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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, Leboucq 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.

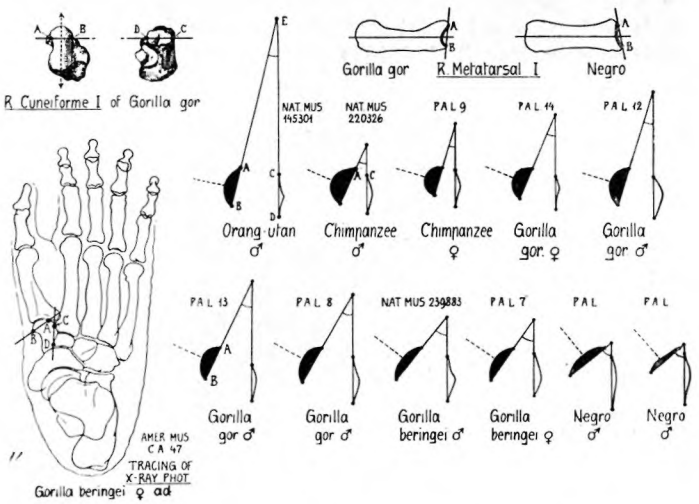


FIG. 1. Tracing of the roentgenogram of the skinned foot of an adult female mountain gorilla (beringei) showing the location of the section through the joint of the hallux and the first cuneiform. Figures on the right are accurate copies of these sections through the first cuneiform bones of various 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)

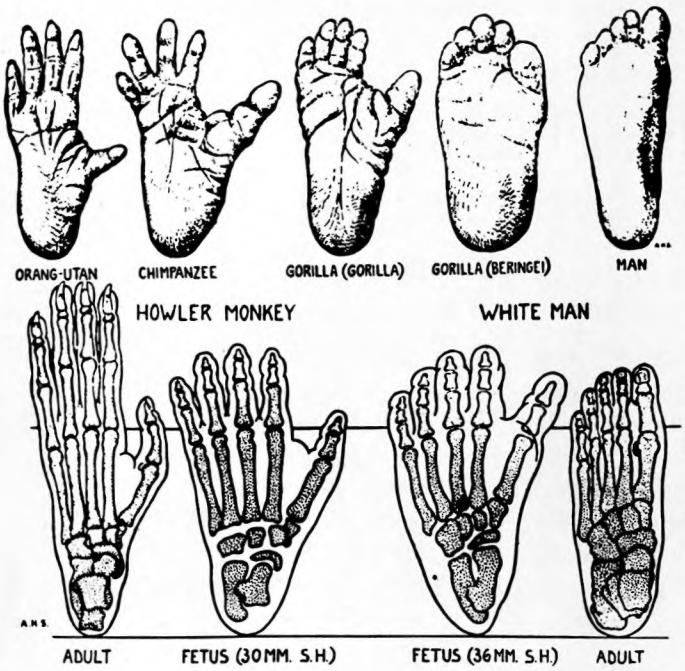


FIG. 2. Note the shortening of the hallucial ray from man to orangutan and also the increased divergence of the big toe in prehensile foot of lower primates as compared with man (upper row). The difference between the big toe in gorilla beringei and that of the Gorilla gorilla is most interesting. Although 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.

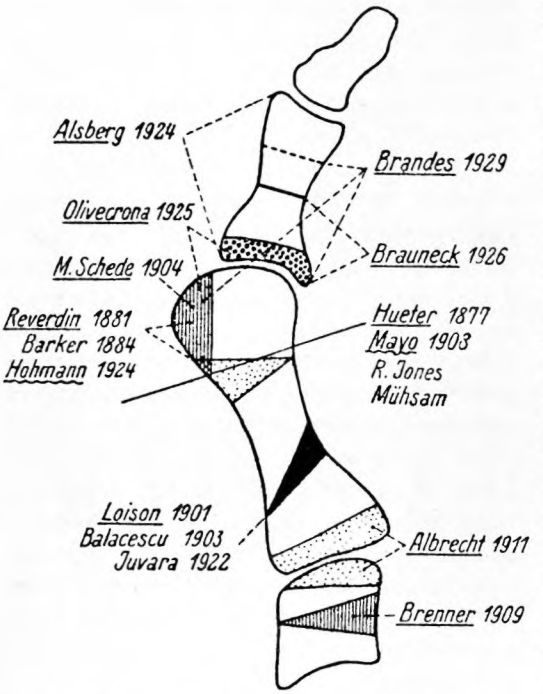


FIG. 3. Schematic drawing of various operative procedures devised for correction of bunion. The name of the author and the year of description of the operation are indicated. (Timmer, H.: Die Behandlung des Hallux valgus, Leipzig, Barth)

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

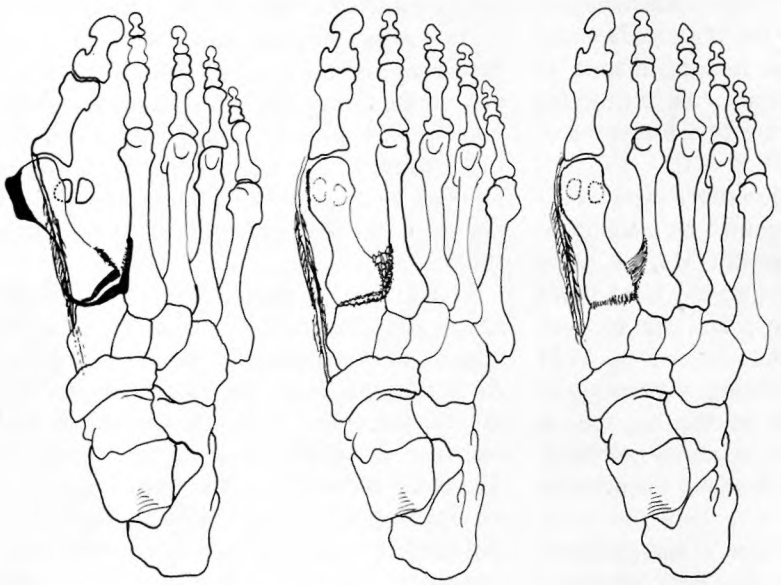


FIG. 4. Operative technic. (Lapidus, P. W.: Surg. Gynec. & Obst. 58:183.) Note the plantar displacement of the abductor hallucis in bunions and its action as a plantar flexor. It is relocated along the medial aspect of the first metatarsal, and its *abduction* action is re-established.

