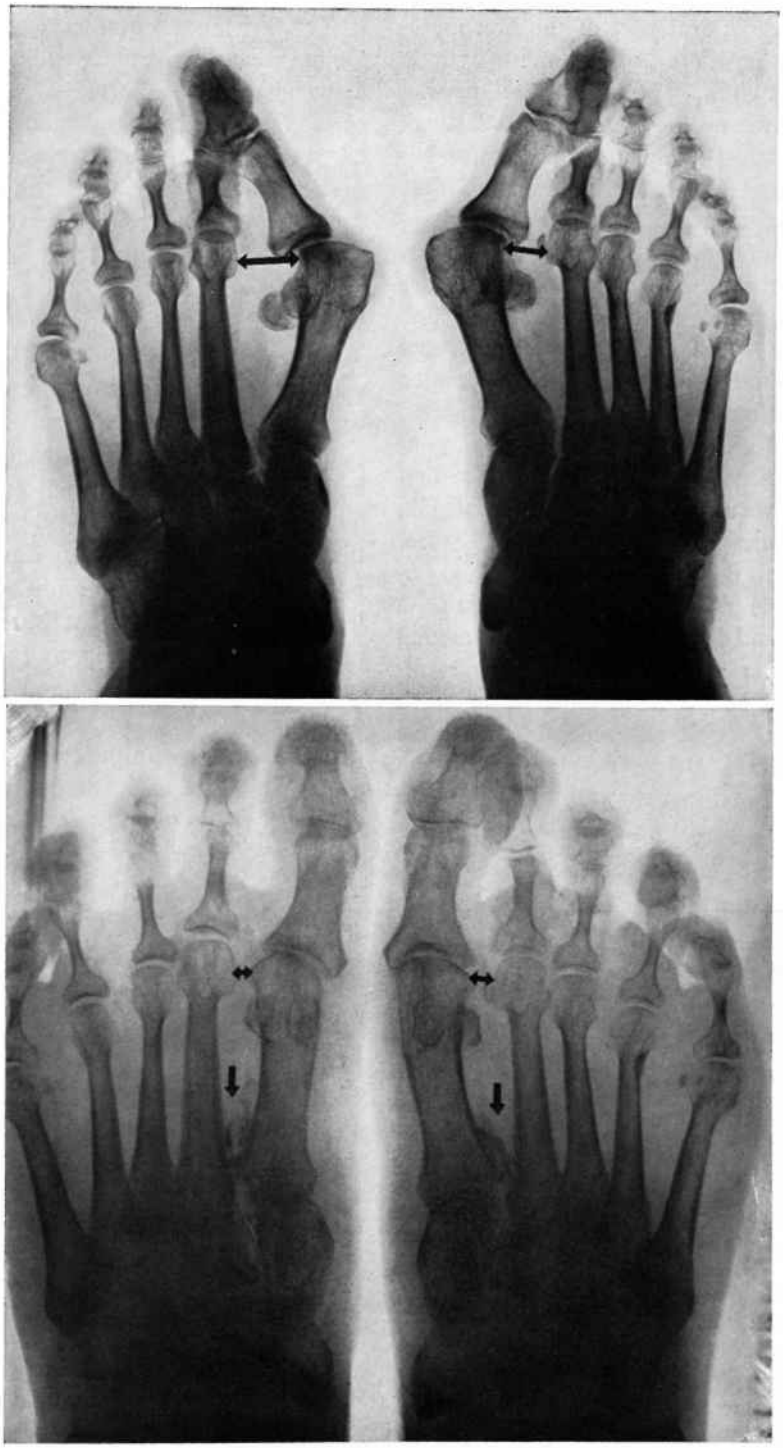


FIG. 7, A.S. (*Top*) Before operation. (*Bottom*) About 6 weeks post-operatively.

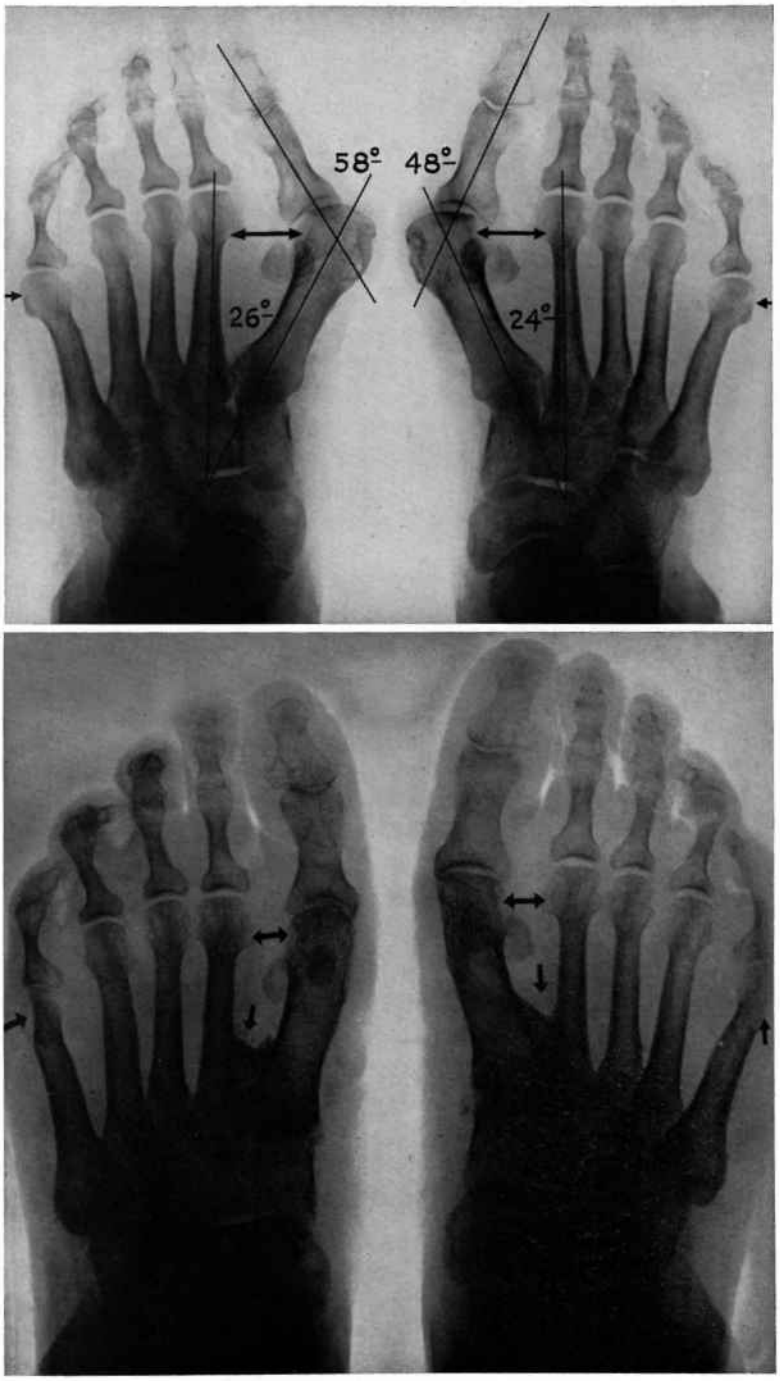
over the dorsolateral part of the first metatarsal base, and No. 0 chromic catgut is passed through it, using a curved needle. Proximally, the needle is introduced through the strong dorsal ligamentous structures between the first and the second cuneiforms. When this stitch is tied, a close approximation is maintained. The pieces of bone obtained from the first metatarsal head are denuded from soft tissue and cartilage and cut in very small bone chips, which are inserted abundantly between the denuded bases of the first and the second metatarsals. They later form a bony bridge that maintains permanently the correction of the first metatarsus varus. Skin is closed with silk without suturing the subcutaneous tissues. A 5-inch (about 12 cm.) long and 5/16-inch (7 mm.) wide steel corset stay is used as a splint and is inserted along the medial aspect of the first metatarsal over well-padded dressing. The big toe is strapped to it at about 10° of varus and in slight external rotation. The first dressing should be done snugly, but not too tightly. After adequate correction, one will find on postoperative roentgenograms complete correction of metatarsus varus primus without tight bandaging across the forefoot. Likewise, the splinting of the big toe should be done most carefully in order to avoid pressure over the suture line. This is very important. One should depend primarily on an adequate surgical correction, the splinting being aimed only at maintaining it, rather than on increasing the correction.

Since the introduction of the antibiotics we have applied an antibiotic ointment routinely to the suture line* and also given the patient an antibiotic starting from one day before the operation and continuing for about 1 week postoperatively. It was noted that better wound healing was gained with prophylactic use of the antibiotics. Particularly, the wound over the bunion showed a more frequent tendency to form stitch abscesses and to separate in our early cases, and that tendency appeared to be greatly decreased by the antibiotics. There was not a single case of true infection in our latest

* Lately we have been using only Telfa.



FIG. 8. Result at the time stated after operation.



FIGS. 9 and 10, H.H., a 52-year-old female with metatarsus varus primus of 26° on the right and 24° on the left, and right hallux valgus of 48° and left of 58°. FIG. 9 (*Top*) Preoperative roentgenograms of both feet showing very marked deformity. (*Bottom*) Same feet about 2½ years after the operation performed on November 4, 1953. Note the heavy bone bridge between the first and the second metatarsals. Lateral prominence of both fifth metatarsal heads was also removed (arrow). (Lapidus, P. W.: Bull. Hosp. Joint Dis. **17**:404)

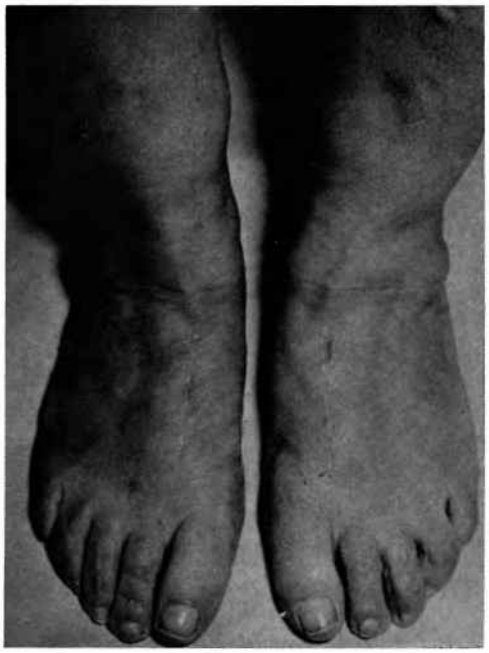


FIG. 10. Both feet on February 13, 1956, 2½ years after the operation. Patient still has very satisfactory correction at the present time. (Lapidus, P. W.: Bull. Hosp. Joint Dis. 17:404)

(treated with antibiotics) cases. In two cases there was pressure necrosis of the soft tissue over the bunion; in one of these (not done by the author), a satisfactory result and complete healing were obtained 4 months after the operation. The second case subsequently developed involvement of the bone of the base of the proximal phalanx of one big toe that later required resection of the Keller-Brandes type. The postoperative disability lasted on and off for about 1 year, and the final result after the Keller-Brandes operation on one foot was considered to be unsatisfactory by our standards. Although we had only two cases with this complication in our large series, we recommend most careful postoperative after-care, especially during the first postoperative week. Usually we change the dressing on the second or the third postoperative day and replace carefully the steel corset stay, maintaining the big toe at 10° of varus. A great number of our patients have been able to go to the bathroom bearing weight on their heels on the second or the third postoperative day and were discharged from the hospital at the end of the first week after operation. Only a few patients required the use of crutches for the first week or two. A number of housewives were able to begin some light housework 2 or 3 weeks after the operation.

The stitches usually are removed at the end of 2 weeks, and snug bandaging and adhesive strapping across the metatarsal heads over an adequate padding are continued for about 4 to 6 weeks. The splinting of the big toes may be discontinued 3 or 4 weeks after the operation, depending on the amount of correction. During the first 2 weeks there may be slight overcorrection with a few degrees of varus of the big toe. This should not be allowed to remain permanently. Control postoperative dorsoplantar roentgenograms are taken to ascertain the amount of the approximation of the first and the second metatarsal heads and the relation of the big toe to its metatarsal. Also, they show the amount of bone bridge formation between the first and the second metatarsal bases and the degree of fusion of the first cuneiformometatarsal joint. Both are usually quite solid at the end of 3 months, with subsequent roentgenograms showing further consolidation of the intermetatarsal bridge.

At first, special canvas shoes or wool socks with leather soles are worn. During the second postoperative month, the patient may wear wide soft shoes or sandals. After

FIG. 11 (*on facing page*), C.J., a 16-year-old girl. About 2 years previously, she had been operated upon elsewhere. Bilateral osteotomy (large arrows) at the first metatarsal base was performed (Mitchell's procedure) in addition to bunionectomy; also successful correction of second and third hammertoes had been performed (arrows). There was prompt recurrence of

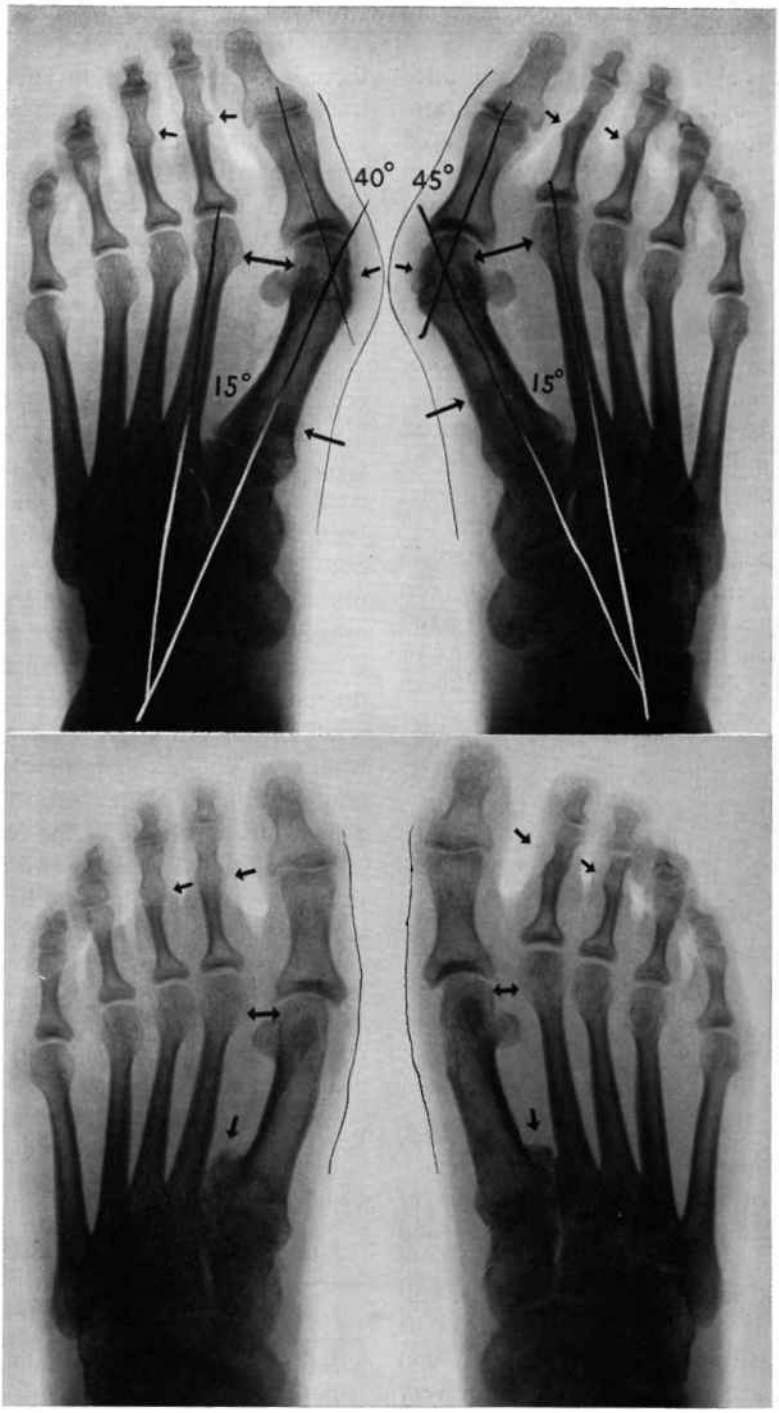


FIG. 11 (*Continued from facing page*)
bunions and extensive keloid formation over the postoperative scars (skin outline retouched over the bunions).

(*Top*) 1 year and 8 months following the first operation elsewhere. (*Bottom*) 3½ months after the second operation by the author. Note the distance between the first and the second metatarsal heads and bony bridging already present between their bases. Excellent correction is still maintained.

that time he is able to use regular well-fitted but perhaps slightly larger shoes. Housewives, as a rule, can resume their usual work about 2 months after the operation; patients having to do a great deal of walking or standing may require another week or two before going back to their 8-hour workday.

Hammertoes and overlapping hammertoes, frequently associated with bunions, usually are corrected at the same sitting. Essentially, the technic used is that described by the author in 1939, except that now he also resects the distal 3 mm. of the proximal phalanx, care being taken to remove all prominent bone edges and to establish proper alignment of the toe. He has been able to reduce the sometimes present fixed dorsal subluxation of the basal phalanx of the lesser toes by a thorough dorsal subcutaneous tenotomy and capsulotomy. After correction of the hammertoe deformity, the toe is immobilized with gently applied adhesive strapping, maintaining the plantar flexion at the metatarsophalangeal joint and dorsiflexion at the interphalangeal joints, care again being taken not to produce any ischemic changes.

SUMMARY

A very large number of our bunion cases were treated conservatively and required no surgery.

When surgical correction was indicated, we used our modification of the Silver procedure, consisting of anchoring the abductor hallucis tendon into mediocapsular flap and thereby supplying active muscular power in addition to a passive correction of the valgus of the big toe. This operation can be performed easily under local anesthesia and needs no tourniquet. It may give a very satisfactory result in cases without metatarsus varus primus or when the varus of the first metatarsal is not very extensive and is correctible.

In cases with pronounced and unreducible metatarsus varus—in other words, when there is a fixed abduction (tibialward) contracture of the first cuneiformometatarsal joint—better results were obtained following resection of the first cuneiformometatarsal joint and creating a bony bridge between the first and the second metatarsal bases in order to maintain permanent correction. This procedure is especially advisable in robust and not too old individuals.

Our present-day operative technic has been described in detail. Our operation, first performed on April 8, 1931, has been given adequate trial over the years, and our results—particularly in recent years—have been most gratifying and warrant continuation of our surgical approach in bunion problems. The popular Keller-Brandes type operation is a much simpler procedure, but it seldom, if ever, results in restoration of practically normal anatomic and functional relationship. Although our technic is somewhat more complicated, it certainly is within easy reach of any qualified orthopaedic surgeon with knowledge of the foot.

An additional week or two of postoperative recovery seems to us to be a very sound investment for the ultimate results in our cases reviewed years after the operation.

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Le Operation del Autor ab 1931 Usque 1959

Summario in Interlingua

Es discutite le tractamento del tumescentia in le bursa mucose del eminentia al pollice del pede que es hic designate per le termino anglese "bunion."

Un grande numero de nostre casos de buniones esseva tractate conservatorimente e requireva nulle intervention chirurgic.

Quando un correction chirurgic esseva indicate, nos ha servite nos de nostre modification del technica de Silver que consiste in ancorar le musculo abductor del halluce in un panno del capsula medie pro provider active fortia muscular in ultra del correction passive del pollice valge. Iste operation es facile e effectuar sub anesthesia local e non require le uso de un tourniquet. Illo produce multo satisfacente resultatos in casos sin metatarso prime varo in que le aspecto var del metatarso prime non es extense e pote esser corrigite.

In casos con metatarso marcatemente e irreducibilemente var—in altere parolas: in casos con fixate contraction abductional (verso le tibia) in le prime articulation cuneiforme-metatarsal—melior resultatos esseva obtenite per primo resectionar le prime articulation cuneiforme-metatarsal e crear un ponte ossee inter le prime e le secunde base metatarsal pro assecurar le permanentia del correction. Iste technica es specialmente recommendate in subjectos robuste e de etate non troppo avantiate.

Le technica chirurgic que nos usa currentemente es describite in detalio. Nostre operation—primo effectuate le 8 de april 1931—ha essite testate satis perennemente, e nostre resultatos (particularmente in recente annos) ha essite multo incoragiante e justifica le continue uso de nostre methodo operatori in casos de bunion problematic. Le frequentemente usate typo de operation secundo Keller-Brandes es multo plus simple, sed illo resulta rarmente—si del toto—in le restauration de practicamente normal relationes anatomic e functional. Ben que nostre technica es un pauco plus complicate, illo certo non excede le capabilitates de un qualificate chirurgo orthopedic qui possede un bon cognoscentia del pede.

Un o duo septimanas additional de recuperation postoperatori impressiona nos como un molto sage investimento de tempore si on considera le ultime resultatos que nos ha obtenite per nostre methodo a judicar secundo un revista del casos annos post le execution del operation mesme.

Exhibit 1013

Surgery, Gynecology and Obstetrics

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OPERATIVE CORRECTION OF THE METATARSUS VARUS PRIMUS IN HALLUX VALGUS

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THE enormous wealth and great diversity of the operative procedures devised for the correction of hallux valgus deformity is eloquent proof that this problem is far from being adequately solved. However, it is not within the scope of this preliminary communication to go into any review of the very abundant literature on this subject.

The operation for correction of hallux valgus, as given below, is the result of the writer's personal study of this condition. There is no priority or originality claimed by the writer, except for the details of the operation, as he is fully aware, after a review of the literature, that there were a few surgeons in this country, as well as abroad, who had approached this problem in more or less a similar way to the one here presented.

The purpose of this paper is to stress the mechanical importance of the metatarsus varus primus, as one of the most frequent and most prominent factors of the hallux valgus deformity.

The cases of hallux valgus may be classified under three groups.

1. Cases with congenital predisposition toward hallux valgus formation, due to metatarsus varus primus. (The deformity may appear in early youth (Fig. 1) and is often hereditary.)

2. Arthritic hallux valgus, due to inflammatory periarticular contractures.

3. Paralytic hallux valgus, caused by loss of muscular balance.

It is unnecessary to say that this classification is more or less artificial, and there are possibilities of combinations of any of the features of these three classes in the same case.

The first group is the largest one, and the one mainly considered in the presentation.

It is admitted that in the process of phylogenetic development, the *homo sapiens* went through an arboreal stage of life. During this period, the foot had to adapt itself to a grasping motion when climbing trees, and therefore resembled the hand—because of greater mobility of the joints, and the presence of opposition of the big toe, similar to that of the thumb.

Sameness between the hand and the foot is also observed in primates, who use their feet for grasping. In man, the foot serves mainly as a supporting limb, and therefore the human foot had to lose its mobility—the hallux becoming strengthened, and the other toes diminishing. The hallux of primates resembles more the thumb, because of its freer range of motion, and the large angle formed by the first and second metatarsals (Fig. 2). To a lesser degree, it may be noted in the human embryo, and infants.

Among many changes that took place in the plantigrade human foot, due to special demands made upon it, in the course of human evolution, there is a marked differentiation between the hallux and the thumb. The first metatarsal in the well developed human foot is nearly parallel to the second (Figs. 3, A and B). Classical paintings and sculpture depict the long and rather narrow foot as an example of beauty and perfection, long before orthopedic surgeons thought of it. Thus it may be assumed that the adult foot, presenting marked fan-shaped spreading of the metatarsals (*spreiz-fuss* of German authors), with a large angle between the first and second metatarsals (metatarsus varus primus), and therefore with a large space between the first and second metatarsal heads, must be considered as an atavistic foot, which never became fully developed. This is a type of foot which most commonly forms a hallux valgus (Fig. 1) and thus the often observed hereditary predisposition toward this deformity can be readily understood.

An excellent illustration of this atavistic type of foot, with metatarsus varus primus, presenting congenital potential predisposition toward hallux valgus formation was observed by the author in a case of middle aged brother and sister. The sister developed "bunions" in young age, as a result of wearing the usual distorting ladies' shoes, while her brother's feet remained normal, because of wide, straightlast shoes, which checked this potential tendency (Fig. 4, A and B).

The first precursors of incipient "bunion" as a rule are observed in girls with atavistic foot at the age of about thirteen and fourteen when they first start to wear a narrow pointed shoe with a high heel. The weight bearing is thrown more on the forefoot, and the force of gravity itself tends to produce further spreading of metatarsals and to increase the metatarsus varus primus.

The thumb-like hallux has no room in the narrow, and often short, shoe. It is gradually de-

[1]From the service of Dr. Leo Mayer. [2]From the service of Dr. Percy Willard Roberts.



Fig. 1. Roentgenogram of feet of a girl 9 years old. Typical atavistic foot with metatarsus varus primus and hallux valgus deformity in spite of the fact that the child had never worn narrow shoes.

viated toward the second toe and adopts a valgus position, which consequently becomes fixed. The base of the proximal phalanx subluxates laterally upon the first metatarsal head and pushes the latter medially. The already congenitally relaxed transverse ligament between the first and second metatarsal heads becomes even more stretched, thus contributing to the increase of the original metatarsus varus primus.

The first metatarsal head protrudes medially and sometimes a bony proliferation forms over its medial part as a result of chronic trauma against the shoe. As pointed out by Hiss, the abductor hallucis is the only muscle preventing hallux valgus formation. This muscle is much weaker than the adductor hallucis, the latter's action favoring the valgus position of the big toe. Besides that the short and long flexors and extensors of the big toe also contribute to the hallux valgus deformity as they become displaced laterally to the first metatarsophalangeal joint and their pull increases the angulation between the first metatarsal and the basal phalanx. The lateral displacement of the sesamoids over which run the tendons of the two heads of the flexor hallucis brevis is a commonly observed condition (Fig. 5, A and others).

In cases of considerable varus position of the first metatarsal, there is a large space between the first and second toes. This space may accommodate the big toe in hallux valgus position (sometimes over 45 degrees) without the big toe overlapping the second or being overlapped by the latter. On the other hand, this overlapping of the big toe by the second, or the reverse, must necessarily take place, even in mild cases of hallux valgus deformity, without presence of the metatarsus varus primus, because the first and second toes lie very close to each other.

I believe that the congenital metatarsus varus primus in the majority of cases is the primary deformity leading to secondary formation of the hallux valgus. In other words, the medially opened angulation between the first cuneiform and the first metatarsal, causes the compensatory angulation open laterally between the big toe and the first metatarsal. This occurs in somewhat similar manner as the dorsal kyphosis of the spine is compensated by an increased lumbar lordosis. It can readily be seen that any attempt at correction of hallux valgus by only adducting medially the big toe and bringing it in alinement with the first metatarsal, will be futile, in a foot presenting metatarsus varus primus. In this case, after successful correction, the big toe will be widely separated from the second toe, and will protrude medially. This kind of foot with a *thumb-like hallux* would fit more easily into a glove than a shoe, unless the big toe were again brought back to hallux valgus position (Fig. 6).

Consequently any operative procedure designed only to straighten the secondary angulation between the first metatarsal and the big toe, or only correcting the hallux valgus itself, is prone to have a recurrence of the deformity, unless the varus position of the first metatarsal will also be corrected, as the latter is the primary underlying cause in the majority of cases of hallux valgus. A few operative procedures in the past aimed to correct the medial deviation of the first metatarsal, by means of varied osteotomies at different parts of this bone, or through the first cuneiform.

The only way to make a straight line of two lines forming an angle less than 180 degrees, is by moving the free end of one of the lines around the point of their cross section as a center, until the two lines will form an angle of 180 degrees. In order to correct any bony angulation, the osteotomy should be made at the apex of the angulation. The knock knee deformity is treated by an osteotomy as near the knee joint as possible, as the apex of the angulation between the tibia and the femur is usually located near this

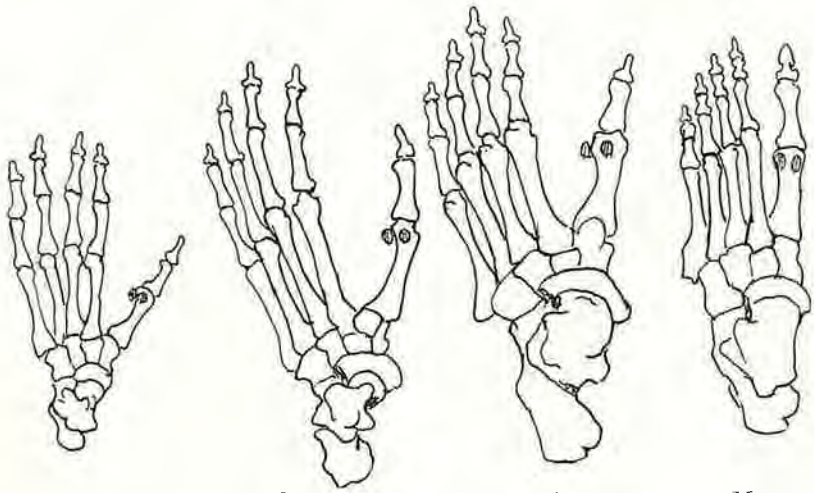


Fig. 2. Note the thumb-like big toe of primates with marked varus position of the first metatarsal. (Adapted with modification from Hiss, J. M. Am. J. Surg., 1931, xi, 53).

joint. No one would try to correct a knock knee by osteotomizing at the middle of the tibia, or of the femur, for example. Therefore, the only mechanically sound osteotomy for correction of metatarsus varus primus should be located at the first cuneiformometatarsal joint, which is the apex of the angulation between the first metatarsal and the first cuneiform.

Without going into detailed description of the anatomy of the region of the first cuneiformometatarsal joint, a few important points should be mentioned. The articulating facets of the first metatarsal and the first cuneiform resemble a lima bean, the long axis of which lies in a dorsiplantar direction. The concavity of the bean is toward the second cuneiform—the convexity toward the medial border of the foot. The plane of this joint extends from dorsal, anterior, and lateral to plantar, posterior, and medial directions; in other words, the articular facet of the first cuneiform, after removal of the first metatarsal, will face medially and slightly plantarward. The more medial slanting of the facet of the first cuneiform, the more pronounced is the varus position of the first metatarsal.

The occasionally present intermetatarsal articular facet and the lateral dorsal part of the first metatarsal base impinge against the adjacent medial aspect of the base of the second metatarsal, and prevents lateral abduction of the first metatarsal, toward the second metatarsal. That is why this part of first metatarsal base should be chiseled off in correcting metatarsus varus primus.

The second cuneiform is shorter than the first. Therefore the line of the second cuneiformometatarsal joint on the dorsum of the foot lies about 1 centimeter proximally from the line of the first cuneiformometatarsal joint. The dorsalis pedis artery with its plantar branch passes closely between the bases of the first and second metatarsal bones and should be spared during the operation.

DESCRIPTION OF THE OPERATION

The operation is better performed without the use of a tourniquet, as the bleeding is negligible, and it is preferable to control it during the operation.

A longitudinal incision, about 5 centimeters long, is made on the dorsimedial aspect of the foot. The incision should correspond to the line of the joint between the first and second cuneiforms. The line of the first cuneiformometatarsal joint should cross the middle of the incision. The tendon of the extensor hallucis longus is retracted medially without opening its synovial sheet. Occasionally it is necessary to lengthen this tendon. The first cuneiformometatarsal joint and the adjacent parts of the bases of the first and second metatarsals are exposed subperiosteally, care being taken not to cut the dorsalis pedis artery and its branches.

The tuberosity of the first metatarsal, impinging against the second metatarsal base, is chiseled off, the plane of the chisel being held parallel with the long axis of the first metatarsal, and strictly in dorsiplantar direction (Fig. 7, A). The adja-



A.



B.

Fig. 3. A, Long narrow feet. The big and second toes lie close together. B, Roentgenogram of the same feet showing first and second metatarsals almost parallel to each other. This type of foot had no potential tendency to hallux valgus formation. Note that even in this type of foot there is a slight "physiological hallux valgus." Two sisters and father of this patient had also similar type of feet.

cent part of the second metatarsal base is also roughened with a curette.

After that, a small wedge with the base laterally, is removed from the articular surfaces of the first metatarsal and the first cuneiform, only over their lateral aspect (Fig. 7, B and C). The medial part of the first cuneiformometatarsal joint should be left intact except being denuded from its cartilaginous covering. The base of either wedge removed from the first metatarsal and the first cuneiform should not be wider than about 3 or 4 millimeters each (somewhat more bone should be removed from the cuneiform). The last two points—(1) not to osteotomize the medial part of the adjacent articular surfaces of the first metatarsal and the first cuneiform; and (2) not to remove too wide a wedge—are of extreme importance, especially the first one. The aim of the operation is to produce a bony fusion of the first metatarsocuneiform joint and adjacent bases of the first and second metatarsals in corrected position. Too large a resection of bone, creating a large gap, may be not favorable for bony fusion.

Transverse resection of the whole first cuneiformometatarsal joint (also over its medial part) as advocated by a few surgeons, will produce a shortening of the first metatarsal, causing considerable disturbance of the statics and dynamics of the foot. The first metatarsal bone serves as a medial buttress of the foot, preventing its pronation. The head of the first metatarsal with the underlying two sesamoid bones, is the medial anterior weight-bearing point of the foot. Any shortening of the first metatarsal, will, therefore, result in an increase of pronation of the foot. Beside that, the second metatarsal head will be much longer, compared with the first, and will become the weight-bearing point, instead of the first metatarsal head, resulting in pain and formation of tender callosity, beneath the anterior arch.

The big toe plays an important part in the process of locomotion. There is a phase in walking, and especially in running, when the whole weight of the body is borne by the first metatarsal head, with the big toe in extreme dorsiflexion (Fig. 4, A, left foot). Shortening of the first metatarsal will weaken the action of the plantar and dorsal flexors of the big toe, because the distance between the origin and insertion of these muscles will become diminished. This will create some disturbance of gait.

Case 1 serves as a good illustration (Fig. 8). About a year following the operation, the patient developed pain and tender callosities beneath the metatarsal heads, especially the second, and markedly diminished power of motion of the big toe was also observed, as a result of the shortening of the first metatarsal. Thus any operation leading to the shortening of the first metatarsal should be emphatically condemned, because the sacrifice of functional disturbance of the foot is too great a price to pay for cosmetic correction of bunion.



A.



B.

Fig. 4. A, Square shaped atavistic feet with widely separated big and second toes. This type of foot has a potential tendency toward hallux valgus formation. The sister of this man, with same type of foot, developed hallux valgus. Left foot is shown during a phase of gait when the whole weight is borne mainly on the first metatarsal head with the big toe in extreme dorsiflexion. B, Roentgenogram of the same feet showing metatarsus varus primus of 12 degrees. Note wide space between big and second toes easily permitting lateral deviation of the big toe in hallux valgus position.

After the resection of the first cuneiformometatarsal joint described, the first metatarsal head can be abducted laterally, without much effort, bringing it closer to the second metatarsal head, and thereby easily correcting the metatarsus varus primus. The capsule and the ligaments of the first cuneiformometatarsal joint should be preserved as much as possible, especially over its plantar aspect.

Most cases of hallux valgus are also associated with a weak foot, presenting flattening of the longitudinal arch and pronation. This is, to some extent, due to the dorsiflexed attitude of the first metatarsal in the cuneiformometatarsal joint. It is advisable, therefore, when resecting the first cuneiformometatarsal joint, to remove slightly more bone over the plantar aspect of this joint, creating, in this way, another wedge with a plantar base. The plantar flexion attitude of the first metatarsal is thereby produced and will increase the longitudinal arch and diminish pronation.

A second incision, also about 5 centimeters long, is made over the dorsimedial aspect of the first metatarsophalangeal joint. The medial part of the joint capsule is bluntly exposed. A tongue-shaped flap, with its base attached to the proximal phalanx, is made over the medial part of the joint capsule. The bony projection over the medial, and often over the dorsal, part of the first metatarsal head is chiseled off, care being taken to remove all the bony projections interfering with motion of the big toe, especially in its dorsiflexion. The adductor tendon and the lateral part of the joint capsule are tenotomized, if necessary, so that the big toe may now be freely brought in an overcorrected position, without using any force. Usually the big toe in hallux valgus has a tendency toward a slight internal rotation, around its long axis, so that the nail is facing medially (Figs. 5, A, 10, A). That tendency may be a remainder of opposition of the big toe, present in primates, and should be taken into consideration during the suturing of the capsule. A heavy chromic mattress suture is inserted first over the plantar distal part of the capsule in front and medially to the tibial sesamoid. The needle is then brought through the dorsal proximal part of the joint capsule and the deep aponeurosis. This suture crosses obliquely the medial part of the first metatarsophalangeal from its plantar and distal toward the dorsal and proximal parts.

After tying of this suture four important points are gained: (1) the big toe is fixed in adduction medially; (2) the internal rotation of the big toe is corrected; (3) the lateral displacement of the sesamoids together with the plantar flexors of the



A. B.

Fig. 5. A, Case of "bunion" with marked medial protrusion of the first metatarsal head and lateral subluxation of the big toe. Note the lateral displacement of the sesamoids and inward rotation of the big toes, the nail facing medially. The foot is very wide across metatarsal heads. B, Same feet after the operation. Note also the correction of internal rotation of the big toe and practically normal position of the sesamoids.

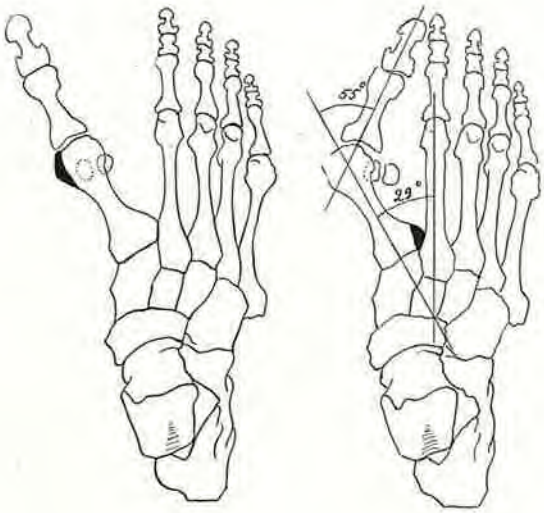


Fig. 6.

Fig. 7, A



Fig. 7, B



Fig. 7, C

Fig. 6. Imaginary postoperative appearance of the foot in case of successful straightening of the big toe without correcting the metatarsus varus primus. (All relations slightly exaggerated.) Note close resemblance with the foot of primates shown in Figure 2. Black area shows the bony prominence which is usually removed.

Fig. 7. Varus position of the first metatarsal is slightly exaggerated for the sake of demonstrability. (The angle between first and second metatarsals is made 29 degrees, while it is seldom over 20 degrees; hallux valgus of 55 degrees is rather common.) Black areas show the parts of bone which are removed. Note the lateral displacement of sesamoids. A, Lateral part of the base of the first metatarsal impinging against the second, is removed. B, Resection of the first cuneiformometatarsal joint over its lateral part only. Note that slightly more bone is removed from the first cuneiform. The adjacent part of the second metatarsal base is roughened with a curette. Removal of the bony proliferation over the first metatarsal head and plastic of the capsule over the medial aspect of the first metatarsophalangeal joint. C, Metatarsus varus primus and hallux valgus are corrected. Note the sesamoids returned to their normal location.

big toe is reduced and this reduction maintained; (4) the deep dorsal aponeurosis with the extensor hallucis longus tendon is pulled medially preventing lateral displacement of this tendon. The tongue-shaped flap of the capsule is now resutured, with the big toe held in adduction, and slight external rotation. The tendon of the abductor hallucis may also be reattached to the medial flap of the joint capsule, thus providing active force, correcting the hallux valgus deformity. The removal of the lateral prominence of the fifth metatarsal heads may also be indicated in some cases.

The deformity must be entirely corrected by the operative procedure alone, so that the big toe will maintain this correction, even if left unsupported. A tight flannel bandage is applied over the well padded forefoot keeping the metatarsals closely approximated. In about 2 or 3 weeks a plaster-of-paris casing is applied to the foot maintaining the correction of metatarsus varus primus. The big toe is not included in the casing and its active and passive motion is encouraged.

A few points in pre-operative preparation of the skin are worth mentioning, as insuring primary union of the wound. It is advisable to prepare the skin over the "bunion" by means of shaving off the callosity and applying salicylic acid ointment a few days or sometimes a few weeks before the operation. A very often present, but usually overlooked, trichophytosis of the foot should be cured before the operation is undertaken.

The writer also believes that the often used oval excision of the skin around the "bunion" should not be practiced, as it may cause tension when the skin is resutured and lead to separation and sloughing of the wound edges. No attempt to remove the bursa is made by me, as a rule, as both the callosity and the bursa readily disappear after the underlying cause—the undue pressure—is eliminated with the correction of the deformity.

It is also important to stress the postoperative care in these cases. A rigid metal plate should be worn by every patient for a few months following the operation, as the keystone of the longitudinal arch—the first cuneiformometatarsal joint—is weakened by this operation, and has to be protected until it will regain its strength. Full weight bearing should not be allowed before 6 or 7 weeks in order to insure solid fusion of the resected cuneiformometatarsal joint.

The somewhat prolonged period of postoperative disability and the resection of the joint supporting the longitudinal arch may be considered the weak points of this operative procedure. The



Fig. 8. Case 1. Right foot of girl 21 years old before and after the operation. (Operated upon April 8, 1931.) Excellent correction of the hallux valgus. Note the marked postoperative shortening of the first metatarsal. About one year after the operation this patient developed heavy callosity over the whole anterior arch, which became markedly convexed. There was tenderness over projecting plantarward second metatarsal head. When she stood the big toe was kept above the floor and there was marked loss of power on motion of the big toe. Functional result is therefore considered by the author as unsatisfactory because of shortening of the first metatarsal.

number of cases is too small as yet, and the time following the operation too short, to make any definite conclusions. (The first case was operated upon April 8, 1931.) However, the writer feels that both the functional and cosmetic results thus far obtained are more than encouraging, and therefore warrants giving this operation further trial in cases of hallux valgus with metatarsus varus primus (Fig. 9, A, B, C, D, 10, A, B).

Not every patient with "bunion" should be operated upon, operation being limited to cases of functional disturbance, or where cosmetics plays an important part. Each case requires individual study.

SUMMARY

1. In a great majority of cases of hallux valgus, there is metatarsus varus primus, which is the primary underlying cause of the deformity—hallux valgus occurring secondarily because of shoe pressure.

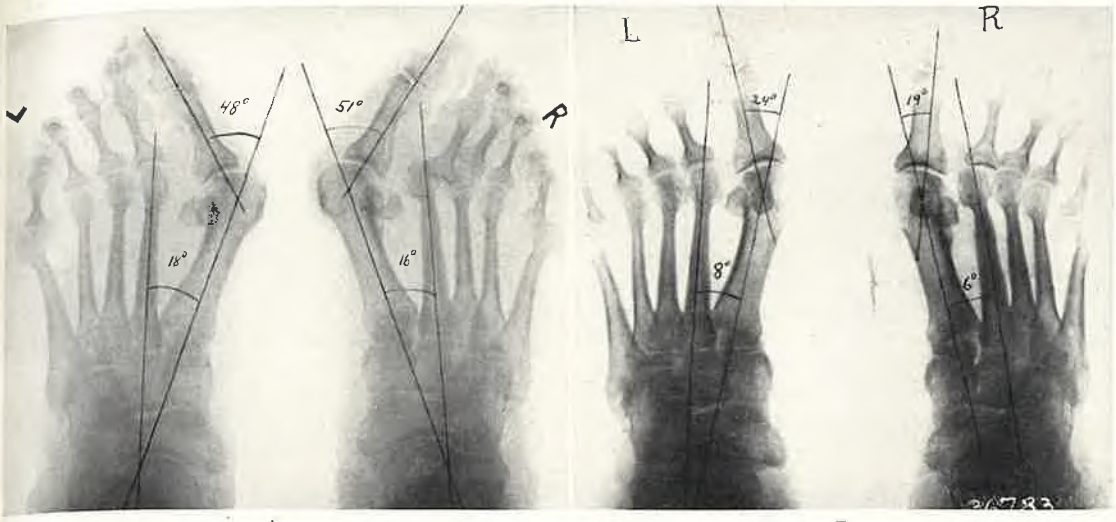
2. Hallux valgus, or "bunion," is not so much a lateral deviation of the big toe, as the medial



Fig. 9. Case 2. A, Feet of a girl 21 years old. Note that in spite of very marked hallux valgus deformity, there is no overlapping of the big and second toes. B, Roentgenogram in the same case showing atavistic feet with metatarsus varus primus of 19 degrees and hallux valgus of 52 degrees. C, Appearance of the same feet 6 weeks after the operation performed on February 3, 1932. Excellent cosmetic and functional result. The circumference of the foot across metatarsal heads became about 2 centimeters less than before the operation. D, Postoperative roentgenogram in the same case. The metatarsus varus primus is reduced from 19 degrees to 9; the hallux valgus from 52 degrees to 12.

protrusion of the first metatarsal head forming bony proliferation because of constant trauma.

3. There is a type of square foot, with a widely spread metatarsal head and metatarsus varus primus. This foot closely resembles that of primates and is considered atavistic. In a well developed human foot, the first and second metatarsals lie almost parallel; the latter type very seldom developing "bunion."



A. B.

Fig. 10. Case 3. A, Feet of woman 35 years old. Note also dorsal subluxation of the basal phalanx of the right second toe and the lateral projection of the fifth metatarsal heads. B .Postoperative roentgenogram in the same case.

4. This atavistic foot has a congenital potential tendency toward hallux valgus formation, and therefore hallux valgus is often hereditary, appearing in youth, mostly in women, because of their type of shoe.

5. No operative procedure is satisfactory, unless correction of the metatarsus varus primus is accomplished.

6. Operation for correction of metatarsus varus primus by resection of a small wedge, at the lateral part of the first cuneiformometatarsal joint, is described.

7. Any operation creating shortening of the first metatarsal, or the big toe, is emphatically condemned as unphysiological, and causing static and dynamic disturbance of the foot.

8. Conservatism and individualization in indication for operative correction of "bunion" is advocated.

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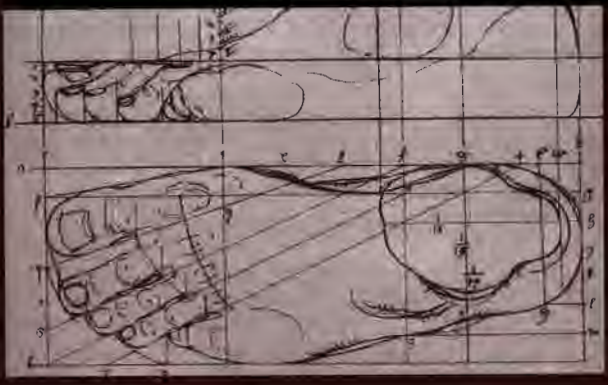
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Lapidus bunionectomy: arthrodesis of the first metatarsocunieform joint

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Arthrodesis of the first metatarsal cuneiform joint (MCJ) was first described in 1911 by Albrecht [1]. Truslow [2] and Kleinberg [3] revisited the procedure shortly thereafter. But it was not until 1934 when Lapidus published his first article on the etiology and surgical technique that the procedure became popular. He followed this with two more articles further discussing the rationale for the procedure [4–6].

Lapidus believed that certain types of hallux abducto valgus are a result of an atavistic trait. The metatarsal is excessively adducted (what he described as metatarsus primus varus) because of an arrest of ontogenic development. More importantly, Lapidus understood that the deformity should be corrected at its apex. He realized that the metatarsal cuneiform joint was abnormally angulated and that correction should therefore be directed to that joint. He also stated, "Osteotomies of the first metatarsal, particularly over the distal part, never have seemed mechanically sound" [5].

The procedure Lapidus described included fusion of the first metatarsal cuneiform joint and fusion of the base of the first metatarsal to the base of the second metatarsal. The fusions were held in place with drill holes and catgut suture. Lapidus never published objective reports but did say that after 25 years he found the procedure useful in "properly selected cases." Over the next 70 years, modifications of the Lapidus procedure have gone in and out of favor. Many surgeons find it technically demanding, there are problems with shortening, and some report high nonunion rates. But for the surgeon who feels comfortable with the procedure, it can be a "versatile means of addressing positional and structural problems with the medial column" [7].