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

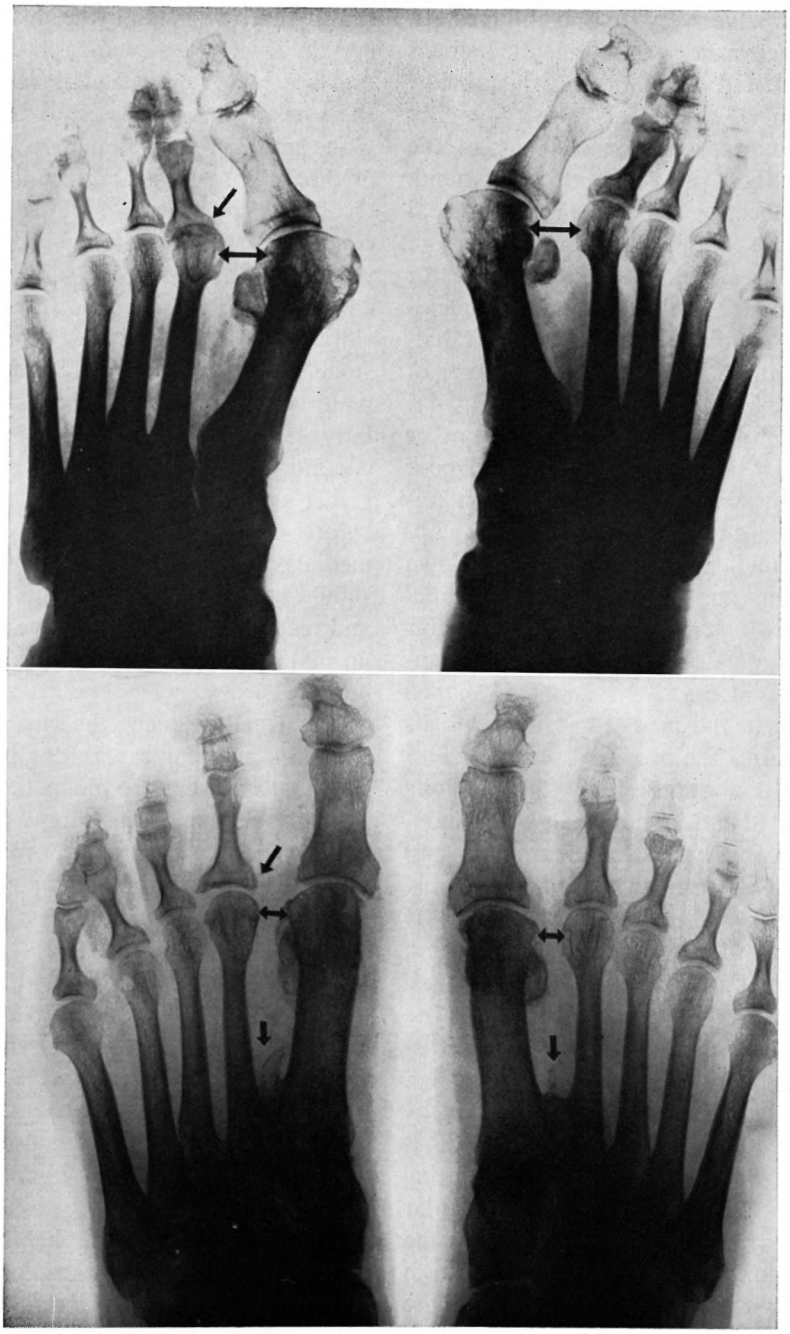
A survey of end-results of various operative procedures for correction of hallux valgus performed at the Hospital for Joint Diseases during 10 years (1931-1940) has seemed to indicate that better results were observed when metatarsus varus primus also was corrected.