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Indications

Some of the indications for fusion of the first MCJ include severe metatarsus primus adductus (MPA), patients with moderate MPA with hypermobility of the first ray, generalized ligamentous laxity, adolescent hallux abducto valgus deformity (HAV), degenerative changes of the first MC joint from arthridities, hallux limitus with elevatus of the first ray in cases of mild to moderate degenerative changes of the first metatarsophalangeal joint (MPJ), and salvage of failed HAV surgery. Unfortunately, one of the main indications for the procedure is difficult to define and more difficult to quantify, yet few argue its existence. Root [8] stated, "In an individual with a normal first ray, the full range of motion will move the first metatarsal head above and below the transverse plane of the dorsiflexed lesser metatarsal heads by the same distance in each direction." In other words, the motion of the first ray should be equally divided into dorsiflexion and plantarflexion. With current understanding of the first ray and its range of motion, hypermobility is then defined as excessive motion about this joint during gait. But, the amount of motion has not been defined, and holding the foot in a neutral position and measuring the excursion are subjective findings leading to inconsistency. Radiographs have also been discussed as a tool for diagnosis of hypermobility of the first ray. Attention is paid to the first MCJ angle and cortical thickening of the second metatarsal as a sign of lesser metatarsal overloading secondary to a hypermobile first ray. Because of the difficulty quantifying hypermobility, the diagnosis continues to be clinical.

Examination

Examination of the patient begins with a gait analysis. Abduction of the rearfoot with elevation of the first ray may be noted. An early heel off may be a sign of tightness of the posterior muscle group.

Seated examination confirms laxity of the first ray, tracking of the great toe and any crepitus. Adjunct gastrocnemius or Achilles equinus and rearfoot deformity is also checked. Proper vascular and neurologic testing is performed. The quality of the skin should also be checked to avoid scarring and to alert the patient to any potential complications before surgery.

Proper informed consent of the patient is essential to avoid discrepancy. It is important to inform the patient of the rate of nonunion/delayed union and other associated complications, including numbness, scar formation, and joint stiffness.

Procedure

To perform the procedure with a minimum of strain to the surgeon, patient positioning is essential. The patient is placed on the table in a supine position with attention to foot position. The foot is placed at the most distal aspect of the bed and bumping of the ipsilateral hip is performed to place the foot in a rectus position. The

procedure may be performed under local or general anesthesia. Our preference is to perform the procedure under monitored anesthesia care in combination with a popliteal fossa block. The popliteal fossa block allows for a high ankle tourniquet placement and also allows for anesthesia of the Achilles tendon and gastrocnemious muscular junction for adjunctive tendon lengthening procedures. Tourniquet use is the surgeon's choice; however, it is essential to place an ankle tourniquet proximal enough to allow for proper positioning of the hand during placement of the distal to proximal screw across the joint. If the ankle tourniquet is distal, it is difficult to position the drill properly for the medial cuneiform to first metatarsal screw.

The procedure is started with a dorsal incision placed over the first MC joint. To properly identify the joint, fluoroscopy may be used. An easy technique to identify the joint is to wet the region and run one's finger over the first metatarsal toward the base. A ledge will be palpated, which is the joint line. A second important point to consider is placement of the incision of the dorsum of the joint. It is more difficult to perform the procedure if the incision is too far medial. The incision is deepened to the level of deep fascia. A communicating branch between the medial and intermediate dorsal cutaneous nerves is usually found traversing the joint. This nerve, if in the incision site, should be sacrificed because it will be difficult to perform the procedure otherwise. The extensor hallucis longus and brevis tendons are identified and retracted medially. The extensor hallucis brevis tendon may be released at the location as desired. A dorsal periosteal incision is performed to access the joint. It is ideal to perform the incision on the dorsum of the joint and not make a medial approach. Periosteal flaps are raised. The dorsal periosteum is well adhered and need to be released with sharp dissection. Once the medial and lateral aspects of the joint are reached, a periosteal elevator may be used. Preservation of the periosteum is essential to increase the rate of arthrodesis and protect neurovascular structures. Dissection of the periosteum as far plantar as possible should be performed to allow greater access to the joint.

It is the surgeon's choice as to joint resection technique, though a saw is commonly used. If this is the desired technique, a long blade must be used as the joint resection depth is approximately 2 cm. A wedge is resected off the base of the first metatarsal and a joint resection of the medial cuneiform is performed. It has been the authors' experience that this is not necessary for joint alignment, and it often decreases joint stability. The authors' current technique for joint preparation is a combination of curettage and sharp resection of the articular surfaces. The preparation is begun with the use of sharp osteotomes. The osteotome is held firmly by hand and run from dorsal the plantar along the articular surfaces. The procedure is repeated until as much articular cartilage is resected as possible. From time to time, a rongeur is used to remove the loose cartilage in the joint. A curette is then used to remove any remaining cartilage, especially at the base of the joint. It is essential to remove the most plantar cartilage to avoid a plantar ledge. If a plantar ledge is left behind, dorsiflexion of the metatarsal may occur. Following removal of all articular cartilage, the subcortical bone is prepared with subchondral drilling or shingling of the joint surface. It has been the authors' experience that use of a small



Fig. 1. Preoperative AP and lateral radiographs of hallux valgus deformity with mild elevatus of the first ray.

osteotome and mallet for joint shingling causes no burning associated with drilling had allows for subchondral bleeding. The subchondral bone is approached at an angle, and the joint surface, if raised slightly. The raised piece is turned 45 degrees and left in the joint.

Attention is then directed to the first MPJ. The joint may be approached with a continuation of the dorsal first MC incision or through a medial incision. It has been the authors' experience that the medial approach allows for better cosmesis. The medial incision is centered over the medial first MPJ and deepened to the joint capsule. The dorsal skin may be raised to allow for lateral release, or a second dorsal incision may be made over the first interspace for lateral release. A dorsal medial capsular incision is then performed and the medial collateral ligament is released. The lateral collateral ligament may be released from a plantar or dorsal joint approach. The medial eminence is removed and the first metatarsal is positioned. An excellent positioning tip is to push medially at the first metatarsal head and dorsiflex the great toe simultaneously. This will reposition and compress the first metatarsal. The first metatarsal is then displaced plantarly in cases of elevatus. If proper alignment is not achieved, the lateral first metatarsal base may need to be resected. This is rarely necessary, and repositioning is often difficult if the fibular sesamoid is not positioned plantar to the metatarsal head adequately.

Once anatomic alignment is achieved in the sagittal and transverse planes, temporary fixation is achieved with the use of a Kirschner wire. If a cannulated screw set is used, the wire may be from the set. The first wire is run from the base of the first metatarsal to the base of the medial cuneiform. To achieve proper wire position, the wire is aimed at the navicular tubersity. This will place the wire directly in the central portion of the medial cuneiform. A second wire is the placed from the medial cuneiform to the lateral base of the first metatarsal. Fluoroscopy is used to check position in the dorsal plantar plane and a lateral plane. Screw placement is then performed with the surgeon's choice of screw. If there is a problem with screw placement or the dorsal ledge fractures and instability of the screw placement is found to be present, a screw may be run from the medial first metatarsal base to the intermediate cuneiform or into the second metatarsal base. A screw into the second metatarsal base will need to be removed after healing is achieved. The authors' choice in cases of difficult fixation of soft bone or cortical fracture is the placement of a dorsal miniplate. The plate may be a compression



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Fig. 1 (*continued*).



Fig. 2. Traditional fixation technique with crossing screws and mild plantar translation of the first metatarsal.

system if compression of the joint is poor, or a stability plate if adequate compression is achieved with a lag screw across the joint.

Before closure, alignment of the metatarsal base and great toe joint and screw placement are checked with fluoroscopy while the foot is loaded. Periosteal and skin closure is performed for both joints. Dressings are applied and a splint or bivalved cast is applied to the region.

The patient is kept non–weight bearing for a period to 4 to 6 weeks or until adequate joint healing is noted with radiographic examination. The patient is then gradually allowed to bear weight on the surgical site with the use of a surgical shoe or below-the-knee walking boot until full healing is noted. Physical therapy of the great toe joint can begin at 3 to 4 weeks postsurgery to prevent stiffness and scarring. It is more difficult to return the plantarflexion motion of the great toe; therefore, plantarflexion exercises are emphasized. Weight-bearing physical therapy is not started until full healing is noted.

Adjunct procedures

Often the underlying hallux limitus/hallux valgus deformity is caused by excessive pronation or tightness of the posterior leg musculature. Two common adjunctive procedures are calcaneal osteotomies (Evans or medial calcaneal slide) and posterior musculature lengthening (Achilles or gastrocnemius tendon lengthening). It is essential to perform these adjunct procedure, when necessary, to achieve adequate outcomes.

Clinical outcomes

In the literature, few articles have been written with objective results, probably due to the technical difficulty and complications. Sangeorzan in 1989 [9] reported on 40 foot procedures for first MCJ fusion. Hypermobility was defined as "relatively increased dorsiflexion of the first ray with soft end point on examination, combined with second metatarsal overload." They also related patients having a medially oriented cuneiform and second metatarsal cortical thickening, indicating overload. The fusion was fixated with two screws, one crossing the fusion and another crossing from the first metatarsal into the second metatarsal base



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Fig. 2 (*continued*).

or second cuneiform. The second screw was not for fusion between the metatarsals but to "ensure rotational stability" and later removed. The intermetatarsal angle changed from 14 degrees preoperatively to 6 degrees postoperatively, and there were four reported nonunions. Good or excellent results were reported at 74%.

Mauldin in 1990 [10] described a modification of the Lapidus in which there was a limited fusion technique, emphasizing the first metatarsocunieform joint, to maintain length. Fifty-one patients were reviewed with average preoperative



Fig. 3. Preoperative AP and lateral radiographs of early hallux limitus secondary to laxity of the first ray. Note mild dorsal spurring of the first metatarsal head on the lateral image and mild decreased joint space on the AP image.

intermetatarsal angles of 14.6 degrees, reducing to 8.7 postoperatively. Nonunion rates were difficult to determine and not well reported. Hallux varus was reported in 15.7% of the patients.

An estimation of "excessive motion of the first metatarsal in both sagittal and transverse planes" was the definition of hypermobility used by Myerson in 1992



Fig. 4. Postoperative AP and lateral radiographs with traditional fixation technique and realignment of the first metatarsal. Note extensive plantar translation of the first metatarsal.



Fig. 4 (*continued*).

[11]. Cortical thickening of the second metatarsal shaft was also a typical radiographic finding. Sixty-seven MCJ fusions were reviewed, with seven nonunions. The intermetatarsal angle decreased from 14.3 preoperatively to 5.8 postoperatively. Myerson placed fixation from the first metatarsal into the second metatarsal but states that "since this further increases stiffness, incorporating the base of the second metatarsal in the arthrodesis is probably unnecessary" [11].

Chang and Ruch in 1994 [7] published an article discussing the procedure and outlining their technique for fixation. The article was not a study, but discussed the author's technique involving a five-hole one-third tubular plate and a compression screw. The plate is prebent to match the contour of the medial aspect of the first metatarsal cuneiform joint. After joint preparation, the fusion site is held in place with a Kirschner wire. The plate is then held in place with two screws in the cuneiform. A screw is then placed into the metatarsal using eccentric drilling through the plate to aid in compression. Next, axial compression is achieved by a placing a cancellous screw across the fusion site. Finally, the remaining holes in the plate are filled with standard concentric drilling.

Grace et al in 1999 [12] published a retrospective review of the modified Lapidus in adolescent HAV. The authors worked with reports of high recurrence rates of adolescent hallux valgus and, in these, report that the initial surgery done probably did not address the instability of the first ray. The theory was that fusion of the first MCJ would give stability to the first ray and reduce recurrence. Radiographs revealed second metatarsal hypertrophy in 60% of the 30 cases they reviewed. First intermetatarsal angles decreased from 13.3 preoperatively to 5.4 postoperatively, and 90% of the patients had good to excellent results in the short term. They reported two recurrences and only one symptomatic nonunion.

Later in 1999, Catanzariti et al [13] reported their review of 47 modified Lapidus procedures. The patients all had HAV and some degree of hypermobility. Again, no consistent measure of hypermobility was discussed. In the same patient population, different combinations of planar resection, bone grafting for short metatarsals, and varying types of fixation were used. Allogenic graft was used if preoperative metatarsal protrusion distance warranted. Three nonunions were reported with average intermetatarsal angles preoperatively (13.8) decreasing to 2.1. Average shortening without grafting was 4.7 mm.

Kenrin et al in 2000 [14] authored an article discussing the modified Lapidus procedure and its use in rheumatoid patients. Twenty-one patients were retrospectively evaluated. Hallux valgus is commonly seen in this patient population; however, first metatarsal phalangeal joint fusions and arthroplasties are more commonly performed. The authors noticed that early and intermediate rheumatoid patients had hallux valgus but maintained a reasonable first metatarsal phalangeal joint space. This observation led the authors to preserve the first metatarsal phalangeal joint and correct the deformity more proximally. This would also help the failing arch. The fusion was achieved with one or two staples. The patients were then evaluated and first intermetatarsal angle decreased from 13 degrees preoperatively to 8.3 degrees postoperatively. There were no reports of nonunions.

McInnes and Bouche in 2001 [15] published on the topic, giving a comprehensive history of the literature and a retrospective study of 25 patients. Fusions were preformed with two 3.5-mm cortical screws, and the average follow-up time was 39 months. The authors also divided the patients into athletic, active, and sedentary. Hypermobility was diagnosed preoperatively by the senior author and used a combination of subjective, objective, and radiographic criteria. It was defined as "excessive motion in the sagittal and transverse planes in conjunction with signs and symptoms of lesser metatarsal overload." Subjective and objective scoring systems were then used.

Five patients stated that the surgery was "ineffective," and 78% regarded the surgery as "completely" or "very" effective. Average preoperative IM measured 16.7 degrees and decreased to 8.2 degrees postoperatively. First metatarsal shortening was 4.5 mm in the patients with a curettage method and 7.5 mm in the patients that had undergone planar resection. There was no significant difference in the subjective and objective scores among the three activity levels; however, the population size was small with only eight patients in the sedentary group. Return to activity in athletes was only 30%, compared with the 86% and 75% of active and sedentary, respectively. Five nonunions, three of which were asymptomatic, were reported (Figs. 1–6).

Coetzee et al in 2003 [16] reported prospectively on 26 modified Lapidus procedures performed as salvage after failed treatment of hallux valgus. The study included the visual analog scale and the American Orthopedic Foot and Ankle Society (AOFAS) Hallux Metatarsophalangeal-Interphalangeal Scale preoperatively and at 24 months. The visual pain scale improved from 6.2 to 1.4, and the AOFAS scale improved from 47.6 to 87.9 with no "dissatisfied" patients. The procedure involves screw fixation across the first tarsometatarsal joint and from the base of the first metatarsal to the base of the second. Coetzee stated, "The tarsometatarsal and first and second metatarsal fusions eliminate any rotation or translation of the first ray," thereby making it "almost impossible for the hallux valgus or metatarsus primus varus deformity to recur" [16]. The procedure addresses the hypermobility that could have contributed to the initial deformity and its recurrence.

The authors have reviewed results on 47 cases with a follow-up of 1 to 3 years. Preoperative diagnosis was hypermobility and hallux valgus deformity in 37 cases,



Fig. 5. Preoperative AP and lateral radiographs of a hallux valgus deformity.



Fig. 6. Postoperative AP and lateral radiographs of a hallux valgus deformity with correction of the first metatarsal angle in two planes (sagittal and transverse) and plate fixation because of softness of the bone and lack of adequate screw fixation attempts.

hallux limitus in nine cases, and degenerative arthritis of the first MC joint in one case. The results revealed only one asymptomatic nonunion in a noncompliant patient who began weight bearing at 2 weeks. Joint resection and realignment of the joint resulted in similar alignment and outcome as wedge realignment of the joint. Intermetatarsal angle was reduced from an average of 14.8 degrees to 6.2 degrees. Time to full healing has been dramatically decreased with atraumatic technique and prevention of joint heating. Time to full fusion has been decreased by 2 weeks with joint curettage and shingling as compared with subchondral drilling or saw resection of the joint surfaces. Two cases of plate use in addition to compression screw use have resulted in adequate fusion. The plates have not needed to be removed to this date. Patient satisfaction has been excellent in 41 cases, good in four cases, and adequate in two cases. The two adequate cases complained of sesamoid pain during exercise secondary to ray plantarflexion. The mild pain was well controlled with orthotic use during exercise. All patients stated that they would undergo the procedure again.

Discussion

Arthrodesis of the first MC joint has grown in popularity as more experience and knowledge as to the function and stability of the medial column has developed. The procedure was originally thought to be difficult, and the rate of nonunion was high. With the advent of internal fixation and increased experience in resection techniques, the rate of nonunion has dramatically decreased.

Fusion of the first MC joint allows for correction of the first metatarsal in three planes, including adduction, plantarflexion, and rotation. It also allows for decreased jamming of the great toe joint and increased medial column stability. Although hypermobility is a difficult diagnosis to make in certain cases, it is best to perform a first MC fusion bunionectomy if there is any doubt as to the stability of the first ray.

As knowledge about other medial column procedures grows, fusion of the first MC joint will continue to grow in popularity. It is an excellent procedure for hallux limitus and also for metatarsus primus elevatus cases.

Although there is no comparison study to date, the authors' opinion is that limited heating of the joint and curettage techniques will produce higher fusion rates. This study is now being undertaken, with results to follow.

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Surgical Strategies: The Lapidus Procedure

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Chicago, IL

BACKGROUND

In 1934, Paul W. Lapidus published his experience with an operation for the correction of hallux valgus that would later bear his name.[10] He did not claim the originality of this operation and readily acknowledged many other surgeons had already reported similar approaches for hallux valgus. With this manuscript, Lapidus intended "to stress the mechanical importance of the metatarsus primus varus, as one of the most frequent and most prominent factors of the hallux valgus deformity." He described an operation composed of an arthrodesis of the first tarsometatarsal joint, the creation of a bony bridge between the bases of the first and second metatarsals and a distal soft-tissue release and repair similar to the Silver procedure that effectively corrected an atavistic "square foot" that he believed had a congenital predisposition toward hallux valgus. He emphasized the importance of resecting bone only from the lateral portion of the joint while denuding it of its articular cartilage to obtain acceptable correction of the deformity and a condition favorable for fusion.

Lapidus refined his indications and modified his operative technique over his career and reported these changes in two subsequent publications.[11,12] Over time he concluded that only the subset of the patients with hallux valgus who manifested a fixed metatarsus primus varus and an intermetatarsal angle larger than 15 (later revised to larger than 10 to 12) degrees required more than a distal soft-tissue procedure. He reported his technique of obtaining an anteroposterior radiograph with the forefoot tightly bandaged to determine the mobility of the first tarsometatarsal joint. He found that leaving the cortical bone chips he had osteotomized from the first and second metatarsals and adding bone morselized from the resected medial eminence fostered the formation of a robust bony synostosis that prevented recurrence of the metatarsus primus varus. Lapidus also learned that minimal resection of bone laterally from the joint was sufficient to correct the metatarsus primus varus and foster prompt union of the arthrodesis. He emphasized the importance of maintaining close apposition between the metatarsal and the medial cuneiform during preparation of the articular surfaces. He also began stabilizing his arthrodesis with an O chromic catgut suture placed from a bone tunnel in the dorsolateral base of the metatarsal to the dorsal ligaments overlying the first intercuneiform joint. In summarizing his 28-year experience with this procedure, Lapidus found the results "most gratifying."

MODIFICATIONS

Several authors have reported positive results with various modifications of Lapidus procedure.[2,3,7,13,14,16] Many have offered techniques to maintain the length the first ray and to improve the stability of the arthrodesis. Giannestras[7] and Bustson[2] independently reported on the insertion of the resected medial eminence into the joint and fixation of the first metatarsal to the second metatarsal with Kirchner wires.[2,7] Butson[2] reported 92% good or excellent results with no nonunions in his series of 119 feet performed with these modifications. However, 11 feet had persistence or new onset of a painful callus beneath the head of the second metatarsal. Sangeorzan and Hansen[16] incorporated rigid screw fixation to allow earlier mobilization and to maintain the position of the metatarsal after surgery. They used a wedge-shaped tricortical bone graft from the iliac crest to restore length in patients with shortened metatarsals. They reported a nonunion rate of 10%, a revision rate of 13% and an overall failure rate of 20% in their preliminary study. They attributed the high rate of failure to the technical complexity and learning curve associated with the operation. Previously, Clark et al.[3] reported more favorable results in adolescent bunions treated with the modified Lapidus procedure. Mauldin et al.[14] circumvented shortening of the

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first ray by creating a rectangular trough across the joint which was filled with the bone from the medial eminence and the resected bone block. A Steinmann pin stabilized the arthrodesis. With this modification, they prevented transfer metatarsalgia and observed a 90% rate of satisfaction with the procedure. However, the authors could confirm definite trabecular bridging across the joint in only 25% of their patients.

The collective results of numerous recent reports indicate that the modified Lapidus procedure reliably and consistently corrects moderate to severe metatarsus primus varus and hallux valgus with a high rate of pain relief and satisfaction and a low incidence of recurrence and nonunion.[1,4,6,9,15] A prospective study found less than a 1-degree increase in the intermetatarsal and hallux valgus angles over the first 4 years after the operation.[4] In a large retrospective series of 201 cases, Thompson et al.[17] reported a 4% nonunion rate and a 2% revision rate of for pain. The authors cited meticulous preparation of the joint with multiple fenestrations of the surface with a Kirschner wire, use of shear-strain relieved grafting (bone-filled recesses at the interface of the arthrodesis) with local autologous bone, and concomitant management of an equinus contracture with lengthening of the Achilles tendon or recession of the gastrocnemius tendon as possible explanations for their high rate of union.

CURRENT INDICATIONS AND CONTRAINDICATIONS

The Lapidus procedure is indicated for the correction of moderate to severe hallux valgus with metatarsus primus varus.[5] It also is indicated for the correction of hallux valgus in adolescents with clinical findings of generalized ligamentous laxity[3] and for the correction of associated hypermobility of the first ray as determined by physical and radiographic examination of the first tarsometarsal joint with or without concomitant clinical signs of deficient weightbearing function of the first ray.[1] These coexistent signs could include transfer metatarsalgia to the second ray, presenting as a painful plantar keratosis beneath the second metatarsal head; synovitis of the second metatarsophalangeal joint with attenuation or rupture of the plantar plate with a supple or fixed hammertoe; or mechanical overload of the second ray, manifesting as cortical hypertrophy of the shaft or primary arthritis of the second tarsometatarsal joint. Also, the Lapidus procedure is a salvage operation for recurrent hallux valgus after prior operative treatment.[5]

This procedure is contraindicated in adults with arterial insufficiency, active infection, Charcot neuroarthropathy, or when noncompliance with the postoperative protocol is anticipated. Children with an open proximal physis of the first metatarsal should not have this procedure. The Lapidus procedure also is not indicated in patients with a short first metatarsal secondary to a congenital, traumatic, or postoperative etiology unless an ancillary procedure to restore the length of the first ray is included. Patients with hallux valgus and arthritis or prior resection of the first metatarsophalangeal may not be candidates for this procedure because the results of combined arthrodesis of the first tarsometataral and metatarsophalangeal joints are unknown.



Fig. 1: A dorsal view of the foot demonstrating a 4-cm incision centered over the first tarsometatarsal joint and following the lateral border of the extensor hallucis longus tendon.

OPERATIVE TECHNIQUE

- The operation usually is performed as an outpatient procedure with a peripheral nerve block. The patient is placed supine on the operative table. A small bump beneath the ipsilateral buttock internally rotates the limb and positions the foot for the operation.
- The procedure is performed through a dorsal longitudinal incision centered over the first tarsometatarsal joint. The incision follows the lateral border of the extensor hallucis longus tendon. An incision 4 to 6 cm in length facilitates adequate exposure during the operation (Figure 1). The location of the joint may be determined by palpation along the subcutaneous dorsomedial border of the foot or by observation of motion at the joint while applying a dorsally directed force to the plantar aspect of the first metatarsal head.

- After the skin and subcutaneous fat have been incised, the interval between the tendons of extensor hallucis longus and the extensor hallucis brevis is identified through the thin, translucent retinacular fascia. The fascia is incised in line with the skin incision, and the two tendons are mobilized. The larger extensor hallucis longus tendon is released and retracted medially to expose the underlying joint. Dissection adjacent to the narrower tendon of the extensor hallucis brevis requires caution because of the close proximity of the dorsal pedis artery and the deep peroneal nerve. The neurovascular bundle is located immediately deep and lateral to this tendon and can be damaged during the exposure of the joint if the plane of deep dissection strays lateral to this tendon.
- With the tendons mobilized, the periosteum of the base of the first metatarsal and the medial cuneiform and capsule of the joint are exposed. These tissues are incised sharply and elevated as one continuous layer. The initial incision follows the dorsal ridge of the first metatarsal to the level of the joint and then angles slightly medial to remain centered over the medial cuneiform and avoid the first intercuneiform joint and the neurovascular bundle. The medial periosteal-capsular flap elevates easily with sharp dissection using the scalpel. This flap should be elevated completely to the plantarmedial aspect of the joint. This will allow better appreciation of the dorsal-to-plantar inclination of the joint during the debridement of the articular surfaces.
- Elevation of the lateral flap is not as extensive; however several factors are critical to the efficacy and safety of this phase of the dissection. The metaphyseal base and proximal shaft of the first metatarsal have a triangular shape with a steep, vertically oriented lateral cortex. Therefore, as the lateral periosteal-capsular flap is elevated off of the bone, the blade of the scalpel rapidly changes from a horizontal to a vertical orientation, aiming directly plantar into the webspace between the first and second metatarsals. If the blade does not follow the steep face of the lateral cortex, the first plantar branch of the dorsal pedis artery may be injured as it enters the webspace 1 to 2 cm distal to the level of the joint. As the elevation of the flap moves proximally and approaches the base of the first metatarsal, the webspace narrows and care must be taken not to injure the neurovascular bundle as the plane of dissection continues onto the medial cuneiform. Lateral dissection on the dorsal aspect of the medial cuneiform is minimal (2 to 3 mm) to avoid encroaching upon the first intercuneiform joint.
- The proximal articular surface of the first tarsometatarsal joint is resected as a biplanar, lateral, and plantar-based wedge osteotomy of the medial cuneiform. The osteotomy is made along the dorsal aspect of the cuneiform perpendicular to the longitudinal axis of this bone extending as a transverse line from the medial border of the bone (Figure 2). Because of the oblique orientation of the joint, this transverse line will exit the lateral border of the cuneiform approximately 2 mm proximal to the joint. When the osteotomy is made in this manner, the resultant lateral wedge will always provide full correction of the metatarsus primus varus deformity when the joint is positioned for arthrodesis. A small plantar wedge of bone also is removed from the cuneiform during the osteotomy to plantarflex the first metatarsal when the joint is positioned for arthrodesis. This maneuver maintains or restores proper weightbearing function to the first ray. Alternatively, the osteotomy can be performed without the plantar wedge of bone and the first metatarsal can be plantarly translated 2 to 3 mm relative to the medial cuneiform when the joint is positioned for arthrodesis. The osteotomy usually is performed with an oscillating saw using a long, narrow (4 × 1 cm) blade, however, hand osteotomes also may be employed (Figure 3).
- The articular cartilage is removed from the first metatarsal with small osteotomes. A flat surface ideally facilitates proper positioning and full apposition of the metatarsal with the cuneiform for arthrodesis (Figure 4). This is a deep joint, commonly measuring 3 cm in the dorsoplantar direction. The cartilage and bone should be



Fig. 2: A close-up view through the dorsal incision with the extensor tendon retracted of the lateral wedge osteotomy marked on the medial cuneiform The planned cut will be perpendicular to the longitudinal axis, beginning from the articular margin medially and exiting 2 to 3 mm proximal to the joint line laterally.

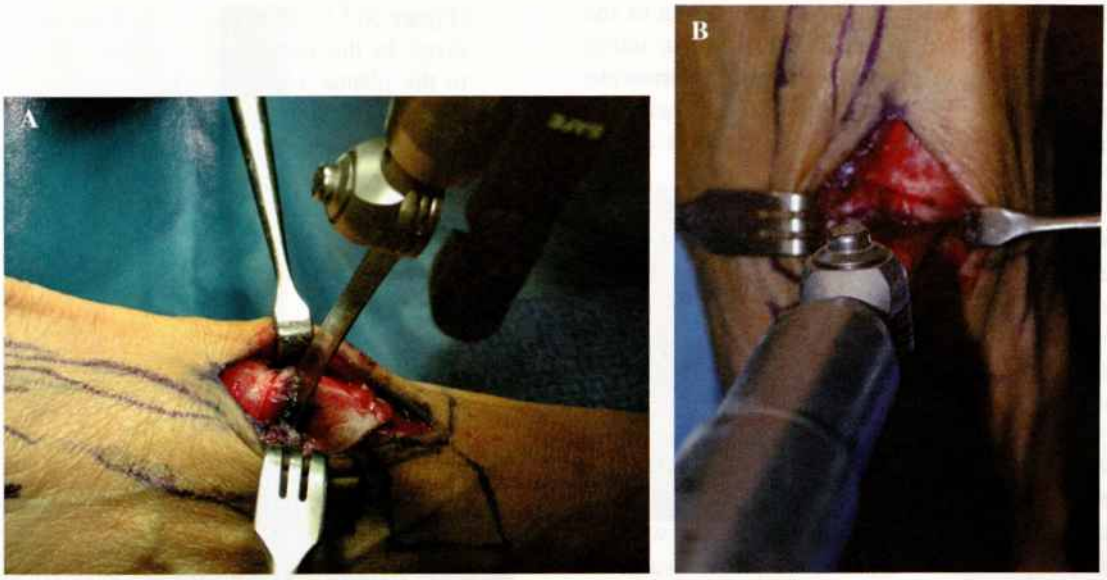


Fig. 3: Lateral and dorsal views illustrating the proper position of the saw blade to perform the biplanar osteotomy. **A,** The blade is slightly plantarflexed relative to the dorsoplantar axis of the joint to resect a wedge of bone that will be slightly thicker plantarly than dorsally. **B,** Keeping the blade perpendicular to the longitudinal axis is important to create a lateral bony wedge of proper thickness. The use of a narrow saw minimizes the risk of inadvertent excursion of the blade into the adjacent second metatarsal.



Fig. 4: With the osteomized bone removed from the joint, the anticipated correction of the metatarsus primus varus may be seen. Also, the dimensions of the fragment can be appreciated. It measured 12 mm in width and 28 mm in height.



Fig. 5: The pilot hole used for the insertion of a distal-to-proximal cortical lag screw has been prepared with a 4-mm burr on the dorsal cortex of the metatarsal. Placing the pilot hole at least 10 to 15 mm distal to the joint provides an adequate bone bridge to avoid fracture during axial compression of the arthrodesis with the screw.

debrided with long strokes of the osteotome from top to bottom to ensure an even resection of the surface. Excessive debridement dorsally or failure to remove bone plantarly will dorsiflex the metatarsal when it is positioned for arthrodesis. The cartilage retained in the central concavity may be removed with small curettes. A small diameter Kirschner wire is used to fenestrate the subchondral bone to expedite union. A wafer of bone, 2 to 3 mm in thickness should be removed from the

lateral base of the metatarsal. The medial aspect of the second metatarsal is decorticated also to allow union with the lateral base of the first metatarsal. Narrowing the base allows the metatarsal to appose fully with the cuneiform without abutting the medial aspect of the second metatarsal.

- At this time, the distal soft tissue and bony procedures are performed. The tendon of the adductor hallus and the lateral capsule of metatarsophalangeal joint are released through a small incision in the distal first webspace. Through a medial longitudinal incision centered over the metatarsophalangeal joint, the capsule is incised longitudinally, and a thin wafer of bone medial to the sagittal sulcus is resected. This resection accomplishes full correction of the hallux valgus because it permits the proximal phalanx to abduct on the metatarsal head and clear the sagittal sulcus without bony abutment when the metatarsus primus varus is corrected.
- The metatarsus primus varus and hallux valgus deformities may now be simultaneously corrected by applying a laterally directed force to the metatarsal head. This adduction maneuver apposes the metatarsal base to the osteotomized cuneiform, eradicating the former deformity. As the metatarsal head moves laterally, it reduces over the sesamoids, and the proximal phalanx abducts to eradicate the latter deformity. The tarsometatarsal arthrodesis is stabilized with a 3.5-mm cortical lag screw placed from a pilot hole made in the dorsal aspect of the metatarsal shaft as described by Hansen and Manoli (Figure 5).[8,13] This pilot hole is placed at least 1 cm distal to the joint, and the screw is directed parallel to the plantar surface of the foot and perpendicular to the joint to maximize compression (Figure 6). A second cortical lag screw is placed from the dorsolateral aspect of the medial cuneiform through the plantar cortex of the first metatarsal. Alternatively, a lag screw may be placed from the medial aspect of the metatarsal base into the second metatarsal (Figure 7).



Fig. 6: The distal-to-proximal cortical lag screw is inserted parallel to the sole of the foot to maximize the axial compression. A small Kocher clamp prevents unwanted rotation of the first metatarsal as the screw is tightened.

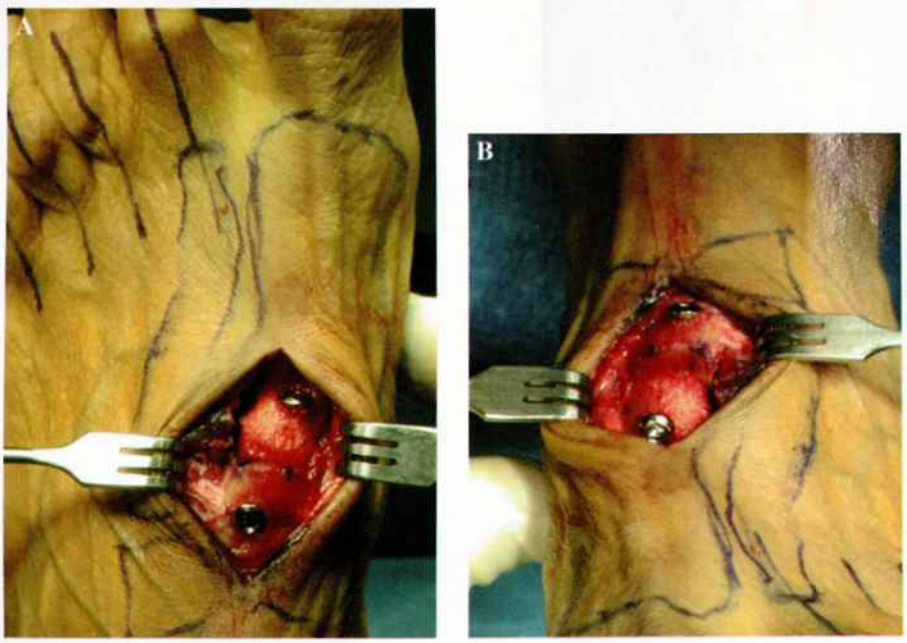


Fig. 7: The second cortical lag screw has been inserted proximal-to-distal and is situated lateral to the first screw **(A)**. This configuration provides additional compression and rotational stability to the arthrodesis and ensures the maximal effect of the closing wedge osteotomy. The metatarsal has been translated 4 mm plantar to the cuneiform to maintain proper weightbearing function of the first ray **(B)**.



Fig. 8: Anteroposterior and lateral radiographs of a 34-year-old woman with metatarsus primus varus and hallux valgus obtained before and 6 months after a Lapidus procedure. The position of the sesamoids, the intermetatarsal, and the hallux valgus angles are markedly improved. In this case, the tip of the distal-to-proximal screw enters the naviculocuneiform joint. When this occurs, it has never been found to produce pain or degeneration of the joint. No screw has ever been removed because of this event.

- The medial capsule of the metatarsophalangeal joint is repaired. True plication of the capsule usually is unnecessary. Aggressive plication of the capsule after full correction of the metatarsus primus varus with the Lapidus procedure could create hallux varus. For the same reason, the hallux is not dressed or taped to produce a varus force on the metatarsophalangeal joint postoperatively.
- Postoperatively, the limb is immobilized in a short-leg splint with medial and lateral side slabs. The splint and sutures are removed 2 weeks after surgery, and the limb is placed into a short leg nonweightbearing cast. At 4 weeks after surgery, radiographs are obtained to confirm union of the arthrodesis. The patient is allowed to progressively bear weight in a commercial walking boot. Physical therapy is prescribed. Modalities to reduce edema, mobilization of the metatarsophalangeal joint, strengthening of plantarflexion of the first ray and restoration of a heel-to-toe gait are emphasized. The patient transitions to conventional shoes by 8 to 10 weeks after surgery. At 3 months, the patient is encouraged to continue a program of independent exercise at home and is released to full activities (Figure 8).

SUMMARY

The Lapidus procedure is a powerful technique for correcting metatarsus primus varus and hallux valgus. Modification and modernization of the operative technique and the introduction of rigid internal fixation with multiple lag

screws has improved the reliability of healing and correction with this procedure.

The main advantage of the Lapidus procedure is its capacity to correct four deformities in three different planes simultaneously. The biplanar osteotomy of the medial cuneiform corrects the metatarsus primus varus and hallux valgus in the medial plane, allows plantar translation or angulation in the sagittal plane and corrects pronation of the toe in the axial plane when the metatarsal is positioned for arthrodesis. Another advantage is that this procedure can be used to salvage the failed operative correction of hallux valgus with good functional outcomes. Also, the postoperative management is minimal. Frequent painstaking dressing changes, with taping or strapping of the hallux to maintain the correction, are unnecessary.

Disadvantages of the Lapidus procedure include the need for an arthrodesis. However, the tarsometatarsal joint is not an essential articulation for accommodative motion or for the dissipation of the shear forces associated with weightbearing. Finally, the Lapidus procedure is a technically demanding operation. Several pitfalls must be avoided to achieve optimal results. Attention to detail and patience will prevent complications for the patient and frustration for the surgeon.

In conclusion, the Lapidus procedure should be considered for the management of moderate to severe metatarsus primus varus and hallux valgus and hypermobility of the first ray.

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Management of Primary and Revision Hallux Valgus

EDITOR
Andy Molloy

CONSULTING EDITOR
Mark S. Myerson

JUNE 2014

Management of Primary and Revision Hallux Valgus

Editor

ANDY MOLLOY

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The Modified Lapidus Fusion

Timo Schmid, MD, Fabian Krause, MD*

KEYWORDS

- Hallux valgus • Modified Lapidus procedure • Metatarsocuneiform fusion
- Technique

KEY POINTS

- Due to its very proximal correction site and long lever arm, the Lapidus fusion, modified or not, is a powerful technique to correct hallux valgus deformities.
- The disadvantages are a high complication rate and a long postoperative rehabilitation period. Therefore, it is currently only performed in 5% to 10% of all hallux valgus deformity corrections.
- Lapidus fusion remains an important procedure, especially in moderate to severe deformities with intermetatarsal angles more than 14°, hypermobility of the first ray, arthritis of the first tarsometatarsal joint (TMTJ), and recurrent deformities.
- Every surgeon dealing with forefoot deformities encounters cases when the Lapidus procedure is a viable option.

INTRODUCTION: NATURE OF THE PROBLEM

In 1911 and more than 20 years before Lapidus published his technique, Albrecht[1] first described a first metatarsocuneiform fusion for correction of hallux valgus deformity. In 1925, Truslow[2] introduced the term, *metatarsus primus varus*, pointing out that the primary deformity of the hallux valgus in these cases is located at the proximal end of the first ray. He stated that any operative procedure that does not incorporate the correction of the deformity at its proximal origin is unscientific and inadequate. In 1932, Kleinberg[3] identified the obliquity of the first TMTJ and the consequent adduction of the first metatarsal as the ultimate cause in the etiology of hallux valgus.

It was not until 1934 that Lapidus described his technique. And although Lapidus himself stressed that he did not introduce a new principle, it is his name that is closely connected to the procedure.[4]

The original technique consisted of an arthrodesis of the first cuneiform-metatarsal joint and the first intermetatarsal joint. The fixation was achieved by simply sewing the

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joint capsules with catgut. Later, fixation by crossed screws was introduced by Clark and colleagues[5] and led to a modified technique without intermetatarsal fusion.

Despite Truslow's statement, the original or the modified Lapidus technique is done in barely 10% of all hallux valgus corrections. This is likely due to a longer postoperative rehabilitation period and a higher complication rate as opposed to other techniques, particularly more distal procedures. The Lapidus procedure is a technically demanding operation: with its long lever arm, the procedure is prone to over- or undercorrection and nonunion.[6]

INDICATIONS/CONTRAINDICATIONS

According to most investigators, a distal bunion procedure is thought insufficient when the intermetatarsal angle exceeds 15° (**Table 1**). Any type of proximal metatarsal osteotomy or the more proximal tarsometatarsal arthrodesis is preferred in these cases.

Hypermobility of the first ray in the TMTJ, as originally suggested by Morton in 1928,[7] continues to be an important indication. Proper measurement of this instability remains, however, difficult. Plantar gapping of the first TMTJ on a lateral weightbearing radiograph seems to be a reliable sign. Clinical evaluation is highly subjective, however, and objective measurement with external calipers is inconvenient in daily practice.[8,9]

Hallux valgus deformity with accompanying arthritis of the first TMTJ can be treated by one single procedure with a Lapidus fusion.

Recurrence after hallux valgus correction is a difficult situation for both patient and surgeon. The Lapidus procedure can provide good correction and high satisfaction rates in this setting.[10,11]

Because the epiphysis of the basis of the first metatarsal contributes to approximately 50% of the length growth of the first ray,[12] a juvenile hallux with open epiphysis is a contraindication.

Potential athletic activity has to be taken into consideration, because only 30% of athletes with a stiffened first ray return to their preoperative level of activity after a metatarsocuneiform fusion. In contrast, 75% of the more sedentary patients achieve this goal.[13] Arthritis of the adjacent joints (eg, first metatarsophalangeal joint [MTPJ]

Table 1
Indications/contraindications

	Indications	Comments
Frequent	Moderate to severe deformity	Intermetatarsal angle >15°
	Hypermobility of the first ray	Plantar gapping of TMTJ 1 on lateral radiograph
	Generalized hyperlaxity	Beighton score >5
Rare	Recurrent hallux valgus	Satisfaction rate 80%
	Juvenile hallux valgus	Only when growth plate is closed
	TMT 1 arthritis	
	Contraindications	**Comments**
Absolute	Arthritis of the first MTPJ	
	Juvenile hallux valgus	Open growth plate
Relative	Short first metatarsal	Consider bone block interposition
	Young active patient	Only 30% achieve preoperative activity level
	Smoker	Higher nonunion rate

and naviculocuneiform) is a relative contraindication because the restricted motion and the enlarged lever arm may lead to an aggravation of a preexisting arthritis.

The Lapidus procedure should be used cautiously in smokers because smoking has proved to negatively influence the union rate.

Even with accurate joint denudement, there is shortening of the first ray. Therefore, a preexistent short first metatarsal is a relative contraindication. With a bone block interposition, a surgeon can overcome this shortening.[6,14]

SURGICAL TECHNIQUE/PROCEDURE

Preoperative Planning

Prior to the Lapidus procedure, a complete and thorough history, clinical examination, and radiographic work-up are mandatory. The following points are useful to determine whether a Lapidus procedure is a good option:

- Pain at the medial Lisfranc joint indicating Lisfranc arthritis, general hyperlaxity, an older sedentary patient, and recurrence after previous hallux valgus correction support a Lapidus procedure.
- Pain in the first MTPJ indicating first MTPJ arthritis, an athletic activity, and nicotine abuse should lead to consideration of other options.
- Clinical examination aims to detect a first ray hypermobility or a generalized hypermobility. Morton first described how to test the first TMTJ instability: with the patient sitting, the knee flexed and the ankle in neutral position, one hand stabilizes the lateral 4 metatarsals, whereas the other hand moves the first ray from dorsomedial to plantar-lateral. The mobility is compared with the contralateral side.[7] This subjective method, however, was shown invalid.[15] To more objectively quantify hypermobility, external calipers, like the Klaue device, may be used.[16] With this device, the first metatarsal head was elevated 9.3 mm ($\pm$1.9 mm) in patients with a hallux valgus as opposed to 5.4 ($\pm$1.4 mm) in the control group in a clinical study.

Intractable plantar keratoses underneath the second metatarsal head or on the dorsum of the first metatarsal head also indicate first TMTJ instability. The measurement of this instability, however, remains imprecise and subjective.

- General joint laxity can be estimated with a Beighton score, which consists of 9 stability assessments: ability to put the hands flat on the ground with straight knees (1 point), hyperextending both elbows (each 1 point) and knees (each 1 point), and bending both thumbs back on the front of the forearms (each 1 point) and both little fingers 90° to the back of the hands (each 1 point).[17] A score of 5 or more indicates significant ligamentous instability.
- Tenderness under palpation and passive motion indicates arthritis of the first TMTJ and the first MTPJ.
- Radiographic work-up consists of weight-bearing dorsoplantar and lateral radiographs. A severe deformity with an intermetatarsal angle greater than 15° and arthritis of the first TMTJ on the dorsoplantar view supports a Lapidus procedure. In contrast, a short first metatarsal, an open growth plate, and arthritis of the first MTP joint are contraindications. Regarding first ray hypermobility, Morton[7] stated that bony hypertrophy of the second metatarsal indicates instability of the first TMTJ, but Grebing and Coughlin[18] were not able to confirm this finding. No association of second metatarsal shaft width and medial cortical hypertrophy with hallux valgus, first ray mobility, or first metatarsal length was seen.

Normally, the first metatarsocuneiform joint is orientated slightly medial, but occasionally it may have an excessive degree of medial inclination. This leads to

a metatarsus primus varus deformity, and a hallux valgus deformity is more common.[2,19–22]

In approximately 8% of patients, an os intermetatarseum is present.[8] It is often accompanied by a rigid first tarsometatarsal articulation that blocks reduction of the 1 to 2 intermetatarsal angle by distal soft tissue repair or distal metatarsal osteotomy and may indicate a Lapidus procedure.

- In approximately 20% of cases of moderate to severe hallux valgus deformity, a gap of the plantar aspect of the first TMTJ on the lateral view is seen that is associated with hallux valgus or first metatarsocuneiform joint instability.[8,9,23] It is obvious in a majority of cases and an objective sign for the often-quoted first ray instability.

Authors' Preferred Technique

The patient is placed in a supine position, sometimes with a bolster under the ipsilateral buttock allowing correct rotation of the foot. Appropriate visualization and safe dissection are ensured either by a sterile Esmarch rubber bandage at the ankle level or a tourniquet inflated to 350 mm Hg at the thigh.

- The first TMTJ is approached through a 5-cm longitudinal incision centered over the dorsomedial aspect of the joint. The accompanying distal soft tissue procedure is performed via a 3- to 4-cm longitudinal incision centered between the first and second MTPJs and a 3- to 4-cm longitudinal incision on the medial aspect of the first MTPJ.

A release of the adductor tendon and the transverse metatarsal ligament is carried out in the first web space. The lateral MTPJ capsule is perforated with several puncture wounds and disrupted by medial angulation of the toe. Medially, the joint capsule is prepared and opened horizontally and the medial bony eminence is removed. The removal of the eminence is a standard step with a resection of 2 to 4 mm in width, superior more than inferior, and without violating the medial sesamoid groove.

The joint capsule of the first TMTJ is approached retracting the extensor hallucis longus tendon laterally. The joint is opened dorsally and medially. If a fusion of the bases of the first and second metatarsal is planned, the joint is approached via the interval between the extensor halluces longus and brevis tendons. Care has to be taken not to harm the neurovascular bundle (the dorsalis pedis artery and deep peroneal nerve).

- The joint is exposed with 2 Hohmann retractors to protect the anterior tibial tendon on the medial side and the neurovascular bundle on the lateral side. With an osteotome and a small curette, the articular cartilage is completely removed. The joint is sinusoidal-shaped and 30 mm in height. Therefore, removing all cartilage of the plantar lateral aspect can be somewhat difficult. A small lamina spreader or a Kirschner wire distractor is useful to better expose the most plantar part of the joint. By resection of a small plantarly and laterally based wedge, better correction of excessive valgus and mild plantar flexion is achieved (**Fig. 1**). Alternatively, a minimal saw cut at the articular surface of the cuneiform with a small plantarly and laterally based wedge can be done if the first metatarsal is not already short.
- For a fusion of the first intermetatarsal joint, the corresponding articular surfaces are also prepared (as discussed previously). During this dissection, the penetrating branch of the dorsalis pedis artery has to be protected. Usually the authors prefer the modified Lapidus technique with simple fusion of the first

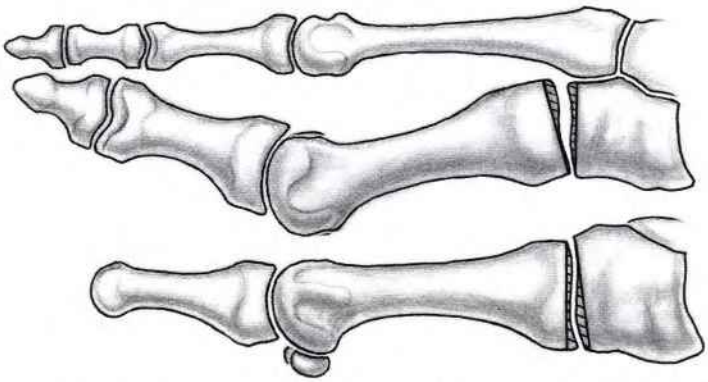


Fig. 1. By resection of a small plantarly and laterally based wedge, better correction of excessive valgus and mild plantar flexion is achieved.