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-

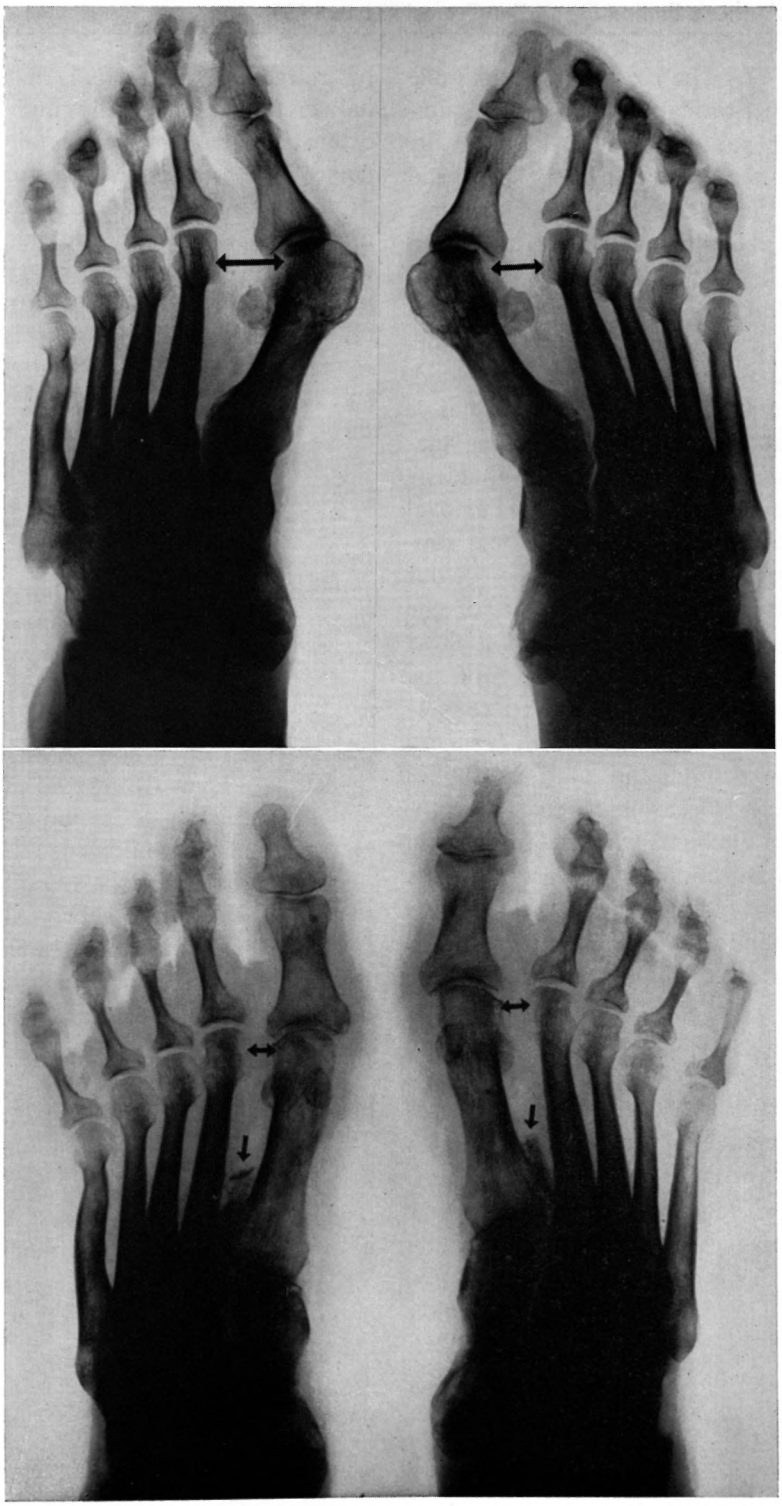


FIG. 6, B.K. (*Top*) Before operation. (*Bottom*) About 6 months after operation.

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

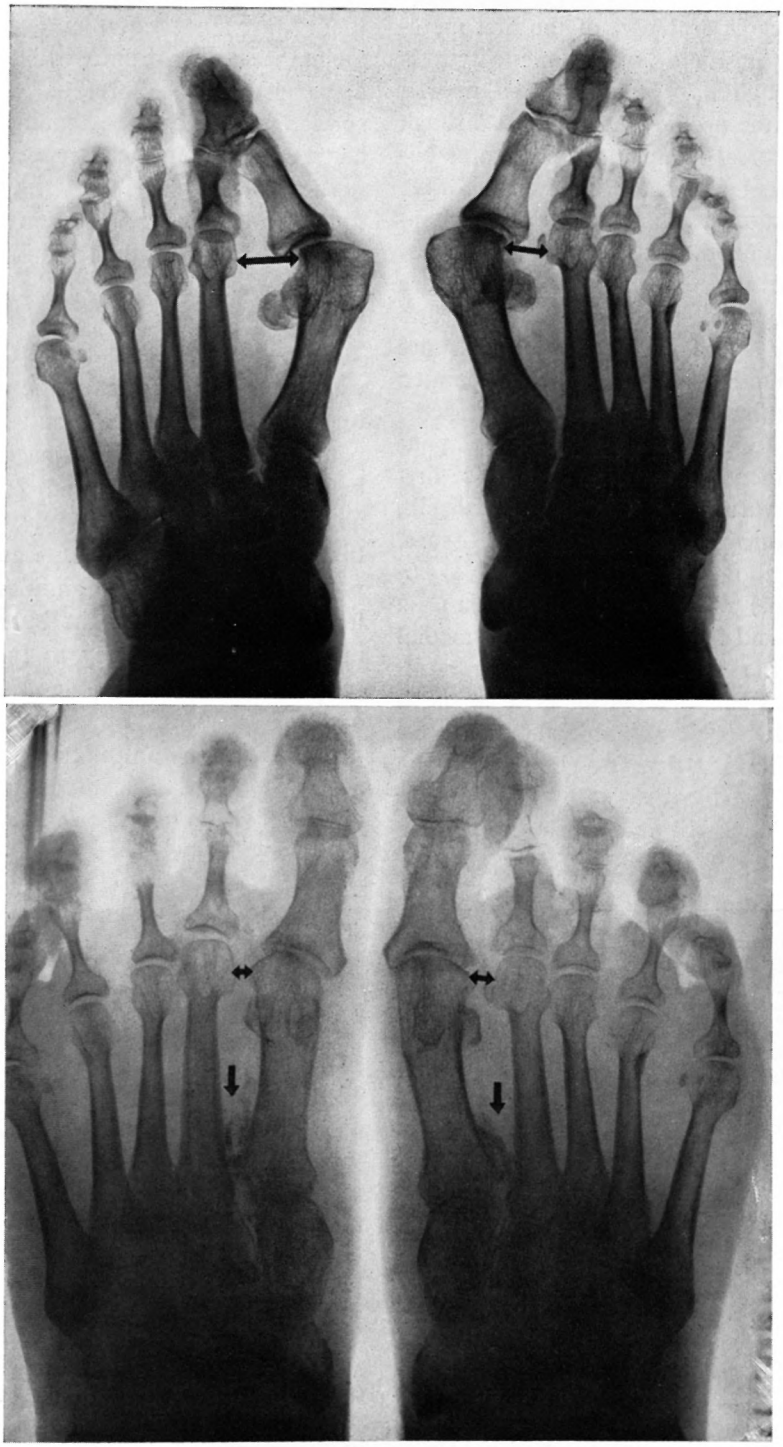


FIG. 7, A.S. (*Top*) Before operation. (*Bottom*) About 6 weeks post-operatively.

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.