TMTJ and only perform this intermetatarsal arthrodesis in cases of a nonunion or presence of an os intermetatarseum.

- The subchondral bone is opened by feathering with an osteotome and multiple 1.5-mm drill holes on both sides of the arthrodesis.
- The joint is gently manipulated from a dorsomedial to a plantar lateral position, thus respecting the joint's biomechanical axis. The first metatarsal is then reduced to close the intermetatarsal angle. Generally, there is a tendency to undercorrect the metatarsal plantarflexion. Too much dorsiflexion of the first ray may lead to transfer metatarsalgia of the second ray. If appropriate plantarflexion cannot be achieved, the plantar lateral aspect of the joint should be revisualized to ensure that the joint is correctly prepared. It is relatively easy to leave residual cartilage or bony fragments on the plantar lateral of the joint aspect, which impede correct positioning. Local bone graft obtained from the medial MTP joint eminence may be placed into the arthrodesis site if there are any defects present. The correct alignment and rotation is fixed with a preliminary Kirschner wire. It is imperative that this checked both clinically and fluoroscopically.

Fixation with 2 crossed 3.5-mm lag screws is usually sufficient. A notch at the entry point of the distal screw prevents a fracture of the dorsal proximal cortex of the first metatarsal (**Fig. 2**). Without the notch, the screw levers the metatarsal cortex dorsally when cortical contact of the screw head forces it upwards. For the notch, a triangle of six 2.5-mm drill holes is created and the cortex surrounded by the drill holes is removed with a rongeur (**Fig. 3**). The medial cuneiform has a width of

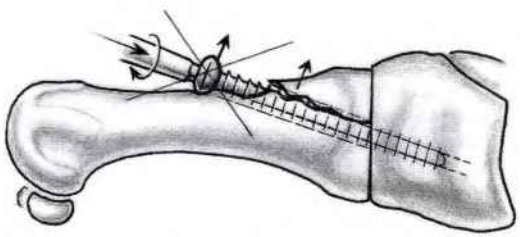


Fig. 2. A notch at the entry point of the distal screw prevents a fracture of the dorsal proximal cortex of the first metatarsal.

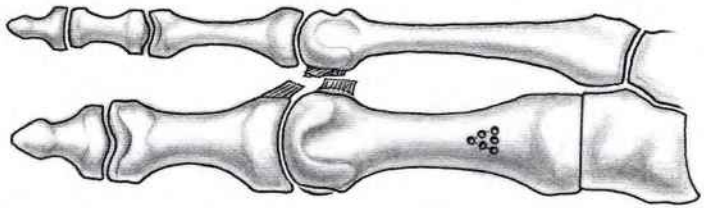


Fig. 3. For the notch, a triangle of six 2.5 mm drill holes is created and the cortex surrounded by the drill holes is removed with a rongeur.

approximately 1.5 cm. Appropriate aiming of the drill is crucial to correctly place the screws and to avoid violation of the intercuneiform joint. Drilling parallel to the medial border of the foot helps direct the drill in axis of the cuneiform. A 3.5-mm gliding hole is created. To allow more lateral correction of the first metatarsal, the 2.5-mm drill can then be directed in the cuneiform slightly more medially than the gliding hole (**Fig. 4**). A second screw is inserted from proximal to distal, aiming distally for the lateral plantar first metatarsal cortex. The screws should not cross within the fusion but rather distally to it, thus adding rotational stability. Dorsiflexion of the first MTPJ while inserting the screws improves compression at the arthrodesis site by tensioning the plantar fascia.

- The capsular tissues on the medial MTPJ are double-breasted for satisfactory alignment of the hallux. At this point, the deformity should be fully corrected. Any correction with dressings is not sufficient to prevent long-term recurrence. If there is residual deformity, the surgeon needs to ascertain the reason for this through clinical and flourscopic examination. Providing the arthrodesis has been fixed in the correct position, the most common reason is hallux interphalangeus. In this situation, an Akin osteotomy can be performed.
- The incision is then closed in layers. A compression dressing and a below-knee cast are applied.

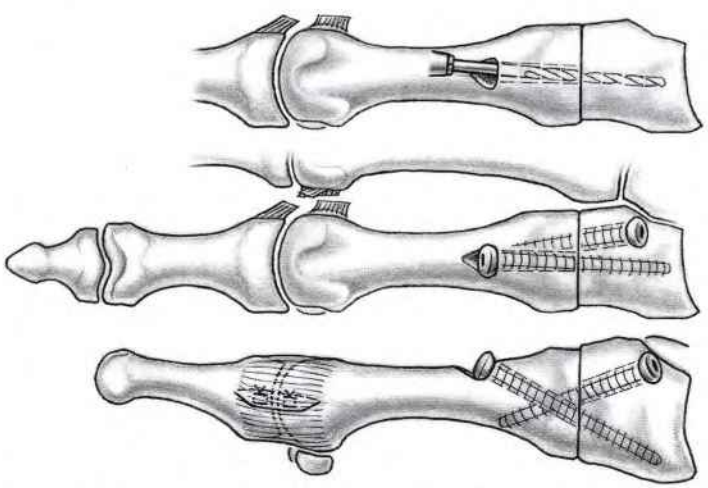


Fig. 4. A 3.5-mm gliding hole is created. To allow more lateral correction of the first metatarsal, the 2.5 mm drill can then be directed in the cuneiform slightly more medially than the gliding hole.

POSTOPERATIVE CARE

A compression dressing is removed 1 to 2 days after surgery and a below-knee cast is applied for 8 weeks. Patients are kept non–weight bearing for 4 weeks. The authors keep patients 10 to 20 kg partial weight bearing for the next 4 weeks.[24] Patients are then allowed transition to full weight bearing in regular shoes after this 8-week period of cast immobilization. In order to ensure progression of healing, the authors obtain dorsoplantar and lateral radiographs after 4 and 8 weeks.

Most investigators recommend non–weight bearing in the first 6 to 8 weeks after the procedure. Newer and stronger implants may provide more primary stability and, therefore, allow a shorter period of immobilization or immediate partial weight bearing postoperatively. Even full weight bearing 2 weeks after the procedure was described to have no adverse effects on alignment or the rate of osseous union.[25–27] Nevertheless, in biomechanical studies, most of these locking plates failed to demonstrate a stronger fixation than the crossed screw technique.[5,28–30] The downside of locking plates is the amount of hardware present in an area with little subcutaneous tissue. It is the authors' belief that locking plates have a greater potential for necessity of hardware removal. Even 2 crossed screws, however, cause implant-related problems in up to 20%.[31]

Because of the poor ratio of the long metatarsal lever arm and the small fusion surface, the authors do not recommend that patients be permitted to weight bear at an earlier stage. This cautiousness is supported by higher nonunion rates in several studies with early weight bearing as well as higher nonunion rates in simultaneous bilateral Lapidus fusion.[6,32]

Therefore, the classic construct of 2 crossed screws and an immobilization of 6 to 8 weeks still seems the gold standard. The authors' experience with this approach is generally good, and patients accept the longer period of cast immobilization and walking on crutches without complaints.

COMPLICATIONS AND MANAGEMENT

- The most common complication after a Lapidus procedure is nonunion. Rates from 2% to 10% are reported in the literature. In simultaneous bilateral operations, the rate even raises up to 33%.[6] Approximately 50% of the patients with nonunions are symptomatic and require revision.[33] Smoking is proved to have a major impact[11]; therefore, smoking is a relative contraindication for a Lapidus procedure in heavy smokers. Patients are informed about these risks and asked to stop or at least cut down smoking, but the authors do not cancel the surgery unless it is a revision surgery.

Table 2
Complications and management

Complications	Frequency (%)	Of Note
Nonunion	2–10[5,6,13,14,24,32,35,38–40]	Simultaneous bilateral operation: 33%[6] Symptomatic in 50%[33]
Transfer metatarsalgia	4–5[11,41]	Due to malalignment/shortening
Malunion	0–10[6,32,36]	
Hallux varus	0–16[39,40]	Mostly caused by excessive lateral release of the MTPJ 1
Recurrence	0–16[6,11,14,32,34,39,42]	

Table 3
Outcomes

Outcome	Rate/Range	Of Note
Reduction of HV angle	10°–22°[10,32,34,36,40]	
Reduction of IMT 1–2 angle	6°–9°[10,32,34,36,40]	
Patient satisfaction rate	74%–96%[3,5,32,34,42,43]	When performed after recurrence: 81%[11] Depending on[13] reduction of first intermetatarsal angle, first MTPJ dorsiflexion >45°, and proper sagittal alignment
Shortening of the first ray	2.9 mm–8 mm[6,11,13,37,41,44]	Management: 5–10 mm: plantarflexion of the first ray >10 mm: Weil osteotomies of second/third ray >20 mm: lengthening with bone graft
Subjective foot stiffness	8%–18%[5,32,36]	
Prolonged pain/swelling	Up to 16%[41]	Usually subsides after 3 mo

- In the presence of a painful nonunion, the authors recommend revision with autologous cancellous bone graft interposition and strong fixation, including fusion of the basis of the first and second metatarsals as originally described by Lapidus.
- Malalignment typically results in shortening and dorsiflexion of the first metatarsal and may lead to transfer metatarsalgia of the second and/or third rays.[14,34,35] It occurs in up to 10% of the cases.[36] It is, therefore, essential that accurate joint preparation is performed and that excessive wedges are not taken from the joint. Interposition of the resected medial eminence helps to prevent significant shortening if there is already a relatively short metatarsal or excessive bone has been resected.[37] A shortening of less than 5 mm with correct position usually does not cause problems. For shortening of 5 to 10 mm, a slight plantarflexion of the first metatarsal suffices to prevent problems. In cases of more than 10 mm, shortening metatarsal osteotomies (eg, Weil osteotomy) of the second and third toe can prevent transfer metatarsalgia. In cases of 20-mm and more first metatarsal shortening, however, a reconstruction of the first ray with a tricortical bone graft is used to adequately restore the correct length (**Tables 2** and **3**).[10]

SUMMARY

- The idea of the modified Lapidus procedure is to correct the hallux valgus where the primary deformity, the metatarsus primus varus, occurs.
- The Lapidus procedure is the most proximal site for forefoot correction and, therefore, offers more power than all metatarsal osteotomies.
- Accounting for 5% to 10% of all hallux valgus corrections, the modified Lapidus procedure is currently mainly used in severe deformities, deformity recurrences, first metatarsocuneiform arthritis, and hypermobility of the first ray.

- Because of its power and the demanding surgical technique, the procedure is prone to complications, which occur in approximately one-fourth of patients.
- With an appropriate surgical technique, good results can be expected, even when used for revision cases.
- Fixation with crossed screws and immobilization for 6 to 8 weeks still seem to be the gold standard.

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S IN PODIATRIC MEDICINE
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Advances in Forefoot Surgery

EDITOR
Charles M. Zelen

CONSULTING EDITOR
Thomas Zgonis

JULY 2013

Advances in Forefoot Surgery

Editor

CHARLES M. ZELEN

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Nathan J. Young and Charles M. Zelen

Arthrodesis of the first metatarsocuneiform 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. Research regarding locking plates seems promising, and data show lower rates of nonunion. Innovative fixation techniques are new and should be considered in the future as further literature is available on their long-term use. Regardless of the fixation, proper joint preparation and good compression is fundamentally the most important. A case of Lapidus fusion with locking plates after a failed arthrodesis with screws alone is presented.

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New Techniques and Alternative Fixation for the Lapidus Arthrodesis

Nathan J. Young, DPM, AACFAS, AAFAS[a,b],
Charles M. Zelen, DPM, FACFAS, FACFAOM[a,b,*]

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[1] but was popularized by Lapidus[2] 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.[2] He abandoned the procedure for a time because of the lack of adequate internal fixation.[3] 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.[4]

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Regardless of the fixation method, one of the potential complications when performing this procedure is nonunion of the arthrodesis.[5] Before advancements in rigid internal fixation, nonunion rates for the Lapidus procedure approached 25%.[6] As a result, many surgeons were hesitant to perform the procedure.[7] After advancements in screw technology, published data suggested the nonunion rate to be between 3.3% and 12.0%.[4,8,9] Patel and colleagues[9] 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[5] 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[6] 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."[6] 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.[4,8,10,11]

In his report, Lapidus[2] 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.[3] Modern principles of bone fixation developed in 1958 by the Swiss association Arbeitsgemeinschaft fuer Osteosynthesisfragen, 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.[12] 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[13] 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[14] 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[8] found that crossing screws alone were equivalent in terms of rigidity compared with crossing screws with a dorsomedial plate. Cohen and colleagues[15] also found that crossing screws were stronger and provided increased rigidity when compared with a dorsal H-plate without any interfragmentary screws.[15] Klos and colleagues,[16] 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.[4,7,11,17,18] Some investigators recommend plantar interfragmentary lag screw insertion combined with plating systems. This technique provides compression across the tension side of the joint.[10,11] 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.[19] 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 (Acumed, 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.[20–23]

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.[24] 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[24] 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.[24] Although this study provided a complication and healing rate that is rather unparalleled in the literature, Treadwell's[25] series provided a more realistic rate of complications often seen with external fixation–related midfoot fusions. Treadwell[25] 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.[25] However, Van Gompel and Dei[26] 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.[27]

Lui and colleagues[28] 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[27,28] 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[29] 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[28] 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 nonunions, many surgeons will limit their patients to a strict non–weight-bearing protocol during this time period.[5] Prolonged non–weight bearing can have deleterious effects for patients, such as disuse osteopenia, muscle atrophy, weight gain, deep vein thrombosis, and pulmonary embolism.[30] 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.[5–7] Others recommend near-immediate weight bearing.[17] 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.[6] Sangeorzan and Hansen[14] promoted early weight bearing and found 92% union rate. Sorenson and colleagues[7] applied locking plates for a Lapidus fusion and allowed weight bearing at 2 weeks and had 100% union. Saxena and colleagues[11] 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[17] 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[31] 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[7] 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.[7] DeVries and colleagues[4] 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.[4] Saxena and colleagues[11] 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.[11]



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.

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Correction of Frontal Plane Rotation of Sesamoid Apparatus during the Lapidus Procedure: A Novel Approach

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ABSTRACT

The Lapidus procedure affords correction of a multitude of first ray pathologic entities. When reconstructing the first ray using the Lapidus procedure, the relocation of the first metatarsal over the sesamoid bones with frontal plane rotation should be considered one of the key components. In the present technical report, we have described a bunion correction with emphasis on sesamoid reduction through indirect frontal plane manipulation. Our technique, borne from applied basic anatomy of the first metatarsophalangeal joint, uses intact soft tissues about the first metatarsophalangeal joint to reduce subluxed or dislocated sesamoids.

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Many factors contribute to the maintenance of hallux abducto valgus (HAV) correction. Adequate alignment, soft tissue balancing, an atraumatic technique, appropriate fixation techniques, and postoperative protocols all play a role in a successful outcome. We describe a bunion correction with emphasis on sesamoid reduction through indirect frontal plane manipulation (Figs. 1 and 2). Our technique, borne from applied basic anatomy of the first metatarsophalangeal joint (MTPJ), uses these intact soft tissues to reduce subluxed or dislocated sesamoids.

The sesamoid apparatus of the first MTPJ consists of the 2 sesamoids encased in a thick plantar plate and connected by an interosseous ligament. The sesamoids are connected to the first metatarsal head by a medial and lateral metatarsosesamoid ligament and suspensory ligaments and are connected to the first proximal phalanx by medial and lateral sesamophalangeal ligaments. The sesamoid apparatus is also enveloped on a nonarticular plantar surface by the flexor hallucis brevis, transverse and oblique segments of the adductor hallucis, the deep transverse metatarsal ligament, and fibers of the plantar aponeurosis. The tibial and fibular sesamoids are true synovial joints with hyaline cartilage interfaces (1,2). Our surgical rational was anatomically based. Frontal plane rotation of the first metatarsal head by manual reduction and ligamentotaxis provided by manipulation of the first proximal phalanx during the modified Lapidus arthrodesis can reliably reduce the sesamoids under the first metatarsal head, leaving the soft tissues intact. This differs from the translational approach, which relies on resection of the lateral soft tissue structures to translate into the transverse plane. Additionally, the standard techniques using typical anteroposterior radiographs provide static views of the deformity and do not foster consideration of the dynamic effects of the soft tissue around the osseous structures.

Surgical Technique

A 4- to 6-cm incision is made over the metatarsal cuneiform joint, and the tarsometatarsal ligaments are resected to expose and prepare the joint. The first tarsal metatarsal joint is destabilized, distracted, and prepared using a combination of a power saw, osteotome, mallet, drills, and picks to ensure good subchondral bone exposure. In contrast to the procedures of the past, dissection of the MTPJ is eliminated, just as is the resection of the medial eminence and the lateral release (Supplemental Video S1).

The reduction maneuver is performed by grasping the hallux and derotating the hallux out of the valgus in a varus direction, which places the nail plate in a neutral position, parallel with the ground. The surgeon then dorsiflexes the first digit while maintaining frontal plane alignment, enabling correction of the sagittal plane. The first metatarsal is put into adduction, and the surgeon's thumb is used to put counterpressure on the first metatarsal head, thus correcting the transverse plane. This allows for the entire hallux, sesamoid, and first

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Fig. 1. Preoperative radiograph.



Fig. 3. Intraoperative view after destabilization of the first tarsometatarsal joint and reduction of valgus rotation of the first metatarsophalangeal joint, with the sesamoids rotated into rectus alignment in the frontal plane.

metatarsal complex to be rotated into a neutral position as 1 unit. The sesamoid correction can be observed under fluoroscopy (Figs. 3 and 4). The first tarsal metatarsal joint is pinned with a 2.0 Kirschner wire from dorsally and distally to plantarally and proximally.

If additional frontal plane rotation is needed, the Kirschner wire is backed out. An additional Kirschner wire is placed in the proximal metaphysis of the first metatarsal, perpendicular to the weightbearing surface, and used as a "joy stick." The original Kirschner wire is then reintroduced for temporary stabilization from the distal first metatarsal into the cuneiform. A third Kirschner wire is introduced as a second point of fixation from the first metatarsal head into the second while applying abductory pressure to the first



Fig. 2. Preoperative radiograph.



Fig. 4. Intraoperative view after destabilization of the first tarsometatarsal joint and reduction of valgus rotation of the first metatarsophalangeal joint, with the sesamoids rotated into rectus alignment in the frontal plane.



Fig. 5. Postoperative views of the great toe derotated to a neutral position, with complete reduction of the hallux valgus angle and well-aligned sesamoids and metatarsophalangeal joint complex.



Fig. 6. Postoperative views of the great toe derotated to a neutral position, with complete reduction of the hallux valgus angle and well-aligned sesamoids and metatarsophalangeal joint complex.

metatarsal head. Kirschner wires are used to maintain the correction obtained by these additional maneuvers. Definitive fixation is achieved with a 3.5-mm cortical screw introduced with a lag technique in a "home-run" fashion, as described by Hansen (3). The screw should be as long as possible from anteriorly to posteriorly and should engage the posterior cortex of the medial cuneiform. Finally, a 6-hole combination locking/nonlocking plate is placed to function as a "large washer" in reducing the intermetatarsal angle with the lag screws and maintaining the correction with the locking screws (Figs. 5 and 6).

Discussion

The frontal plane component of HAV correction has recently received some attention. Dayton et al (4) recently stated that frontal plane malalignment is a key component of the HAV deformity and concluded that it must be addressed during correction to provide anatomic alignment of the first MTPJ. We agree with their statements and offer our technique for reliable reduction of an abnormal sesamoid position in HAV. The HAV deformity is essentially a subluxed joint that is malaligned because of instability and hypermobility. Rather than relying on soft tissue releases and capsular repairs, our technique has been based on the mechanics of ligamentotaxis and precise realignment of the bony segments. Resection of the first tarsometatarsal joint enhances the ability to manipulate the first ray into the anatomic position, and stabilization is accomplished. Once the first metatarsal has been derotated and stress is off the soft tissues, the frontal plane will return to the natural anatomic alignment, and the position can be held by fusing the first tarsometatarsal joint.

The normal sesamoid position is a principle factor contributing to normal gait. The results of a 3-dimensional kinematic analysis in a cadaver model demonstrated that the sesamoid apparatus plays a significant role in the biomechanical function of the first ray and that less than optimal realignment of the apparatus can lead to adverse retrograde forces, with the increased possibility of recurrence (5). Thus, the intraoperative sesamoid position should be evaluated during bunionectomy, regardless of the procedure selected, using either fluoroscopy or direct visualization.

The sesamoids are housed within an intricate network of ligaments, tendons, and capsular structures, all of which function as a



Fig. 7. Clinical photograph of the well-healed foot showing the isolated incision of the tarsometatarsal area.

unit about the first MTPJ (1,6). The traditional methods of sesamoid reduction have involved detaching the restraining structures of the first MTPJ. Various methods have included modifications of McBride's soft tissue release and capsular augmentations, which rely on scar tissue formation to reduce bony deformities (7). Although this has historically been proved to reduce the first metatarsal head under the sesamoid apparatus (8), this technique relies solely on transverse plane motion. Inherently, this will not be an adequate reduction maneuver to reduce the first ray in all 3 planes. Our technique of using the soft tissue-retaining structures of the first MTPJ will also alleviate several postoperative concerns. No scar tissue will be formed along the joint (Fig. 7). The gliding mechanism of the tendon structures about the MTPJ will be maintained. Also, there is no risk of staking the first metatarsal head, and hallux varus is less of a concern, because all the retaining structures about the first MTPJ are intact. Finally, no vascular or nerve concerns exist pertaining to the nutrient artery to the lateral first metatarsal head.

Conclusion

The present report details a technique for using the restraining structures of the first MTPJ rather than severing them. We have seen clinical evidence that the technique we have described is a viable option for correction. From our initial findings, this technique allows the soft tissue to be maintained, affording the patient a less-invasive procedure, with a lower risk of complications. An outcomes study is currently underway to further validate the effectiveness of our technique.

Supplementary Material

Supplementary material associated with this article can be found in the online version at www.jfas.org (doi:10.1053/j.jfas.2013.12.002).

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Exhibit 1035

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REVIEW ARTICLE

One century of Kirschner wires and Kirschner wire insertion techniques : A historical review

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A century ago, in 1909, Martin Kirschner (1879-1942) introduced a smooth pin, presently known as the Kirschner wire (K-wire). The K-wire was initially used for skeletal traction and is now currently used for many different goals. The development of the K-wire and its insertion devices were mainly influenced by the change in operative goals and by the introduction of antibiotics. The first versions of the Kirschner wire were hammered through a predrilled hole into the bone, but later on drilling became the standard technique of insertion. Drilling is considered a simple way of implanting, with many advantages, such as percutaneous and atraumatic insertion. However, this technique also has its disadvantages like temperature elevation, resulting in osteonecrosis and heat-related complications. Despite these complications the K-wire is now standard for the treatment of hand fractures, worldwide.

Keywords : Martin Kirschner ; Kirschner wire ; history ; Steinmann ; World War II.

MARTIN KIRSCHNER

Martin Kirschner was born on the 28th of October 1879, in Breslau, Germany, today known as Wroclaw, Poland. He studied medicine in Freiburg, Zurich and Munich and received his MD degree from the University of Strasbourg in 1904 (*24,36,74*). In 1909 Martin Kirschner introduced one of his most important contributions to emergency medicine : thick, smooth pins which evolved over the years into thin, smooth, stainless steel wires with various tips (*30,48*). The latter we know today as Kirschner wires (K-wires). It took quite some years before the K-wire became what it is now. The development was influenced by various factors such as wound infection, refinement of the insertion method and change of its goals, e.g. it became very useful for small fragile bones rather than thick long bones. During his lifetime Martin Kirschner was promoted to professor of surgery at the University of Königsberg, the University of Tübingen and the University of Heidelberg in 1916, 1927 and 1934 respectively. He remained at Heidelberg until his death, due to an inoperable carcinoma of the stomach, on the 30th of August 1942 (*24,36,74*).

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KIRSCHNER WIRE AND INSERTION DEVICES

Steinmann versus Kirschner

At first, the K-wire was not a wire but a pin which Martin Kirschner used for "Nagelextension", i.e. skeletal traction for fractures of the long bones by means of a nail. The principle of the pin was based on the Steinmann nail which had been introduced by Fritz Steinmann in 1907 (*62*). Steinmann placed two nails in the distal fragment of a broken bone, laterally and medially, whereafter traction was applied to the protruding ends of the nails, so keeping the fragments in proper alignment. In contrast to Steinmann, Kirschner placed only one pin throughout the distal end of the fractured bone ; it was hammered through a predrilled hole. The pins Martin Kirschner used at that moment had a diamond shaped tip and diameters varying from 3.5 to 6.0 mm. Today they are surprisingly known as Steinmann pins (*30,33*).

Throughout the years it became more and more obvious that the Steinmann pins often resulted in infection (*31,62*). According to both Fritz Steinmann and Martin Kirschner, these infections were due to the thickness of the pins and thus the necessity of predrilling, which resulted in to and fro slipping of the pin (*13*). Therefore Martin Kirschner refined and improved an insertion apparatus which made it possible to insert small diameter wires without predrilling, which resulted in a diminished rate of infection. It was in 1927 that he showed his external accordion-like guide which made it possible to insert thin chromium-plated steel piano wires, varying in diameter from 0.7 to 1.5 mm, without the need of predrilling (*31,34*). From that moment on, K-wires could be driven percutaneously through skin, soft tissue and bone. Because predrilling was no longer necessary, the wire was rigidly seated within the bone, so that lateral slipping was avoided, as well as trauma to the soft tissues (*31*). Martin Kirschner called the procedure "Drahtextension" instead of "Nagelextension".

The external accordion-like wire guide could be combined with a hand drill or a power drill. It was, however, difficult to handle. This resulted in the development of an improved and simpler K-wire drill by Mathews in 1931 (*42*). In 1934 the first spiral key-way drive was described by Niedringhaus (*42,49*) ; only a small part of the K-wire protruded to prevent side bending. This particular key-way drive could also be connected to a motor.

More indications

From 1935 on, other indications for the K-wire were described, like maintaining reduction of fracture-dislocations of the ankle joint, the hip and the elbow (*10,55,67*). In 1937 the use of K-wires was advocated for the treatment of hand fractures, which is the main purpose they are used for today. This was because Meekinson (*44*) presented an even simpler hand device for K-wire insertion. In the same year Gerster (*18*) stated that " Kirschner wires, compared to nails, have proven to be less irritating to both soft tissue and bone".

Second World War

In the Second World War surgeons became progressively more innovative in the use of Kirschner wires because of the introduction of antibiotics and corrosion-resistant metals. K-wires with a diameter of 1.5 mm were generally used in World War II, and thinner ones (0.7-1.0 mm) for the fingers. In 1940 Murray (*46*) started to place K-wires in a relatively new manner, longitudinally through the medullary cavity of the clavicle. His enthusiasm pushed him to extend this intramedullary technique to the radius, the ulna and the fibula. Captain Berkman (*5*) from the Medical Corps, United States Army, applied this new technique to metacarpal fractures ; this treatment was very useful in the army where patients could be assigned to light duty immediately after surgery. Today the K-wire is universally used in hand fractures and for many other indications like foot and ankle surgery (*19,39,47,66*), fractures of the long bones in children and adults (*2,9,38,50*), sacral fractures (*70*), treatment of Buerger's disease (*25*), phalloplasty during female to male transsexual surgery (*12*) and stabilization of costal cartilage in nasal surgery to prevent wrapping (*21*).

K-WIRE CHARACTERISTICS

Besides the changes in K-wire insertion devices, the K-wire itself has changed over the years. In 1909 the original Kirschner nail had a diamond shaped tip (*48*). Over the past three decades, research has been done regarding K-wire characteristics like tip and diameter. Namba (*48*) took the initiative in 1987.The most frequently analyzed K-wire tips were the diamond (flat) and trocar (pyramid-shaped) tips (*20,28,48,51,75*). The trocar tip needs the highest insertion force resulting in a significantly higher temperature development compared to the diamond tip, but it results in a significantly better fixation, especially immediately after insertion (*51*). In 1999 (*37,57*) a newly designed tip was proposed : it had two steep flutes for the removal of bone fragments during drilling ; this tip provoked the lowest temperatures elevations during insertion, as compared with the trocar and diamond tip.

Another important K-wire characteristic is the diameter. K-wires with diameters smaller than 1.1mm generate more heat than thicker K-wires, regardless of the tip configuration.

As well as smooth K-wires, regularly used in hand surgery, there are fine-threaded K-wires for foot and ankle surgery (*57*). These threaded K-wires need significantly more extraction force than smooth K-wires.

DRILLING VERSUS HAMMERING

Kirschner's final publication (*32*) appeared on November 15th 1942, shortly after his death. In this publication he made some very interesting remarks. As he discussed the disadvantages of drilling K-wires, like wire migration and pin tract infection, he wondered how to prevent these disadvantages and finally mentioned the insertion of K-wires by hammering instead of drilling. He even described and produced a hammer device which he called the "Drahtnagler" and wrote "Die Kraft des einfachen Hammers versagt nie" ("The force of a simple hammer remains"). He stressed that hammering prevented heat development, which resulted in a longer and better fixation. For this hammer-device, K-wires with a diameter of 1.5 mm were used.

So, initially in 1909, Kirschner nails were hammered through a predrilled hole (*30*), whereafter in 1927 the Kirschner nail changed in a Kirschner wire which was inserted with a drill without predrilling (*31*) and finally, in 1942, the Kirschner wire was hammered into bone (*32*). In spite of Kirschner's last publication K-wires are still inserted with a drill. However, in 1993, Zegunis (*73*) introduced a pneumatic hammer for K-wire insertion. His results showed that hammering resulted in lower temperatures. Based on these results Zegunis suggested that hammering may reduce the risk of thermal injury. After this publication no other papers were published concerning hammering of K-wires, until 2006, when Wassenaar (*69*) showed that, *in vitro*, hammering resulted in a shorter insertion time and better fixation. In 2008 the first author (*16*) showed that hammering resulted in significantly less death of osteocytes, which indicates less or even no thermal damage to the bone.

ADVANTAGES

One advantage of the K-wire is the relative ease of insertion with minimal trauma to the soft tissue and the tendons (*11*). But the greatest advantage is the possibility of atraumatic percutaneous insertion (*71*). This technique is easier than open reduction and internal fixation, has less associated risks, minimizes swelling and stiffness and is still preferred today (*8,26*). Percutaneous K-wire fixation achieves rigid fixation after adequate reduction and will allow early mobilization to prevent permanent deformity and stiffness.

Percutaneous transverse K-wire fixation diminishes and even avoids complications which occur after open reduction and internal fixation, including infection, difficulties in fracture healing, stiffness due to extensive soft tissue dissection, fibrosis, extensor tendon adhesion, plate loosening or breakage and complex regional pain syndrome (*27*). Intramedullary metacarpal K-wire fixation is even more simple and puts the least strain on the tendons (*26*).

DISADVANTAGES

Besides its advantages the use of K-wires has its drawbacks. In 1939 (*59*) the first publications appeared in which the use of K-wires was discouraged. Migration of K-wires, and lack of rigidity and strength when used in femoral neck fractures were described. In 1943, the first cases of K-wire migration from the clavicle to the lungs were reported (*43*). K-wire migration still occurs today and is a serious problem because it can result in non-fatal to devastating complications and even in death (*43,63*). In most of the reported cases the K-wires migrated from the shoulder girdle to the aorta (*17*), heart (*63*), lung (*43,45*), trachea (*14*), mediastinum (*68*), neck (*72*), spleen (*52*) and spinal canal (*54*). There are also reports of migration from other anatomical sites like migration from the hip to the heart (*3*), liver (*4*) or popliteal fossa (*56*) and, even from the left hand into the heart (*22*). The explanation of the K-wire migration remains obscure but in most cases migration can be prevented by bending the distal end of the K-wire (*15*). Nevertheless, even bent wires can migrate after breakage, so follow-up radiographs should be made until the K-wires are removed (*41,45*).

Pin track infections have occurred ever since the introduction of the K-wire (*32*). This complication was one of the factors which resulted in the development of thinner K-wires. But even with smaller diameter K-wires, pin track infections still occur. This is why Stone (*65*), in 1954, described a system of sterile dressings covered with foam rubber anchors, to be placed where the K-wire penetrates the skin, to prevent skin necrosis and infection. The incidence of pin track infections should not be underestimated. Presently, the use of K-wires results in pin track infections in 2.2 to 21% of the cases (*1,7,23,26,61*). This complication may lead to earlier pin removal and thus to non-union (*60*). Early treatment of pin track infection is important, either by immobilization, antibiotics or removal of loose pins. Less infections are seen when K-wires are buried (*23,53*).

Other complications described through the years are damage of peripheral structures (*2,7,26,29,58, 61,64*), traumatic subarachnoid-pleural fistula (*6*) and toxic shock (*40*). Restriction of active motion until the wires are removed can result in diminished function after bone healing (*35*).

CONCLUSION

The increasing use of the Kirschner wire, especially in hand surgery, proves that it has an excellent perspective for the future. The K-wire itself and the K-wire insertion technique have undergone refinements resulting in less complications, but these still occur. Therefore the most important goal is to further minimize these complications by adequate cooling during drilling, bending the protruding ends or if possible burying the wires. Hammering in may be a further step, if the right devices are developed.

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246	1_ | **a**Comprehensive textbook of foot and ankle surgery
250	__ | **a**4th ed. /**b**editor, Joe T. Southerland ; author editor, Daniel F. Vickers ; section editors, Jeffrey S. Boberg ... [et al.].
260	__ | **a**Philadelphia :**b**Wolters Kluwer Health/Lippincott Williams & Wilkins,**c**c2013.
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700 1 McGlamry, E. Dalton.
700 1 Southerland, Joe T.
856 4 **$u** http://solution.lww.com
856 4 1 **$u** http://public.eblib.com/EBLPublic/PublicView.do?ptiID=2031823
856 4 1 **$u** http://0-site.ebrary.com.oasys.lib.oxy.edu/lib/occidental/Doc?id=10822801 **$z** View this book fro m e-brary (Occidental College authentication required)
938 Ingram Library Services **$b** INGR **$n** in018438592
938 Baker and Taylor **$b** BTCP **$n** BK0010984767
938 Coutts Information Services **$b** COUT **$n** 21119746
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Attachment 2C

MARC record

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010	$a sh 85050397
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035	$a (DLC)48745
040	$a DLC $c DLC $d DLC
053 0	$a RD563
150	$a Foot $x Wounds and injuries
681	$i Example under $a Wounds and injuries
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Attachment 2D

MARC record

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035	$a (DLC)5097
040	$a DLC $c DLC $d DLC
150	$a Ankle $x Wounds and injuries
999 f f	$i a44003ee-645c-4fc1-ac52-c977a8430458 $s 6e94a39f-28a5-4c89-a45c-4098271ec1c5

Attachment 2E

MARC record

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010	$a sh 85130766
035	$a (DLC)sh 85130766
035	$a (DLC)126280
040	$a DLC $c DLC $d DLC
053 0	$a RD
150	$a Surgery
360	$i subdivision $a Surgery $i under classes of persons, individual diseases and types of diseases, and individual organs and regions of the body, e.g. $a Children--Surgery; Cancer--Surgery; Heart--Surgery; $i and subdivisions $a Abnormalities--Surgery $i and $a Wounds and injuries--Surgery $i under individual organs and regions of the body, e.g. $a Heart--Abnormalities--Surgery; Foot--Wounds and injuries--Surgery
450	$w nne $a Surgery, Primitive
550	$w g $a Medicine
999 f f	$i 4faaa08d-5919-4a37-befb-1bcc54ec7c95 $s 2595fbbc-0619-44e3-9e86-1bfa4712f638

Attachment 2F

Foot Deformities MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading	Foot Deformities
Tree Number(s)	C05.330
Unique ID	D005530
RDF Unique Identifier	http://id.nlm.nih.gov/mesh/D005530
Annotation	general or unspecified; prefer specifics
Scope Note	Alterations or deviations from normal shape or size which result in a disfigurement of the foot.
Entry Term(s)	Metatarsal Deformity
Previous Indexing	Foot/abnormalities (1966-1987)
Public MeSH Note	88
History Note	88
Entry Combination	congenital:Foot Deformities, Congenital
Date Established	1988/01/01
Date of Entry	1987/04/02
Revision Date	2016/01/20

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Attachment 2G

Foot Injuries MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Foot Injuries
Tree Number(s)
C26.558.300
Unique ID
D018409
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D018409
Annotation
general or unspecified; prefer specifics; consider also /inj with specific sites of foot
Scope Note
General or unspecified injuries involving the foot.
Entry Version
FOOT INJ
Entry Term(s)
Injuries, Foot
Turf Toe
Previous Indexing
Foot/injuries (1966-1994)
Public MeSH Note
95; was FOOT/injuries 1966-94
Online Note
use FOOT INJURIES to search FOOT/injuries 1966-94
History Note
95; was FOOT/injuries 1966-94
Date Established
1995/01/01
Date of Entry
1994/06/28
Revision Date
2016/02/26

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Attachment 2H

Detailed Record View

Registration record TX0007719165

Copyright Catalog
Displaying 2 of 3 entries

Previous Next

McGlamry's Comprehensive Textbook of Foot and Ankle Surgery - Volumes 1 & 2, 4e.

Share Actions

Registration Number / Date	TX0007719165 / 2013-04-09
Previous Registration	2001
Type of Work	Text
Certificate	View PDF
Title	McGlamry's Comprehensive Textbook of Foot and Ankle Surgery - Volumes 1 & 2, 4e.
Application Title	McGlamry's Comprehensive Textbook of Foot and Ankle Surgery - Volumes 1 & 2, 4e.
Date of Creation	2012

Date of Publication	2012-11-09
Copyright Claimant	Wolters Kluwer Health, Transfer: By written agreement from the editors and individual contributors. Address: 2001 Market St., Two Commerce Square, Philadelphia, PA, 19103, United States.
Authorship on Application	Joe T. Southerland; Domicile: United States. Authorship: text, editing. Daniel F. Vickers; Domicile: United States. Authorship: text, editing. Jeffrey S. Boberg; Domicile: United States. Authorship: text, editing. Michael S. Downey; Domicile: United States. Authorship: text, editing. Aprajita Nakra; Domicile: United States. Authorship: text, editing. Linnie V. Rabjohn; Domicile: United States. Authorship: text, editing.
Basis of Claim	text, editing.
Material Excluded	text.
ISBN	9780781765800
Description	Book, 2 v.
Nation of First Publication	United States
Names	Southerland, Joe T. Vickers, Daniel F. Boberg, Jeffrey S. Downey, Michael S. Nakra, Aprajita Rabjohn, Linnie V. Wolters Kluwer Health

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Attachment 9A

Bibliographic Record - OCLC Number: 27182191

LDR	Record Status	'c' - Corrected or revised
	Type of Record	'a' - Language material
	Bibliographic Level	's' - Serial
	Type of Control	' ' - No specified type of control
	Encoding Level	' ' - Full level
	Descriptive Cataloging Form	'a' - AACR2
001	27182191	
005	20251105200619.6	
008	Date Entered on File	'921230'
	Type of Date/Publication Status	'c' - Continuing resource currently published
	Date1/Beginning Date of Publication	'1993'
	Date2/Ending Date of Publication	'9999'
	Place of Publication, Production, or Execution Code	'mdu' - Maryland
	Frequency	'b' - Bimonthly
	Regularity	'r' - Regular
	Type of Continuing Resource	'p' - Periodical
	Form of Original Item	' ' - None of the following
	Form of Item	' ' - None of the following
	Nature of Entire Work	' ' - No specified nature of entire work
	Nature of Contents	' '
	Government Publication	' ' - Not a government publication
	Conference Publication	'0' - Not a conference publication
	Original Alphabet or Script of Title	'a' - Basic Roman
	Entry Convention	'0' - Successive entry
	Language Code	'eng' - English
	Modified Record	' ' - Record is not modified
	Cataloging Source Code	'c' - Cooperative cataloging program

010 sn 92006834

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222 4 The Journal of foot and ankle surgery
245 0 4 The Journal of foot and ankle surgery.
260 Baltimore, MD : **$b** Williams & Wilkins, **$c** ©1993-
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337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
362 0 Vol. 32, no. 1 (Jan./Feb. 1993)-
500 Title from cover.
500 Published: Baltimore, MD : Data Trace Pub., <1998->
530 Also issued in online version.
550 "Official journal of the American College of Foot and Ankle Surgeons."
650 0 Ankle **$x** Surgery **$v** Periodicals.
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856 4 1 **$u** http://www.jfas.org
891 3 3 **$9** 853 **$8** 1 **$a** v. **$b** no. **$u** 06 **$v** r **$i** (year) **$j** (month/month) **$w** b **$x** 01
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Attachment 1A

Bibliographic Record - OCLC Number: 27182191

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	Bibliographic Level	's' - Serial
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	Encoding Level	' ' - Full level
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008	Date Entered on File	'921230'
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	Date1/Beginning Date of Publication	'1993'
	Date2/Ending Date of Publication	'9999'
	Place of Publication, Production, or Execution Code	'mdu' - Maryland
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	Regularity	'r' - Regular
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	Nature of Entire Work	' ' - No specified nature of entire work
	Nature of Contents	' '
	Government Publication	' ' - Not a government publication
	Conference Publication	'0' - Not a conference publication
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	Cataloging Source Code	'c' - Cooperative cataloging program

010 sn 92006834

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032 922540 **$b** USPS

037 **$b** Williams & Wilkins, 428 E. Preston St., Baltimore, MD 21202

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222 4 The Journal of foot and ankle surgery
245 0 4 The Journal of foot and ankle surgery.
260 Baltimore, MD : **$b** Williams & Wilkins, **$c** ©1993-
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310 Bimonthly
336 text **$b** txt **$2** rdacontent
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338 volume **$b** nc **$2** rdacarrier
362 0 Vol. 32, no. 1 (Jan./Feb. 1993)-
500 Title from cover.
500 Published: Baltimore, MD : Data Trace Pub., <1998->
530 Also issued in online version.
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650 0 Ankle **$x** Surgery **$v** Periodicals.
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655 2 Periodical.
655 7 Periodicals. **$2** fast **$0** (OCoLC)fst01411641
710 2 American College of Foot and Ankle Surgeons. **$1** https://id.oclc.org/worldcat/entity/E39QH7JmqhfH ftRmw3VbPc3FhR
776 1 **$t** Journal of foot and ankle surgery (Online) **$x** 1542-2224 **$w** (DLC) 2002213269 **$w** (OCoLC)50 849610
780 0 0 **$t** Journal of foot surgery **$x** 0449-2544 **$w** (DLC)sn 79006255 **$w** (OCoLC)3711674
850 DNLM **$a** MiU **$a** MoSW-M **$a** WaU
856 4 1 **$u** http://www.sciencedirect.com/science/journal/10672516
856 4 1 **$u** http://www.jfas.org
891 3 3 **$9** 853 **$8** 1 **$a** v. **$b** no. **$u** 06 **$v** r **$i** (year) **$j** (month/month) **$w** b **$x** 01
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Attachment 1B

MARC record

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Attachment 1C

MARC record

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053 0	$a PN4700 $b PN5650 $c History
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450	$a Magazines
550	$w g $a Library materials
550	$w g $a Mass media
550	$w g $a Serial publications
550	$a Newspapers
550	$a Press
670	$a UMI business vocab. $b (Journals)
680	$i Here are entered works on the periodicals of the world and, with appropriate subdivisions, works on special aspects or sections of periodicals. Works on periodicals in a specific language, or in a specific country or larger area, are entered under the adjectival form of the language or area, e.g. $a Arabic periodicals; Canadian periodicals.
999 f f	$i f3c2f118-a0af-4986-bcda-385995e5c57d $s 6e61730c-f0c8-4352-b06f-cb3fc2acd8a0

Attachment 1D

MARC record

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Attachment 1E

Ankle MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Ankle
Tree Number(s)
A01.378.610.050
Unique ID
D000842
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D000842
Annotation
primates only; use TARSUS, ANIMAL for non-primate vertebrates; differentiate from ANKLE JOINT; ANKLE BONES see TARSAL BONES is also available; do not confuse X ref TARSUS with tarsus or tarsal referring to the eyelid
Scope Note
The region of the lower limb between the FOOT and the LEG.
Entry Term(s)
Regio tarsalis
Tarsus
See Also
Ankle Joint
Tarsal Bones
Public MeSH Note
1963; see ANKLE INJURIES to search ANKLE/injuries 1966-91; for TARSUS see TARSUS 1988-2001
History Note
1963; use ANKLE INJURIES to search ANKLE/injuries 1966-91
Entry Combination
injuries:Ankle Injuries
Date Established
1963/01/01
Date of Entry
1999/01/01
Revision Date
2019/07/01

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Attachment 1F

Foot MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Foot
Tree Number(s)
A01.378.610.250
Unique ID
D005528
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D005528
Annotation
vertebrates only: for invertebrates use EXTREMITIES: dis of foot = FOOT DISEASES; skin dis on foot = FOOT DERMATOSES: see note there; neopl of foot: use neopl coords (IM) + FOOT DISEASES (IM); foot prints (like finger prints) = PLANTAR PRINTS see DERMATOGLYPHICS
Scope Note
The distal extremity of the leg in vertebrates, consisting of the tarsus (ANKLE); METATARSUS; phalanges; and the soft tissues surrounding these bones.
Entry Term(s)
Feet
See Also
Foot Bones
Entry Combination
abnormalities:Foot Deformities, Congenital
injuries:Foot Injuries
Date Established
1966/01/01
Date of Entry
1999/01/01
Revision Date
2009/07/31

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Attachment 3A

MARC Bibliographic Record

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035		$a(CKB)954927698005
035		$a(EXLCZ)99954927698005
037		$bElsevier Health Sciences Division, 170 S Independence Mall W 300

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082	00	$a617/.585/005$219
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210	0_	$aClin. podiatr. med. surg.$b(Online)
222	_0	$aClinics in podiatric medicine and surgery$b(Online)
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246	18	$aPodiatric medicine and surgery
246	1_	$iVols. for <2005-> have PDF cover title:$aClinics in podiatric me
246	13	$aCPEM
260		$aPhiladelphia, PA :$bW.B. Saunders Co.
310		$aQuarterly
336		$atext$btxt$2rdacontent
337		$acomputer$bc$2rdamedia
338		$aonline resource$bcr$2rdacarrier
362	1_	$aPrint began with vol. 3, no. 1 (Jan. 1986).
500		$aRefereed/Peer-reviewed
500		$aPublished: Elsevier Health Sciences Division <2005->
588		$aDescription based on: Vol. 19, no. 1 (Jan. 2002); title from ban
588		$aLatest issue consulted: Vol. 22, Issue 3 (Aug. 2005) (Elsevier T
650	_0	$aPodiatry$vPeriodicals.