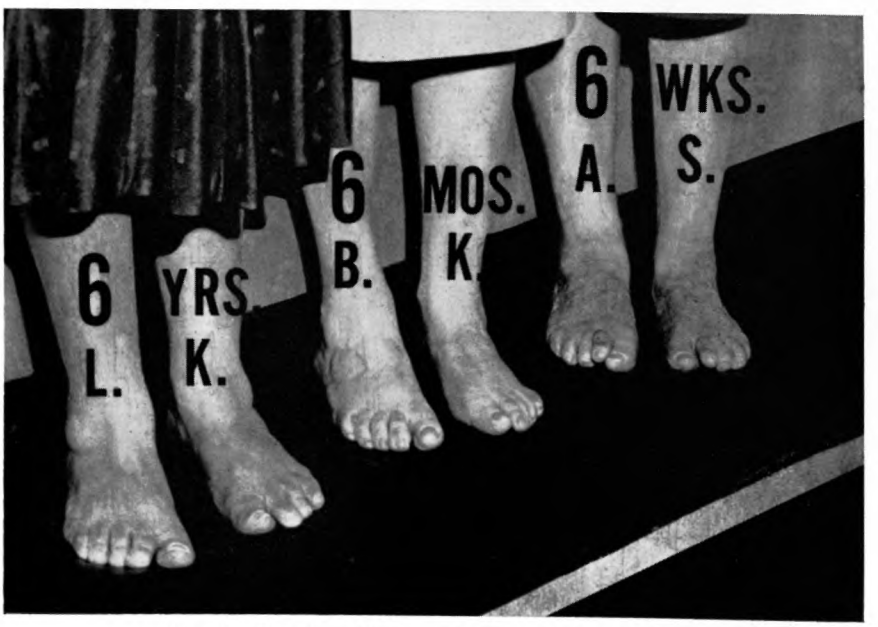
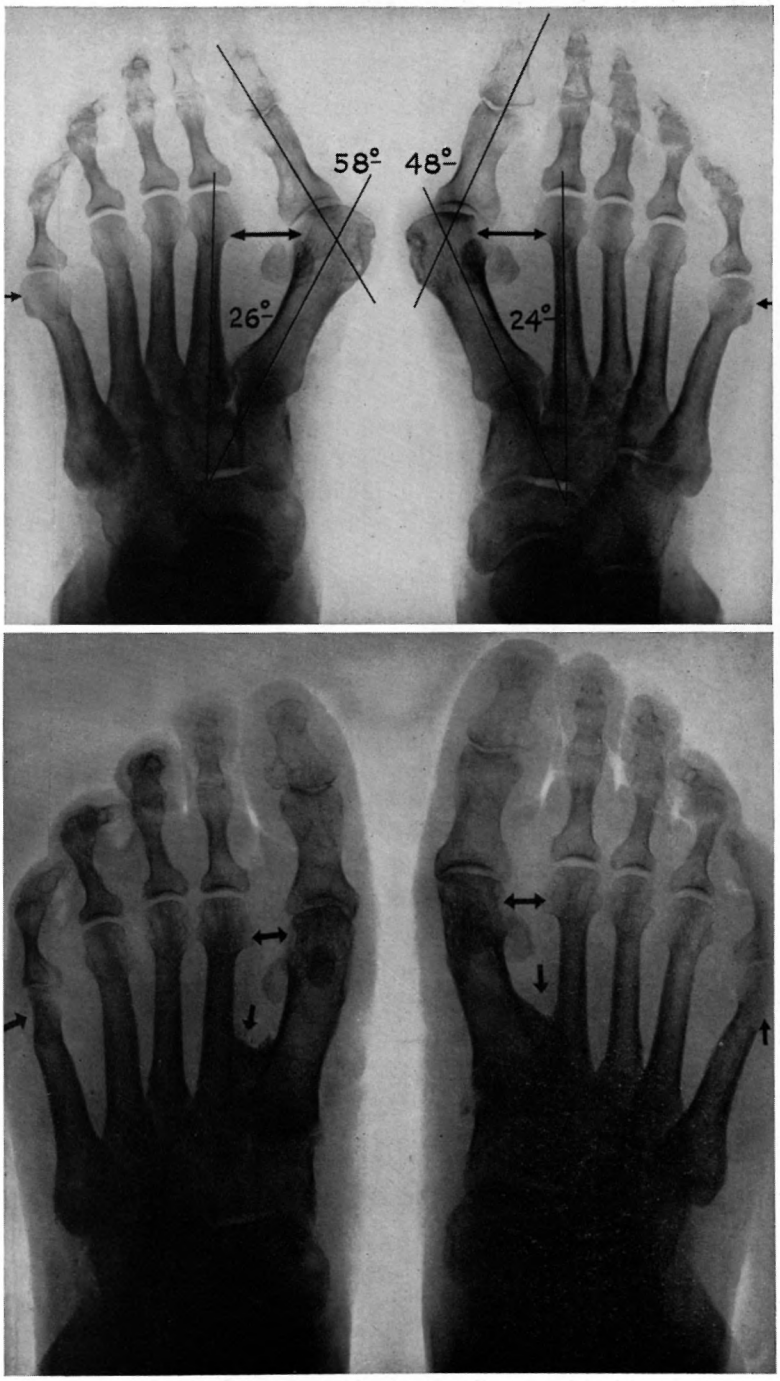


FIG. 8. Result at the time stated after operation.



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)

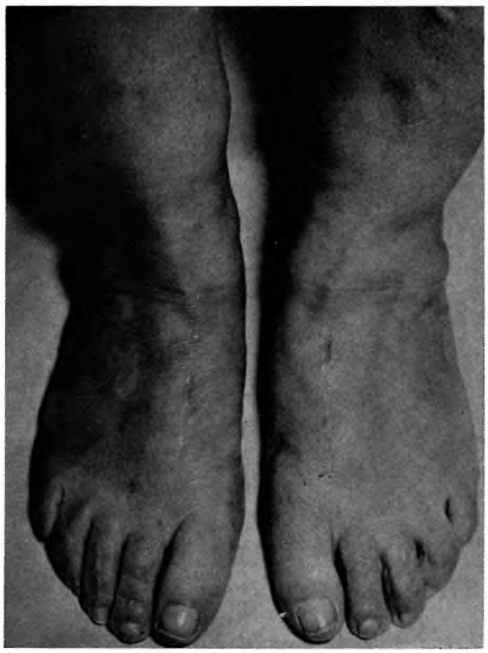


FIG. 10. Both feet on February 13, 1956, 2½ years after the operation. Patient still has very satisfactory correction at the present time. (Lapidus, P. W.: Bull. Hosp. Joint Dis. 17:404)

(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

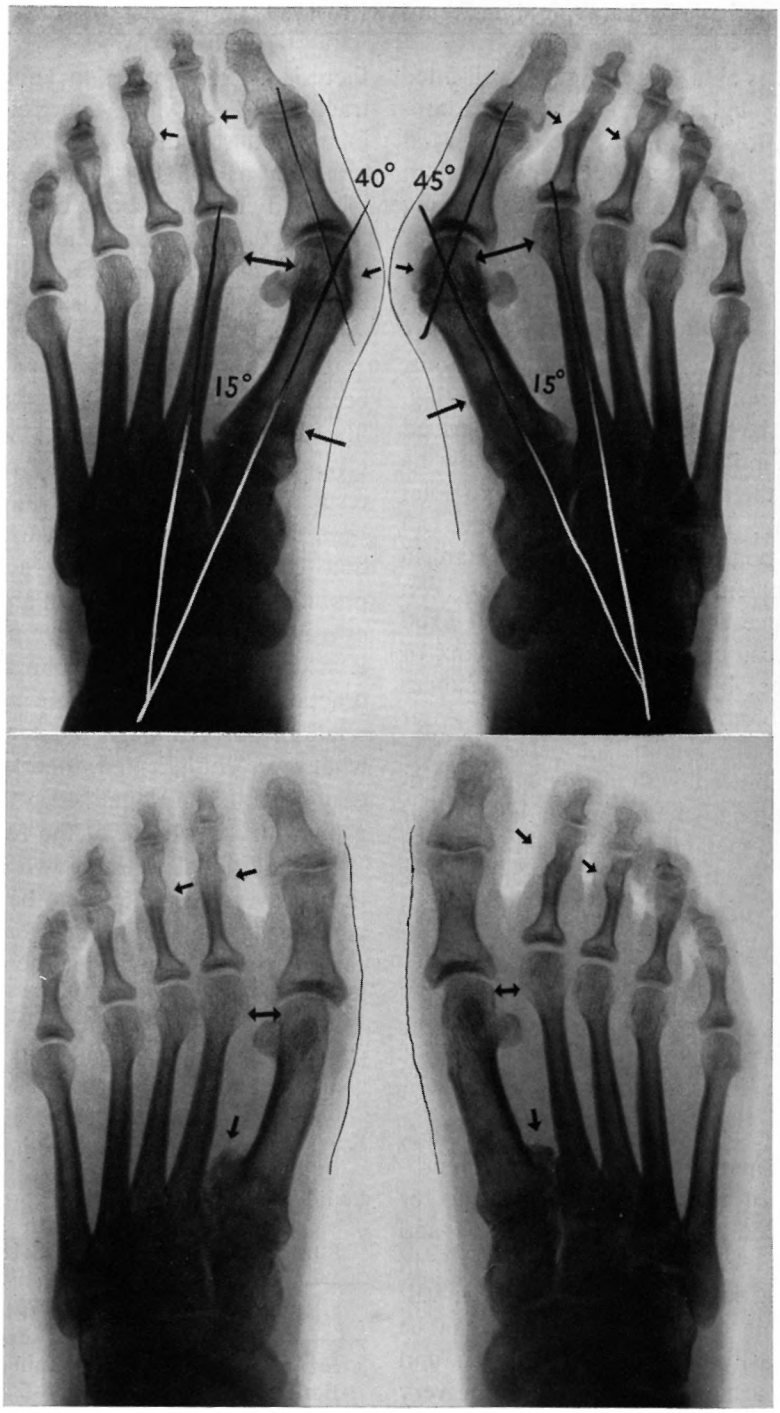


FIG. 11 (*Continued from facing page*)
bunions and extensive keloid formation over the postoperative scars (skin outline retouched over the bunions).

(*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 1011

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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.

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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

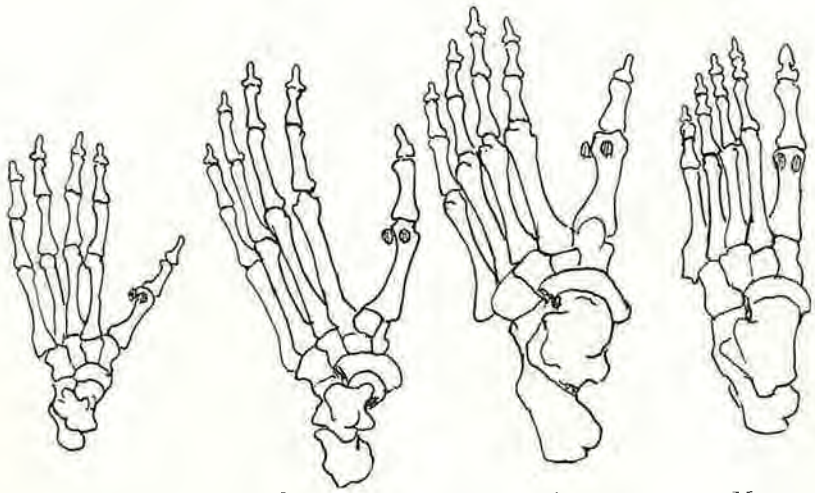


Fig. 2. Note the thumb-like big toe of primates with marked varus position of the first metatarsal. (Adapted with modification from Hiss, J. M. Am. J. Surg., 1931, xi, 53).

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.

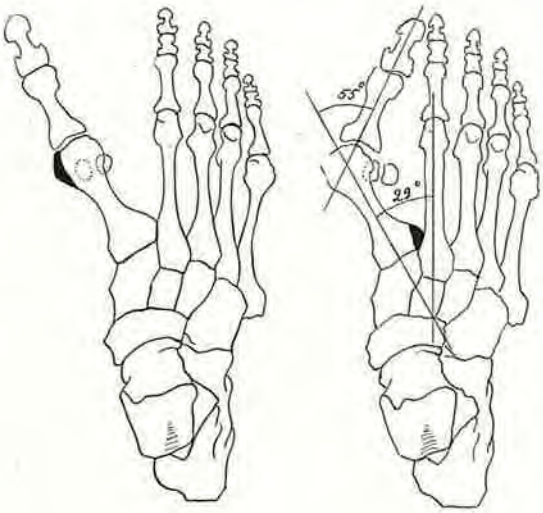


Fig. 6.

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.