650	_0	$aFoot$xSurgery$vPeriodicals.
650	_2	$aPodiatry.
650	_6	$aPied$xChirurgie$vPériodiques.
650	_7	$aFoot$xSurgery.$2fast$0(OCoLC)fst00931326
650	_7	$aPodiatry.$2fast$0(OCoLC)fst01067635
655	_2	$aPeriodical.
655	_7	$aPeriodicals.$2fast$0(OCoLC)fst01411641
776	08	$x0891-8422
780	00	$tClinics in podiatry$w(CKB)954927686727
906		$aJOURNAL

MMS IDs

Document ID:

9911025916302121

Network Electronic IDs:

9911025916302121

Network Physical IDs:

Attachment 3B

MARC record

LC control no.:	sh 85103669
LCCN Permalink:	https://lccn.loc.gov/sh85103669 (link opens in a new tab)
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005	20250804133431.9
003	DLC
008	860211i| anannbabn |b ana
010	$a sh 85103669
035	$a (DLC)sh 85103669
035	$a (DLC)100060
040	$a DLC $c DLC $d DLC
053 0	$a RD563
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450	$w nne $a Chiropody
450	$a Podiatric medicine
550	$w g $a Medicine
550	$a Foot $x Diseases
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Attachment 3C

Podiatry MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Podiatry
Tree Number(s)
H02.696
Unique ID
D011032
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D011032
Annotation
for /educ, coordinate with medical education terms if pertinent
Scope Note
A specialty concerned with the diagnosis and treatment of foot disorders and injuries and anatomic defects of the foot.
Entry Term(s)
Chiropody
NLM Classification #
WE 890
See Also
Foot Diseases
Date Established
1966/01/01
Date of Entry
1999/01/01
Revision Date
2008/07/08

page delivered in 0.17s

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Bethesda, MD 20894

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FOIA
HHS Vulnerability Disclosure

NLM Support Center
Accessibility
Careers

NLM | NIH | HHS | USA.gov

Attachment 3D

Bibliographic Record - OCLC Number: 13324960

LDR	Record Status	'c' - Corrected or revised
	Type of Record	'a' - Language material
	Bibliographic Level	's' - Serial
	Type of Control	' ' - No specified type of control
	Encoding Level	' ' - Full level
	Descriptive Cataloging Form	'a' - AACR2
001	13324960	
005	20251105200604.7	
008	Date Entered on File	'860321'
	Type of Date/Publication Status	'c' - Continuing resource currently published
	Date1/Beginning Date of Publication	'1986'
	Date2/Ending Date of Publication	'9999'
	Place of Publication, Production, or Execution Code	'pau' - Pennsylvania
	Frequency	'q' - Quarterly
	Regularity	'r' - Regular
	Type of Continuing Resource	' ' - None of the following
	Form of Original Item	' ' - None of the following
	Form of Item	' ' - None of the following
	Nature of Entire Work	' ' - No specified nature of entire work
	Nature of Contents	' '
	Government Publication	' ' - Not a government publication
	Conference Publication	'0' - Not a conference publication
	Original Alphabet or Script of Title	'a' - Basic Roman
	Entry Convention	'0' - Successive entry
	Language Code	'eng' - English
	Modified Record	' ' - Record is not modified
	Cataloging Source Code	'c' - Cooperative cataloging program

010 86643213 **$z** 2005201925

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012 3 **$i** 8612 **$k** 1 **$l** p **$m** 1

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023 0 0891-8422 **$2** 1

032 000707 **$b** USPS

037 **$b** W.B. Saunders, West Washington Square, Philadelphia, PA 19105

042 pcc **$a** nsdp

043 n------

050 0 0 RD563 **$b** .C63

060 0 0 W1 **$b** CL831DE
082 0 0 617/.585/005 **$2** 19
210 0 Clin. podiatr. med. surg.
222 0 Clinics in podiatric medicine and surgery
245 0 0 Clinics in podiatric medicine and surgery.
246 1 8 Podiatric medicine and surgery
246 1 **$i** Vols. for 2004- called: **$a** Clinics in podiatric medicine and surgery of North America
260 **$3** 1986- : **$a** Philadelphia : **$b** W.B. Saunders, **$c** ©1986-
260 3 **$3** <2014-> **$a** New York, NY : **$b** Elsevier Inc.
300 18 volumes : **$b** illustrations, portraits ; **$c** 24 cm
310 Quarterly
336 text **$b** txt **$2** rdacontent
337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
362 0 Vol. 3, no. 1 (Jan. 1986)-
500 Each volume has also a distinctive title.
530 Also issued online.
650 0 Podiatry **$v** Periodicals.
650 0 Foot **$x** Surgery **$v** Periodicals.
650 1 2 Podiatry.
650 1 2 Foot **$x** surgery.
651 2 North America.
650 7 Foot **$x** Surgery. **$2** fast **$0** (OCoLC)fst00931326
650 7 Podiatry. **$2** fast **$0** (OCoLC)fst01067635
653 Health and medical sciences
653 Man **$a** Feet **$a** Diseases
655 2 Periodical.
655 7 Periodicals. **$2** fast **$0** (OCoLC)fst01411641
776 1 **$t** Clinics in podiatric medicine and surgery (Online) **$x** 1558-2302 **$w** (DLC) 2005213182 **$w** (OCoLC)61680715
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029 1 AU@ **$b** 000004684678
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Attachment 4A

MARC Bibliographic Record

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336		$atext$btxt$2rdacontent
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362	1_	$aPrint began with no. 1, published in 1953.
362	1_	$aPrint ceased with no. 25.
530		$aAlso issued in print.
538		$aMaster and use copy. Digital master created according to Benchma Library Federation, December 2002.$uhttp://purl.oclc.org/DLF/bench
538		$aMode of access: World Wide Web.
555		$aNo. 1 (spring 1953)-no. 6 (fall 1955). 1 v.; No. 7 (spring 1956)
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650	_0	$aOrthopedic surgery$vPeriodicals.
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650	_7	$aOrthopedics.$2fast$0(OCoLC)fst01048565
655	_2	$aPeriodical.
655	_7	$aPeriodicals.$2fast$0(OCoLC)fst01411641
776	08	$x0095-8654
785	00	$tCLINICAL ORTHOPAEDICS AND RELATED RESEARCH$w(CKB)954925391294$w(
906		$aJOURNAL

MMS IDs

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Network Physical IDs:

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mms_lc_ids:

99992913402125

Attachment 4B

MARC record

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150	$a Orthopedics $v Periodicals
667	$a Record generated for validation purposes.
670	$a Work cat.: Acta orthopaedica Scandinavica,
999 f f	$i 6dd91cee-a6fd-452c-be0f-1ef731200a69 $s cd994a32-f7b6-4854-9409-927ebeed5163

Attachment 4C

MARC record

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LCCN Permalink:	https://lccn.loc.gov/sh85095812 (link opens in a new tab)
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001	sh 85095812
005	20250804133344.9
003	DLC
008	860211i| anannbabn |b ana
010	$a sh 85095812
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035	$a (DLC)92436
040	$a DLC $c DLC $d DLC
053 0	$a RD701 $b RD789
150	$a Orthopedic surgery
450	$a Operative orthopedics
550	$w g $a Orthopedics
550	$w g $a Surgery, Operative
999 f f	$i d2582f55-4a55-40b3-bd9c-1fe66278bd7e $s 2c1bacbe-c768-401b-9154-29cf4c263044

Attachment 4D

Bone and Bones MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Bone and Bones
Tree Number(s)
A02.835.232
A10.165.265
Unique ID
D001842
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D001842
Annotation
/cytol: consider also OSTEOBLASTS; OSTEOCLASTS; OSTEOCYTES; /embryol: consider also OSTEOGENESIS; /surg: consider also OSTEOTOMY or ARTHRODESIS or FRACTURE FIXATION & its specifics; differentiate from SKELETON which is almost never used: restrict SKELETON to bone arrangement as a whole & not for "skeletal" which usually means "bone" (= BONE AND BONES); inflammation = OSTEITIS; necrosis = OSTEONECROSIS;
Scope Note
A specialized CONNECTIVE TISSUE that is the main constituent of the SKELETON. The principal cellular component of bone is comprised of OSTEOBLASTS; OSTEOCYTES; and OSTEOCLASTS, while FIBRILLAR COLLAGENS and hydroxyapatite crystals form the BONE MATRIX.
Entry Version
BONE BONES
Entry Term(s)
Bone
Bone Tissue
Bone and Bone
Bones
Bones and Bone
Bones and Bone Tissue
Bony Apophyses
Bony Apophysis
Condyle
See Also
Arthrodesis
Calcification, Physiologic
Osteogenesis
Osteotomy
Consider Also
consider also terms at OSSI- and OSTE-
Public MeSH Note
/transplantation was BONE TRANSPLANTATION 1963-65; was BONE AND BONES/transplantation 1966-89
Online Note
use BONE TRANSPLANTATION to search BONE AND BONES/transplantation 1966-89

History Note
/transplantation was BONE TRANSPLANTATION 1963-65; was BONE AND BONES/transplantation 1966-89
Entry Combination
growth & development:Bone Development
transplantation:Bone Transplantation
Date Established
1960/01/01
Date of Entry
1999/01/01
Revision Date
2021/06/30

page delivered in 0.134s

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Attachment 4E

Orthopedics MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Orthopedics
Tree Number(s)
H02.403.810.494
Unique ID
D009985
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D009985
Annotation
specialty; ORTHOPEDIC PROCEURES is available for orthopedic therapeutic techniques
Scope Note
A specialty which utilizes medical, surgical, and physical methods to treat and correct deformities, diseases, and injuries to the skeletal system, its articulations, and associated structures.
NLM Classification #
WE 21
See Also
Orthopedic Procedures
Osteology
Entry Combination
instrumentation:Orthopedic Equipment
nursing:Orthopedic Nursing
Date Established
1966/01/01
Date of Entry
1999/01/01
Revision Date
2019/07/05

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Attachment 4F

Bibliographic Record - OCLC Number: 1778089

LDR	Record Status	'c' - Corrected or revised
	Type of Record	'a' - Language material
	Bibliographic Level	's' - Serial
	Type of Control	' ' - No specified type of control
	Encoding Level	' ' - Full level
	Descriptive Cataloging Form	'a' - AACR2
001	1778089	
005	20251105200621.8	
008	Date Entered on File	'751101'
	Type of Date/Publication Status	'd' - Continuing resource ceased publication
	Date1/Beginning Date of Publication	'1953'
	Date2/Ending Date of Publication	'1962'
	Place of Publication, Production, or Execution Code	'pau' - Pennsylvania
	Frequency	'u' - Unknown
	Regularity	'u' - Unknown
	Type of Continuing Resource	' ' - None of the following
	Form of Original Item	' ' - None of the following
	Form of Item	' ' - None of the following
	Nature of Entire Work	' ' - No specified nature of entire work
	Nature of Contents	' '
	Government Publication	' ' - Not a government publication
	Conference Publication	'0' - Not a conference publication
	Original Alphabet or Script of Title	'a' - Basic Roman
	Entry Convention	'0' - Successive entry
	Language Code	'eng' - English
	Modified Record	' ' - Record is not modified
	Cataloging Source Code	' ' - National bibliographic agency

010 sf 85003079 **$z** 53007647

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012 3 **$b** 3 **$e** n **$i** 8505

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022 0095-8654 **$2** 1

023 0 0095-8654 **$2** 1
042 nsdp **$a** pcc
050 0 0 RD701 **$b** .C55
060 0 0 W1 **$b** CL761
210 1 0 Clin Orthop
222 0 Clinical orthopaedics
245 0 0 Clinical orthopaedics.
260 [Philadelphia] : **$b** [Lippincott], **$c** [-1962]
300 25 volumes : **$b** illustrations ; **$c** 26 cm
336 text **$b** txt **$2** rdacontent
337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
362 1 Began with: No. 1, published in 1953.
362 0 -no. 25.
555 No. 1 (spring 1953)-no. 6 (fall 1955). 1 v.; No. 7 (spring 1956)-no. 12 (fall 1958) in no. 13; No. 13-no. 18, in no. 19; No. 19-no. 24, in no. 25.
588 Description based on: No. 25, published in 1962.
650 0 Orthopedics **$v** Periodicals.
650 2 Bone and Bones.
650 2 Orthopedics.
650 6 Orthopédie **$v** Périodiques.
650 7 Orthopedics. **$2** fast **$0** (OCoLC)fst01048565
655 2 Periodical.
655 7 Periodicals. **$2** fast **$0** (OCoLC)fst01411641
655 7 Periodicals. **$2** lcgft
655 7 Periodicals. **$2** rbgenr
776 0 8 **$i** Online version: **$t** Clinical orthopaedics (Online) **$x** 2332-3906 **$w** (DLC) 2013236800 **$w** (OCoLC)60624421
785 0 0 **$t** Clinical orthopaedics and related research **$x** 0009-921X **$w** (DLC) 53007647 **$w** (OCoLC)1554937
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029 1 UKMGB **$b** 012396419

Attachment 5A

MARC Bibliographic Record

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082		$a617/.005
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222	_0	$aSurgery, gynecology & obstetrics
245	00	$aSurgery, gynecology & obstetrics.
246	0_	$aSurgery, gynecology and obstetrics
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260		$a[Chicago] :$b[Franklin H. Martin Memorial Foundation, etc.]
300		$a177 volumes :$billustrations, color plates ;$c24-28 cm
336		$atext$btxt$2rdacontent
337		$aunmediated$bn$2rdamedia
338		$avolume$bnc$2rdacarrier
362	0_	$aVol. 1, no. 1 (July 1905)-v. 177, no. 6 (Dec. 1993).
500		$aOfficial scientific journal of the American College of Surgeons.
510	1_	$aExcerpta medica
510	2_	$aBiological abstracts$x0006-3169
510	2_	$aChemical abstracts$x0009-2258
510	2_	$aEnergy research abstracts$x0160-3604
510	2_	$aIndex medicus$x0019-3879
510	2_	$aLife sciences collection
510	0_	$aNuclear science abstracts$x0029-5612
555		$aVols. 1-40, 1905-25. 1 v.; Vols. 41-80, 1925-45. 1 v.; Vols. 8 1945-55. 1 v.; Vols. 101-110, 1955-60. 1 v.; Vols. 111-120, 1960

		v.; Vols. 121-130, 1965-70. 1 v.; Vols. 131-140, 1970-75. 1 v.
500		$aEditor: 1905-<19> F. H. Martin.
650	_0	$aSurgery$vPeriodicals.
650	_0	$aGynecology$vPeriodicals.
650	_0	$aObstetrics$vPeriodicals.
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Network Electronic IDs:

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Attachment 5B

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670	$a Work cat.: Mémoires de l'Académie royale de chirurgie, 1781-
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Attachment 5C

MARC record

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Attachment 5D

MARC record

LC control no.:	sh2008108563
LCCN Permalink:	https://lccn.loc.gov/sh2008108563 (link opens in a new tab)
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670	$a Work cat.: Current women's health reports, c2001-
999 f f	$i 72a57dab-01a6-4eb9-96fa-f65add379024 $s 830a470b-336f-456f-b832-0bb73ab80dcd

Attachment 5E

Gynecology MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Gynecology
Tree Number(s)
H02.403.763.750
H02.403.810.310
Unique ID
D006176
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D006176
Annotation
specialty; corresponding organ term is GENITALIA, FEMALE
Scope Note
A medical-surgical specialty concerned with the physiology and disorders primarily of the female genital tract, as well as female endocrinology and reproductive physiology.
Entry Version
GYNECOL
See Also
Genital Diseases, Female
Gynecologic Surgical Procedures
Reproductive Medicine
Date Established
1966/01/01
Date of Entry
1999/01/01
Revision Date
2021/03/12

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8600 Rockville Pike
Bethesda, MD 20894

Web Policies
FOIA
HHS Vulnerability Disclosure

NLM Support Center
Accessibility
Careers

NLM | NIH | HHS | USA.gov

Attachment 5F

Obstetrics MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Obstetrics
Tree Number(s)
H02.403.810.450
Unique ID
D009774
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D009774
Annotation
specialty; do not use for "obstetric diseases" (= probably PREGNANCY COMPLICATIONS, etc.)
Scope Note
A medical-surgical specialty concerned with management and care of women during pregnancy, parturition, and the puerperium.
See Also
Obstetric Surgical Procedures
Pregnancy Complications
Date Established
1966/01/01
Date of Entry
1999/01/01
Revision Date
2008/07/08

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Web Policies
FOIA
HHS Vulnerability Disclosure

NLM Support Center
Accessibility
Careers

NLM | NIH | HHS | USA.gov

Attachment 5G

General Surgery MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
General Surgery
Tree Number(s)
H02.403.810.300
Unique ID
D013502
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D013502
Annotation
use for the specialty only; prefer /surg with organs and diseases; use SURGICAL PROCEDURES, OPERATIVE or specifics for the surgery patient or surgical procedures
Scope Note
A specialty in which manual or operative procedures are used in the treatment of disease, injuries, or deformities.
Entry Term(s)
Surgery
See Also
Barber Surgeons
Surgical Procedures, Operative
Public MeSH Note
2009; see SURGERY 1974-2008
History Note
2009 (1974)
Date Established
1966/01/01
Date of Entry
1999/01/01
Revision Date
2015/06/23

page delivered in 0.133s

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Careers

NLM | NIH | HHS | USA.gov

Attachment 5H

Bibliographic Record - OCLC Number: 1766861

LDR	Record Status	'c' - Corrected or revised
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	Bibliographic Level	's' - Serial
	Type of Control	' ' - No specified type of control
	Encoding Level	' ' - Full level
	Descriptive Cataloging Form	' ' - Non-ISBD
001	1766861	
005	20251105200632.8	
008	Date Entered on File	'751101'
	Type of Date/Publication Status	'd' - Continuing resource ceased publication
	Date1/Beginning Date of Publication	'1905'
	Date2/Ending Date of Publication	'1993'
	Place of Publication, Production, or Execution Code	'ilu' - Illinois
	Frequency	'm' - Monthly
	Regularity	'r' - Regular
	Type of Continuing Resource	'p' - Periodical
	Form of Original Item	' ' - None of the following
	Form of Item	' ' - None of the following
	Nature of Entire Work	' ' - No specified nature of entire work
	Nature of Contents	' '
	Government Publication	' ' - Not a government publication
	Conference Publication	'0' - Not a conference publication
	Original Alphabet or Script of Title	'a' - Basic Roman
	Entry Convention	'0' - Successive entry
	Language Code	'eng' - English
	Modified Record	' ' - Record is not modified
	Cataloging Source Code	' ' - National bibliographic agency

010 07005593

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210 0 Surg. gynecol. obstet.
222 0 Surgery, gynecology & obstetrics
245 0 0 Surgery, gynecology & obstetrics.
246 3 Surgery, gynecology and obstetrics
246 1 3 SGO **$f** <, Feb. 1976>
260 [Chicago], **$b** [Franklin H. Martin Memorial Foundation, etc.]
300 177 volumes **$b** illustrations, color plates **$c** 24-28 cm
310 Monthly
336 text **$b** txt **$2** rdacontent
337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
362 0 v. 1-177, no. 6; July 1905-Dec. 1993.
500 Editor: 1905-<19> F.H. Martin.
510 2 Chemical abstracts **$x** 0009-2258
515 Issued in 2 vols. per year; six issues constitute a vol.
550 Official scientific journal of the American College of Surgeons.
555 Vols. 1-40, 1905-25. 1 v.; Vols. 41-80, 1925-45. 1 v.; Vols. 81-100, 1945-55. 1 v.; Vols. 101-110, 1955-60. 1 v.; Vols. 111-120, 1960-65. 1 v.; Vols. 121-130, 1965-70. 1 v.; Vols. 131-140, 1970-75. 1 v.
650 0 Surgery **$v** Periodicals.
650 0 Gynecology **$v** Periodicals.
650 0 Obstetrics **$v** Periodicals.
650 2 General Surgery
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650 2 Obstetrics
650 6 Chirurgie **$v** Périodiques.
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650 6 Obstétrique **$v** Périodiques.
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655 7 Abstracts. **$2** lcgft **$0** http://id.loc.gov/authorities/genreForms/gf2014026038
655 7 Periodicals. **$2** rbgenr
700 1 Martin, Franklin H. **$q** (Franklin Henry), **$d** 1857-1935. **$1** https://id.oclc.org/worldcat/entity/E39PBJxt4rDvb3GXjBw4HbyTpP

710 2 Franklin H. Martin Memorial Foundation. **$1** https://id.oclc.org/worldcat/entity/E39QH7Jmrdhpj7kdvjfDKqgjRg

710 2 American College of Surgeons. **$1** https://id.oclc.org/worldcat/entity/E39QH7JmpM7CdcGCBKmwk9mCp6

770 0 **$t** International abstracts of surgery **$w** (OCoLC)1587817

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785 0 0 **$t** Journal of the American College of Surgeons **$x** 1072-7515 **$w** (DLC)sn 93004645 **$w** (OCoLC)29192491

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Attachment 6A

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246 1 $i Vols. for 2004- called: $a Clinics in podiatric medicine and surgery of North America
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260 3	$3 <2014-> $a New York, NY : $b Elsevier Inc.
300	$a 18 volumes : $b illustrations, portraits ; $c 24 cm
310	$a Quarterly
336	$a text $b txt $2 rdacontent
337	$a unmediated $b n $2 rdamedia
338	$a volume $b nc $2 rdacarrier
362 0	$a Vol. 3, no. 1 (Jan. 1986)-
500	$a Each volume has also a distinctive title.
530	$a Also issued online.
650 0	$a Podiatry $v Periodicals.
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906	$a 7 $b cbc $c serials $d 3 $e ncip $f 19 $g n-oclcserc
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Attachment 6B

Bibliographic Record - OCLC Number: 13324960

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	Date1/Beginning Date of Publication	'1986'
	Date2/Ending Date of Publication	'9999'
	Place of Publication, Production, or Execution Code	'pau' - Pennsylvania
	Frequency	'q' - Quarterly
	Regularity	'r' - Regular
	Type of Continuing Resource	' ' - None of the following
	Form of Original Item	' ' - None of the following
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	Nature of Entire Work	' ' - No specified nature of entire work
	Nature of Contents	' '
	Government Publication	' ' - Not a government publication
	Conference Publication	'0' - Not a conference publication
	Original Alphabet or Script of Title	'a' - Basic Roman
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222 0 Clinics in podiatric medicine and surgery
245 0 0 Clinics in podiatric medicine and surgery.
246 1 8 Podiatric medicine and surgery
246 1 **$i** Vols. for 2004- called: **$a** Clinics in podiatric medicine and surgery of North America
260 **$3** 1986- : **$a** Philadelphia : **$b** W.B. Saunders, **$c** ©1986-
260 3 **$3** <2014-> **$a** New York, NY : **$b** Elsevier Inc.
300 18 volumes : **$b** illustrations, portraits ; **$c** 24 cm
310 Quarterly
336 text **$b** txt **$2** rdacontent
337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
362 0 Vol. 3, no. 1 (Jan. 1986)-
500 Each volume has also a distinctive title.
530 Also issued online.
650 0 Podiatry **$v** Periodicals.
650 0 Foot **$x** Surgery **$v** Periodicals.
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650 7 Foot **$x** Surgery. **$2** fast **$0** (OCoLC)fst00931326
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Attachment 7A

MARC Bibliographic Record

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337		$aunmediated$bn$2rdamedia
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260	3_	$3<2013-> :$aThousand Oaks, CA :$bSage Publications
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500		$aRefereed/Peer-reviewed
538		$aMode of access: World Wide Web.
588	0_	$aVol. 20, #1 (Jan. 1999); title from title screen (publisher's We
588	1_	$aVol. 34, no. 2 (Feb. 2013) (Sage journals, viewed March 15, 2013
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650	_2	$aFoot
650	_2	$aFoot Injuries
650	_7	$aAnkle$xAbnormalities.$2fast$0(OCoLC)fst00809673
650	_7	$aFoot$xAbnormalities.$2fast$0(OCoLC)fst00931269
650	_7	$aOrthopedics.$2fast$0(OCoLC)fst01048565
650	_7	$aTurmell$2thub
650	_7	$aPeu$2thub
650	_7	$aFerides i lesions$2thub
655	_2	$aPeriodical
655	_7	$aPeriodicals.$2fast$0(OCoLC)fst01411641
655	_7	$aPeriodicals.$2lcgft
655	_7	$aRevistes electròniques$2thub
710	2_	$aAmerican Orthopaedic Foot and Ankle Society.$1https://id.oclc.or
710	2_	$aSwiss Foot and Ankle Society.$1https://id.oclc.org/worldcat/enti
776	08	$x1071-1007
780	00	$tFoot and Ankle$w(CKB)954927627227
906		$aJOURNAL

MMS IDs

Document ID:

999728431802121

Network Electronic IDs:

9911025754602121

Network Physical IDs:

999728431802121

mms_mad_ids:

9929267793602122, 991021971720502122

mms_ec_ids:

99925246954802134

mms_gb_ids:

991007120727102123

mms_lc_ids:

991016480375402125

mms_osh_ids:

991005125295302126

mms_rf_ids:

991013805796802129

mms_sf_ids:

991014914643102130

mms_st_ids:

991013573429702131

mms_sup_ids:

99916461324402132

mms_ww_ids:

991015510484702133

Attachment 7B

Ankle Joint MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Ankle Joint
Tree Number(s)
A02.835.583.378.062
Unique ID
D000843
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D000843
Annotation
primates only; differentiation from ANKLE
Scope Note
The joint that is formed by the inferior articular and malleolar articular surfaces of the TIBIA; the malleolar articular surface of the FIBULA; and the medial malleolar, lateral malleolar, and superior surfaces of the TALUS.
Entry Term(s)
Ankle Syndesmosis
Articulatio talocruralis
Distal Tibiofibular Joint
Inferior Tibiofibular Joint
Talocrural Joint
Tibiofibular Ankle Syndesmosis
Tibiofibular Syndesmosis
See Also
Ankle
Public MeSH Note
65; /injuries was ANKLE JOINT/injuries 1965-91
Online Note
use ANKLE INJURIES to search ANKLE JOINT/injuries 1966-91
History Note
65; /injuries was ANKLE JOINT/injuries 1965-91
Entry Combination
injuries:Ankle Injuries
Date Established
1965/01/01
Date of Entry
1999/01/01
Revision Date
2017/02/24

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Attachment 7D

Bibliographic Record - OCLC Number: 28552032

LDR	Record Status	'c' - Corrected or revised	
	Type of Record	'a' - Language material	
	Bibliographic Level	's' - Serial	
	Type of Control	' ' - No specified type of control	
	Encoding Level	' ' - Full level	
	Descriptive Cataloging Form	'a' - AACR2	
001	28552032		
005	20251105200603.3		
008	Date Entered on File	'930802'	
	Type of Date/Publication Status	'c' - Continuing resource currently published	
	Date1/Beginning Date of Publication	'1994'	
	Date2/Ending Date of Publication	'9999'	
	Place of Publication, Production, or Execution Code	'mdu' - Maryland	
	Frequency	'm' - Monthly	
	Regularity	'r' - Regular	
	Type of Continuing Resource	'p' - Periodical	
	Form of Original Item	' ' - None of the following	
	Form of Item	' ' - None of the following	
	Nature of Entire Work	' ' - No specified nature of entire work	
	Nature of Contents	' '	
	Government Publication	' ' - Not a government publication	
	Conference Publication	'0' - Not a conference publication	
	Original Alphabet or Script of Title	'a' - Basic Roman	
	Entry Convention	'0' - Successive entry	
	Language Code	'eng' - English	
	Modified Record	' ' - Record is not modified	
	Cataloging Source Code	'c' - Cooperative cataloging program	

010 sn 93002850

040 NSD **$b** eng **$c** NSD **$d** CAS **$d** NSD **$d** HUL **$d** WAU **$d** DLC **$d** NLM **$d** EYM **$d** SYS **$d** OCLCQ **$d** NLGGC **$d** NSD **$d** AU@ **$d** OCLCQ **$d** UKMGB **$d** NLM **$d** CUS **$d** OCLC F **$d** CUS **$d** OCLCO **$d** OCLCQ **$d** OCLCO **$d** PRB **$d** OCLCQ **$d** IOC **$d** OCLCO **$d** OC LCQ **$d** OCLCA **$d** GILDS **$d** OCLCA **$d** OCLCL **$d** CGU **$d** OCLCL **$d** OCLCQ

012 **$i** 9403 **$k** 1 **$l** 1 **$m** 1

016 7 9433869 **$2** DNLM

016 7 SR0079016 **$2** DNLM

016 7 012115812 **$2** Uk

016 7 000025085905 **$2** AU

019 316296761 **$a** 1057983814 **$a** 1064397865 **$a** 1202856819 **$a** 1242780568 **$a** 1246536086

022 0 1071-1007 **$2** 2

023 0 1071-1007 **$2** 2

030 FAINE4

032 552390 **$b** USPS

037 **$b** Williams & Wilkins, 428 E. Preston St., Baltimore, MA 21202

042 nsdp **$a** pcc
050 1 4 RD781
060 0 0 W1 **$b** FO511RM
082 1 0 617 **$2** 12 **$1** https://id.oclc.org/worldcat/ddc/E3YM8MMTVgYPgDmxF4cHh8XGcP
210 0 Foot ankle int.
222 0 Foot & ankle international
245 0 0 Foot & ankle international / **$c** American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society.
246 3 0 Foot and ankle international
246 3 0 Foot and ankle
246 1 7 Foot & ankle
260 Baltimore, MD : **$b** Williams & Wilkins, **$c** ©1994-
260 3 2013- ; **$a** Thousand Oaks, CA : **$b** Sage Publications
300 volumes : **$b** illustrations, portraits ; **$c** 28 cm
310 Monthly
336 text **$b** txt **$2** rdacontent
337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
362 0 Vol. 15, no. 1 (Jan. 1994)-
500 Title from cover.
530 Also issued online.
650 0 Foot **$x** Abnormalities **$v** Periodicals.
650 0 Ankle **$x** Abnormalities **$v** Periodicals.
650 0 Orthopedics **$v** Periodicals.
650 2 Ankle.
650 2 Ankle Injuries.
650 2 Foot.
650 2 Foot Injuries.
650 6 Pied **$x** Malformations **$v** Périodiques.
650 6 Cheville **$x** Malformations **$v** Périodiques.
650 6 Orthopédie **$v** Périodiques.
650 6 Pied **$x** Maladies.
650 7 Ankle **$x** Abnormalities. **$2** fast **$0** (OCoLC)fst00809673
650 7 Foot **$x** Abnormalities. **$2** fast **$0** (OCoLC)fst00931269
650 7 Orthopedics. **$2** fast **$0** (OCoLC)fst01048565
650 1 7 Voeten. **$2** gtt
650 1 7 Enkels. **$2** gtt
655 2 Periodical.
655 7 Periodicals. **$2** fast **$0** (OCoLC)fst01411641
655 7 Periodicals. **$2** lcgft
710 2 American Orthopaedic Foot and Ankle Society. **$1** https://id.oclc.org/worldcat/entity/E39QH7JmqKTCkXpQXY9BhmCgWt
710 2 Swiss Foot and Ankle Society. **$1** https://id.oclc.org/worldcat/entity/E39QH7Jmq6p4TK9C6WdyrtQfkt

776 1 **$t** Foot & ankle international (Online) **$x** 1944-7876 **$w** (DLC) 2008215765 **$w** (OCoLC)606267644

776 0 8 **$i** Online version: **$t** Foot & ankle international **$w** (OCoLC)752907905

780 0 0 **$t** Foot & ankle **$x** 0198-0211 **$w** (DLC) 81642437 **$w** (OCoLC)6182855

850 DNLM **$a** MBCo **$a** MiU **$a** MoSW-M **$a** WaU

856 4 1 **$u** http://journals.sagepub.com/home/fai/

856 4 1 **$u** http://www.datatrace.com/e-chemtracts/emailurl.html?http://www.newslettersonline.com/user/user.fas/s=563/fp=20/tp=37?T=open_non_issue,5167,3&P=non_issue

891 1 2 **$9** 853 **$8** 1 **$a** v. **$b** no. **$u** 12 **$v** r **$i** (year) **$j** (month) **$w** m **$x** 01

891 4 0 **$9** 863 **$8** 1 **$a** <15>- **$i** <1994>- **$x** provisional

029 1 AU@ **$b** 000010453590

029 1 AU@ **$b** 000023041294

029 1 AU@ **$b** 000025085905

029 1 NLGGC **$b** 11136986X

029 1 NLM **$b** 9433869

029 1 NZ1 **$b** 12454468

029 1 NZ1 **$b** 5082344

029 1 UKMGB **$b** 012115812

Attachment 7E

MARC record

LC control no.:	sh2007006032
LCCN Permalink:	https://lccn.loc.gov/sh2007006032 (link opens in a new tab)
000	00549cz a2200181n 4500
001	sh2007006032
005	20250804135917.0
003	DLC
008	070801 | anannbabn |n ana
010	$a sh2007006032
035	$a (DLC)7252303
035	$a (DLC)sh2007006032
035	$a (DLC)362756
040	$a DLC $b eng $c DLC
150	$a Foot $x Abnormalities $v Periodicals
667	$a Record generated for validation purposes.
670	$a Work cat.: Foot & ankle, c1980-1993
999 f f	$i a02e1f6a-64cc-4eec-b582-ef3465f60e48 $s 9921bf1d-ed38-4b4f-a3f7-890bf7076696

Attachment 7F

MARC record

LC control no.:	sh2007005372
LCCN Permalink:	https://lccn.loc.gov/sh2007005372 (link opens in a new tab)
000	00550cz a2200181n 4500
001	sh2007005372
005	20250804135916.5
003	DLC
008	070716 | anannbabn |n ana
010	$a sh2007005372
035	$a (DLC)7235666
035	$a (DLC)sh2007005372
035	$a (DLC)362066
040	$a DLC $b eng $c DLC
150	$a Ankle $x Abnormalities $v Periodicals
667	$a Record generated for validation purposes.
670	$a Work cat.: Foot & ankle, c1980-1993
999 f f	$i fdbb5be8-cd27-47dd-989c-9eae7fbf2424 $s fcca5209-4ef4-4b6d-af15-b84c20c138f4

Attachment 7G

Ankle Injuries MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Ankle Injuries
Tree Number(s)
C26.558.100
Unique ID
D016512
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D016512
Annotation
consider also TARSAL BONES /inj
Scope Note
Harm or hurt to the ankle or ankle joint usually inflicted by an external source.
Entry Version
ANKLE INJ
Entry Term(s)
Ankle Sprains
Injuries, Ankle
Syndesmotic Injuries
NLM Classification #
WE 882
Previous Indexing
Ankle/injuries (1966-1991)
Public MeSH Note
92; was ANKLE/injuries 1966-91
Online Note
use ANKLE INJURIES to search ANKLE/injuries 1966-91
History Note
92; was ANKLE/injuries 1966-91
Date Established
1992/01/01
Date of Entry
1991/05/31
Revision Date
2013/07/08

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Attachment 7H

Foot Injuries MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Foot Injuries
Tree Number(s)
C26.558.300
Unique ID
D018409
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D018409
Annotation
general or unspecified; prefer specifics; consider also /inj with specific sites of foot
Scope Note
General or unspecified injuries involving the foot.
Entry Version
FOOT INJ
Entry Term(s)
Injuries, Foot
Turf Toe
Previous Indexing
Foot/injuries (1966-1994)
Public MeSH Note
95; was FOOT/injuries 1966-94
Online Note
use FOOT INJURIES to search FOOT/injuries 1966-94
History Note
95; was FOOT/injuries 1966-94
Date Established
1995/01/01
Date of Entry
1994/06/28
Revision Date
2016/02/26

page delivered in 0.167s

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Attachment 8A

LDR	01579cas a2200517 a 4500
001	998174893406676
005	20250227142239.0
007	cr|cn#||||||||
008	961219c19969999pauqr p 0||| 0eng
010	__ | **a**sn 95005854
022	__ | **a**1083-7515**l**1083-7515**9**PY**7**(Print)
022	__ | **a**1558-1934**9**EN**7**(Electronic)
035	__ | **9**9615073
040	__ | **a**DNLM**c**DNLM
041	0_ | **a**eng
044	__ | **9**United States
060	00 | **a**W1**b**FO511RR
210	10 | **a**Foot Ankle Clin**2**DNLM
222	_0 | **a**Foot and ankle clinics
245	00 | **a**Foot and ankle clinics.
260	__ | **a**Philadelphia :**b**W.B. Saunders,**c**c1996-
300	__ | **a**v. :**b**ill.
310	__ | **a**Quarterly
336	__ | **a**text**b**txt**2**rdacontent
337	__ | **a**unmediated**b**n**2**rdamedia
338	__ | **a**volume**b**nc**2**rdacarrier
362	0_ | **a**Vol. 1, no. 1 (Sept. 1996)-
500	__ | **a**Each issue has also a distinctive title.
510	1_ | **9**1**a**MEDLINE**b**v5n1, Mar. 2000-
510	1_ | **9**1**a**PubMed**b**v5n1, Mar. 2000-
510	1_ | **a**Index medicus
530	__ | **a**Also issued online.
650	_2 | **a**Ankle Injuries
650	_2 | **a**Foot Diseases
650	_2 | **a**Foot Injuries
655	_2 | **a**Periodical
856	4_ | **u**https://www.sciencedirect.com/journal/foot-and-ankle-clinics
911	__ | **a**Electronic and print, print canceled 2018
914	__ | **a**Portico**b**Current to 2025 as of 20250227**c**ISSN_10837515
935	__ | **a**(DNLM)817489-nlmdb
995	__ | **a**AUTH**b**19961219**c**REV**d**20250227
996	__ | **a**NOTCNSR**b**20000101
998	__ | **a**ERMSLC 108649**b**20081003
999	__ | **a**AUTH
035	__ | **a**(DNLM)SR0085591(s)

035	__ | **a**(OCoLC)32877539

Attachment 8B

Bibliographic Record - OCLC Number: 32877539

LDR	Record Status	'c' - Corrected or revised
	Type of Record	'a' - Language material
	Bibliographic Level	's' - Serial
	Type of Control	' ' - No specified type of control
	Encoding Level	' ' - Full level
	Descriptive Cataloging Form	'a' - AACR2
001	32877539	
005	20251105200603.7	
008	Date Entered on File	'950726'
	Type of Date/Publication Status	'c' - Continuing resource currently published
	Date1/Beginning Date of Publication	'1996'
	Date2/Ending Date of Publication	'9999'
	Place of Publication, Production, or Execution Code	'pau' - Pennsylvania
	Frequency	'q' - Quarterly
	Regularity	'r' - Regular
	Type of Continuing Resource	'p' - Periodical
	Form of Original Item	' ' - None of the following
	Form of Item	' ' - None of the following
	Nature of Entire Work	' ' - No specified nature of entire work
	Nature of Contents	' '
	Government Publication	' ' - Not a government publication
	Conference Publication	'0' - Not a conference publication
	Original Alphabet or Script of Title	'a' - Basic Roman
	Entry Convention	'0' - Successive entry
	Language Code	'eng' - English
	Modified Record	' ' - Record is not modified
	Cataloging Source Code	'c' - Cooperative cataloging program

010 sn 95005854

040 NSD **$b** eng **$c** NSD **$d** NLM **$d** NSD **$d** NLM **$d** OCLCQ **$d** NSD **$d** AU@ **$d** OCLCQ **$d** UKMGB **$d** OCLCF **$d** OCLCO **$d** OCLCQ **$d** OCLCO **$d** OCLCL **$d** OCLCQ

012 **$i** 9612 **$k** 1 **$l** 1 **$m** 1

016 7 9615073 **$2** DNLM

016 7 SR0085591 **$2** DNLM

016 7 008533515 **$2** Uk

019 1063258787

022 0 1083-7515 **$2** 1

023 0 1083-7515 **$2** 1

032 016368 **$b** USPS

037 **$b** W.B. Saunders Company, Periodicals Fulfillment, Orlando, FL 32887-4800 **$c** $99.00

042 nsdp **$a** pcc

060 0 0 W1 **$b** FO511RR

082 1 0 616 **$2** 12 **$1** https://id.oclc.org/worldcat/ddc/E3JgrcHwDwT3D4ty3F7FPPcp7d

210 0 Foot ankle clin.
222 0 Foot and ankle clinics
245 0 0 Foot and ankle clinics.
260 Philadelphia : **$b** W.B. Saunders, **$c** ©1996-
300 volumes : **$b** illustrations
310 Quarterly
336 text **$b** txt **$2** rdacontent
337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
362 0 Vol. 1, no. 1 (Sept. 1996)-
500 Each issue has also a distinctive title.
530 Also issued online.
650 0 Ankle **$x** Wounds and injuries **$v** Periodicals.
650 0 Foot **$x** Diseases **$v** Periodicals.
650 0 Foot **$x** Wounds and injuries **$v** Periodicals.
650 2 Ankle Injuries.
650 2 Foot Diseases.
650 2 Foot Injuries.
650 6 Pied **$x** Lésions et blessures **$v** Périodiques.
650 6 Cheville **$x** Lésions et blessures **$v** Périodiques.
650 6 Pied **$x** Maladies **$v** Périodiques.
650 7 Ankle **$x** Wounds and injuries. **$2** fast **$0** (OCoLC)fst00809687
650 7 Foot **$x** Diseases. **$2** fast **$0** (OCoLC)fst00931290
650 7 Foot **$x** Wounds and injuries. **$2** fast **$0** (OCoLC)fst00931336
655 2 Periodicals.
655 7 Periodicals. **$2** fast **$0** (OCoLC)fst01411641
776 1 **$t** Foot and ankle clinics (Online) **$x** 1558-1934 **$w** (DLC) 2005213173
850 DNLM
856 4 1 **$u** http://www.foot.theclinics.com/
029 1 AU@ **$b** 000011867824
029 1 AU@ **$b** 000053310029
029 1 GEBAY **$b** 6488074
029 1 NLM **$b** 9615073
029 1 ZWZ **$b** 040343863
029 1 UKMGB **$b** 008533515

Attachment 8C

MARC record

LC control no.:	sh 85050368
LCCN Permalink:	https://lccn.loc.gov/sh85050368 (link opens in a new tab)
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001	sh 85050368
005	20250804133017.2
003	DLC
008	860211i| anannbabn |a ana
010	$a sh 85050368
035	$a (DLC)sh 85050368
035	$a (DLC)48716
040	$a DLC $c DLC $d DLC
053 0	$a RC951
150	$a Foot $x Diseases
450	$a Foot diseases
550	$a Podiatry
670	$a MESH $b (Foot diseases)
681	$i Example under $a Pathology; $i and under reference from $a Diseases of the heart, [foot, etc.]
999 f f	$i b71949d9-1f49-445e-8d48-16b6a937c4f6 $s 95a88f92-1815-4402-9af9-59dff3a2ec37

Attachment 8D

MARC record

LC control no.:	sh 85050397
LCCN Permalink:	https://lccn.loc.gov/sh85050397 (link opens in a new tab)
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001	sh 85050397
005	20250804133017.6
003	DLC
008	860211i| anannbabn |n ana
010	$a sh 85050397
035	$a (DLC)sh 85050397
035	$a (DLC)48745
040	$a DLC $c DLC $d DLC
053 0	$a RD563
150	$a Foot $x Wounds and injuries
681	$i Example under $a Wounds and injuries
999 f f	$i 5f5f9368-84b3-40dc-9f8c-8b144ff7483b $s 3229dade-bbc2-4261-8f92-52ba570c0fa7

Attachment 7C

Foot Diseases MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Foot Diseases
Tree Number(s)
C05.360
C17.800.321
Unique ID
D005534
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D005534
Annotation
skin disease on foot = FOOT DERMATOSES; neoplasms of foot: coordinate FOOT DISEASES with appropriate neoplasm terms
Scope Note
Anatomical and functional disorders affecting the foot.
Entry Version
FOOT DIS
Date Established
1966/01/01
Date of Entry
1999/01/01
Revision Date
2016/04/26

page delivered in 0.19s

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Attachment 7G

Ankle Injuries MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Ankle Injuries
Tree Number(s)
C26.558.100
Unique ID
D016512
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D016512
Annotation
consider also TARSAL BONES /inj
Scope Note
Harm or hurt to the ankle or ankle joint usually inflicted by an external source.
Entry Version
ANKLE INJ
Entry Term(s)
Ankle Sprains
Injuries, Ankle
Syndesmotic Injuries
NLM Classification #
WE 882
Previous Indexing
Ankle/injuries (1966-1991)
Public MeSH Note
92; was ANKLE/injuries 1966-91
Online Note
use ANKLE INJURIES to search ANKLE/injuries 1966-91
History Note
92; was ANKLE/injuries 1966-91
Date Established
1992/01/01
Date of Entry
1991/05/31
Revision Date
2013/07/08

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Attachment 7H

Foot Injuries MeSH Descriptor Data 2025

Details | Qualifiers | MeSH Tree Structures | Concepts

MeSH Heading
Foot Injuries
Tree Number(s)
C26.558.300
Unique ID
D018409
RDF Unique Identifier
http://id.nlm.nih.gov/mesh/D018409
Annotation
general or unspecified; prefer specifics; consider also /inj with specific sites of foot
Scope Note
General or unspecified injuries involving the foot.
Entry Version
FOOT INJ
Entry Term(s)
Injuries, Foot
Turf Toe
Previous Indexing
Foot/injuries (1966-1994)
Public MeSH Note
95; was FOOT/injuries 1966-94
Online Note
use FOOT INJURIES to search FOOT/injuries 1966-94
History Note
95; was FOOT/injuries 1966-94
Date Established
1995/01/01
Date of Entry
1994/06/28
Revision Date
2016/02/26

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Attachment 10A

LEADER 03222cas a2200853 a 4500
001 11313651
005 20251107151440.4
008 860321c19869999pauqr 0 a0eng c
010 $a 86643213 $z 2005201925
015 $a GB8817364 $2 bnb
016 7 $a 8604974 $2 DNLM
016 7 $a SR0056206 $2 DNLM
019 $a 56890144 $a 1051561645 $a 1056938285 $a 1226063254
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246 1 $i Vols. for 2004- called: $a Clinics in podiatric medicine and surgery of North America
260 $3 1986- : $a Philadelphia : $b W.B. Saunders, $c ©1986-

260 3	$3 <2014-> $a New York, NY : $b Elsevier Inc.
300	$a 18 volumes : $b illustrations, portraits ; $c 24 cm
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338	$a volume $b nc $2 rdacarrier
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650 0	$a Podiatry $v Periodicals.
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Attachment 10B

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210 0 Clin. podiatr. med. surg.
222 0 Clinics in podiatric medicine and surgery
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246 1 8 Podiatric medicine and surgery
246 1 **$i** Vols. for 2004- called: **$a** Clinics in podiatric medicine and surgery of North America
260 **$3** 1986- : **$a** Philadelphia : **$b** W.B. Saunders, **$c** ©1986-
260 3 **$3** <2014-> **$a** New York, NY : **$b** Elsevier Inc.
300 18 volumes : **$b** illustrations, portraits ; **$c** 24 cm
310 Quarterly
336 text **$b** txt **$2** rdacontent
337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
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500 Each volume has also a distinctive title.
530 Also issued online.
650 0 Podiatry **$v** Periodicals.
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Attachment 14A

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Attachment 14B

Bibliographic Record - OCLC Number: 27182191

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222 4 The Journal of foot and ankle surgery
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260 Baltimore, MD : **$b** Williams & Wilkins, **$c** ©1993-
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362 0 Vol. 32, no. 1 (Jan./Feb. 1993)-
500 Title from cover.
500 Published: Baltimore, MD : Data Trace Pub., <1998->
530 Also issued in online version.
550 "Official journal of the American College of Foot and Ankle Surgeons."
650 0 Ankle **$x** Surgery **$v** Periodicals.
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525 ##$aSupplements accompany some issues.
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650 12$aOrthopedics
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710 2#$aSociété belge d'orthopédie, de traumatologie et de chirurgie de l'appareil moteur.
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	Date1/Beginning Date of Publication	'1946'
	Date2/Ending Date of Publication	'9999'
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	Regularity	'r' - Regular
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	Original Alphabet or Script of Title	'b' - Roman, extended
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338 volume **$b** nc **$2** rdacarrier
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500 "Organe officiel de la Société belge de Chirurgie orthopédique et de Traumatologie."
525 Supplements accompany some issues.
546 Text in French; some summaries in Dutch, English, Esperanta, German, Italian or Spanish.
550 Official organ of the Société Belge d'Orthopédie et de Chirurgie de l'Appareil moteur, 1946-58; of the Société belge de d'Orthopédie, de Traumatologie, et de Chirurgie de l'Appareil moteur, 1959- Juill/Août 1973; of the Société belge de Chirurgie orthopédique et de Traumatologie, Sept./Oct. 1973-
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710 2 Société belge d'orthopédie et de chirurgie de l'appareil moteur.
710 2 Société belge d'orthopédie, de traumatologie et de chirurgie de l'appareil moteur.
770 0 **$t** Acta orthopaedica belgica. Supplementum **$x** 0772-7623
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029 1 NLM **$b** 2985165R

029 1 ZWZ **$b** 038657465
029 1 UKMGB **$b** 009185378