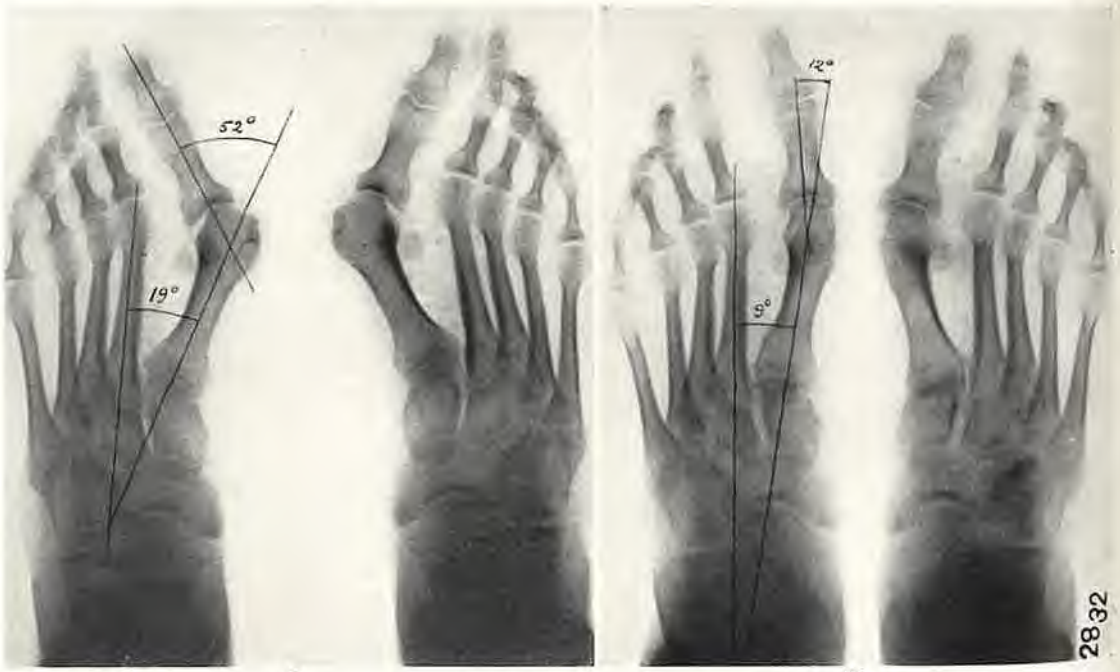
SUMMARY

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



A. C.

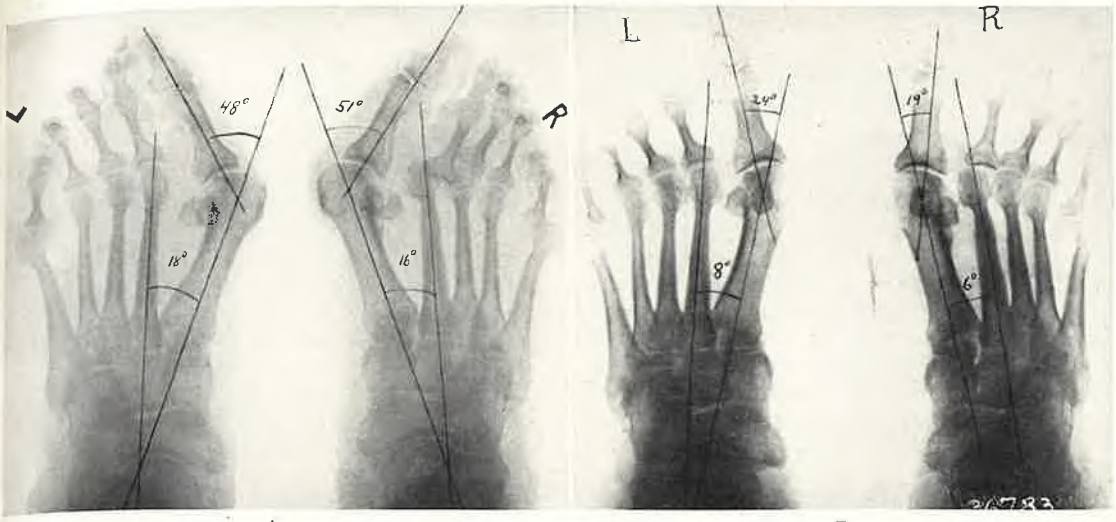


B. D.

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.

Indebtedness is acknowledged to Dr. Leo Mayer, for kind permission to use this operation on his service.

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Fixation of Lapidus Arthrodesis with a Plantar Interfragmentary Screw and Medial Locking Plate: A Report of 88 Cases

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weightbearing

ABSTRACT

Lapidus arthrodesis is a powerful procedure that can be used to correct pathologic features within the forefoot or midfoot. Many different methods of fixation for this procedure have been reported. The use of plating constructs has been shown to provide increased stability compared with screw-only constructs. The technique we have described consists of a plantar to dorsal retrograde lag screw across the arthrodesis site, coupled with a low-profile medial locking plate. A total of 88 consecutive patients were treated with this modification of the Lapidus procedure by 2 surgeons and were retrospectively evaluated. All patients followed an early post-operative weightbearing protocol. Patient age, gender, follow-up duration, interval to weightbearing and radiographic fusion, preoperative and postoperative intermetatarsal angle, hardware removal, preoperative and postoperative American Orthopaedic Foot and Ankle Society midfoot scores, and adjunct procedures were analyzed. The mean follow-up period was 16.76 ± 5.9 (range 12 to 36) months, and all healed fusions demonstrated radiographic union at a mean of 51 ± 19.1 (range 40 to 89) days. The patients were treated with weightbearing starting a mean of 10.90 ± 4.1 (range 5 to 28) days postoperatively. Complications included 15 patients (17%) requiring hardware removal, 2 cases (2%) of hallux varus, 6 cases (7%) of radiographic recurrent hallux valgus, and 2 patients (2%) with first metatarsocuneiform nonunion. The results of the present study have demonstrated that plantar lag screw fixation with medial locking plate augmentation for Lapidus arthrodesis allows for early weightbearing with satisfactory outcomes, improved clinical and radiographic alignment, and improved American Orthopaedic Foot and Ankle Society scores.

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More than 130 procedures have been described for the treatment of hallux abductovalgus (HAV) (1). Indications for the Lapidus procedure include the presence of hypermobility in the first ray, a large first intermetatarsal angle (IMA), arthrosis of the first metatarsocuneiform joint, recurrent HAV, instability of the medial column, and some cases of juvenile HAV. Many different internal fixation options have been described for the Lapidus procedure. Furthermore, a number of surgeons have recommended a postoperative course of non-weightbearing for up to 6 to 8 weeks or longer after Lapidus arthrodesis. In the present retrospective cohort study, we have described an alternative internal fixation option for the Lapidus procedure that will provide increased construct stability and, ultimately, allow the patient to bear weight on the operated foot early in the postoperative period. The construct consists of the combination of a retrograde plantar to dorsal lag screw directed from the plantar aspect of the first metatarsal to the superior aspect of the medial cuneiform, combined with a low-profile, medially applied, locking plate placed across the arthrodesis site.

Patients and Methods

To be included in the cohort, consecutive patients had to have undergone Lapidus arthrodesis with a plantar to dorsal retrograde lag screw combined with a low-profile locking plate applied medially across the arthrodesis site and to have had a minimum of 1 year of follow-up. Two surgeons (J.M.C., A.M.V.) performed all the procedures, and the patients were identified in the surgeons' practices. A retrospective chart assessment was performed of all patients with a minimal follow-up of 1 year, and the data were reviewed by both of us (J.M.C., A.M.V.). Additional inclusion criteria were a painful HAV deformity for which conservative treatment had failed, an IMA greater than 10°, clinical or radiographic evidence of first MTC instability in the coronal or sagittal plane (ie, plantar gapping of first MTC joint on lateral view), clinical signs of systemic laxity, and any revision hallux valgus correction procedure. The exclusion criteria included any previous attempted Lapidus fusion, Charcot neuropathy, diabetes, an intermetatarsal angle less than 10°, and first metatarsal-phalangeal joint arthritis.

The demographic variables, including gender, age, extremity involved, pre- and postoperative first IMAs, follow-up duration, and interval to full weightbearing were recorded. The radiographic review included evaluation of the interval to union of the arthrodesis site and evaluation of the weightbearing preoperative and postoperative

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Conflict of Interest: Drs. Cottom and Vora are consultants for Arthrex, which had no role in the design of the investigation, data analysis, or writing of the report.

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first IMAs. The first IMA was measured and compared using the technique described by Sangeorzan and Hansen (2) with a digital caliper. Osseous union was ascertained by the presence of trabeculation across the fusion site on 3 radiographic views taken with a digital x-ray machine and evaluated by us (J.M.C., A.M.V.). Any hardware complications were recorded, along with the removal of hardware and the mean interval to removal. Adjunct procedures performed in conjunction with the Lapidus arthrodesis were also recorded. In addition, the American Orthopaedic Foot and Ankle Society preoperative and postoperative midfoot scores were compared (3,4).

The data were considered in regard to type and distribution. Statistical comparisons were made between the preoperative and postoperative radiographic values and American Orthopaedic Foot and Ankle Society scores. Statistical significance was defined at the 5% level ($p \leq .05$).

Surgical Technique

The surgical procedure was performed according to the technique described by Cottom (5). A standard lateral release of the first metatarsal-phalangeal joint was performed. Next, after meticulous preparation of the fusion site, a guide wire for a 4.5-mm screw was placed in the central aspect of the first metatarsal base and driven inferior, aiming for the proximal metaphyseal–diaphyseal junction of the first metatarsal (Fig. 1). The wire was driven though the plantar skin under the first metatarsal; the tip of the wire should just be visible within the first metatarsal so that the joint surfaces can be apposed. If deemed necessary, demineralized bone matrix (used by J.M.C.) or autogenous bone (used by A.M.V.) can be placed within the fusion site. The first IMA was then reduced with a large, pointed, bone reduction clamp. This was done by placing 1 arm of the clamp on the lateral aspect of the second metatarsal head through the incision used to perform the lateral release, with the other arm placed over the medial aspect of the first metatarsal. The clamp was then closed, and the first IMA was "dialed" to the desired amount of correction (Fig. 2). The hallux was then dorsiflexed, and the surgeon was able to compress the fusion site and manipulate the base of the first metatarsal in the sagittal plane to the desired level. The guide wire was then driven in a retrograde manner into the medial cuneiform. Placement of the wire was confirmed with both anteroposterior and lateral views intraoperatively to ensure the navicular–cuneiform joint was not compromised (Fig. 3). Through a small stab incision plantarly, and with careful retraction of the soft tissues, a 4.5-mm cannulated screw was then inserted and compression of the arthrodesis site noted. At that point, a low-profile, locking plate (LPS Lapidus Plate, Arthrex, Naples, FL) was positioned along the medial aspect of the first metatarsal and medial cuneiform. Careful attention must be given to avoid transecting the insertion of the anterior tibial tendon. A small "pocket" was then created with a small hemostat, lifting as little as possible of the anterior tibial tendon off the medial aspect of the medial cuneiform, to create room for the plate. The plate was then provisionally fixed to the medial column and the position checked using fluoroscopy (Fig. 4). Occasionally, a bony prominence will be noted at the base of the first metatarsal and must be resected to allow the plate to lie flush with the bone. Once the position was confirmed, locking screws were inserted proximally within the plate into the medial cuneiform. Next, the compression slot within the plate was drilled, aiming either proximally across the fusion site between the locking screws or, alternatively, eccentrically and perpendicular to the shaft of the second metatarsal. If the screw was to be placed proximally, it was inserted using a lag technique. Finally, the distal locking screw was inserted within the plate, and the bone reduction clamp was removed. At this point, the hypertrophic bone at the medial aspect of the head of the first metatarsal can be resected if necessary (Fig. 5). Closure was performed in anatomic layers, and a sterile gauze bandaged was applied. Postoperatively, the patient used a short-leg boot walker and crutches. Postoperatively, the patient was kept nonweightbearing for 7 to 10 days until skin wound healing had occurred. The patient was then allowed full weightbearing in the boot walker, with an attempted return to regular shoe gear at 6 to 8 weeks postoperatively, as allowed by the swelling about the operative site. In addition, once the patient returned to regular shoe gear, physical therapy was initiated.



Fig. 2. Bone reduction clamp placed on the first and second metatarsal heads and the first intermetatarsal angle is reduced and checked with fluoroscopy. One must be careful not to fracture the metatarsal heads with this maneuver.

Results

A total of 88 patients met our inclusion criteria and were included in the analyses. No patients were lost to follow-up. The mean duration of follow-up was 16.76 (range 12 to 36) months. Of the 88 patients, 72 were females (81.82%) and 16 were males (18.18%). Their mean age

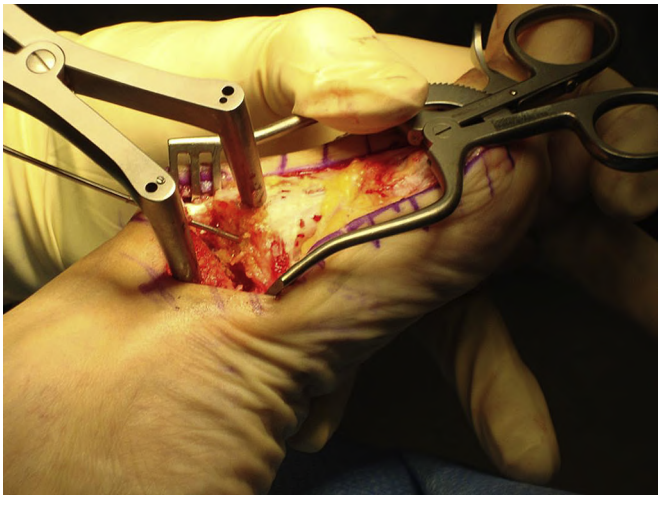


Fig. 1. Guide wire for 4.5-mm cannulated screw introduced into base of first metatarsal and directed out the plantar aspect of the first metatarsal at the proximal diaphyseal–metaphyseal junction. The wire should exit the plantar aspect of the foot. Note, the central placement of the wire in the first metatarsal base.

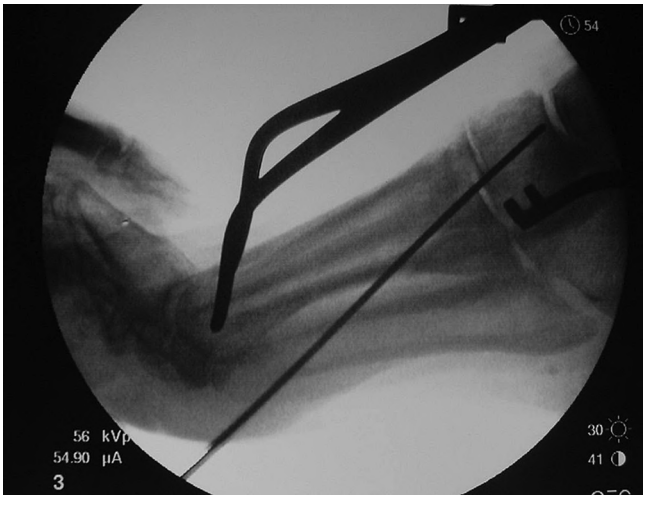


Fig. 3. The hallux is dorsiflexed and the Windlass mechanism engaged. The first metatarsal can be manipulated in the sagittal plane and the fusion site compressed. The guide wire is then moved retrograde into the medial cuneiform. The position of the wire is checked using fluoroscopy.

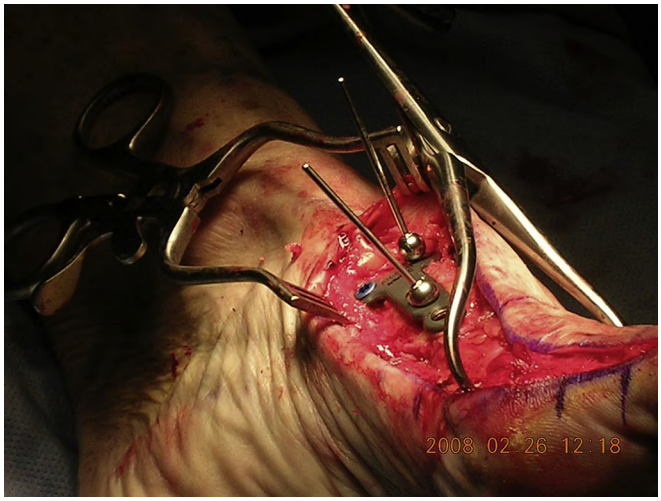


Fig. 4. Low-profile locking plate applied to the medial aspect of the fusion site. Careful attention should be paid not to disrupt the insertion of the anterior tibial tendon. The position of the plate is checked with fluoroscopy before definitive fixation is placed.

was 61.9 (range 22 to 81) years at surgery. The right foot was involved in 55 cases (63%) cases and the left in 33 (37%). No bilateral cases were included in the present series. The mean interval to full weightbearing in a controlled ankle motion walking boot was 10.9 (range 7 to 28) days. Radiographic union at the Lapidus arthrodesis site was deemed complete at a mean of 51 (range 41 to 68) days. Adjunct procedures included distal soft tissue first metatarsophalangeal joint lateral release in all 88 patients (100%). Additional procedures included bone marrow aspiration from the ipsilateral calcaneus and deposited at the fusion site in 66 (75%), autogenous calcaneal bone graft harvest and interposition at the fusion site in 22 (25%), Weil osteotomy of a lesser metatarsal in 51 (57.8%), DuVries lesser metatarsal head condylectomy in 19 (21.6%), tailor's bunionette correction in 4 (4.55%), Youngswick-modified chevron bunionectomy in 4 (4.55%), and an Akin hallux osteotomy in 10 (11.36%). In 2 patients, (2.27%), nonunion occurred at the Lapidus fusion site; 1 patient (1.14%) underwent revision at 6 months and the other at 9 months postoperatively. One of the nonunion cases was revised with hardware removal, distal tibial bone graft, and revision plate and screw fixation. In this revision, a similar construct with an additional dorsal to plantar screw was used. The plate was applied further dorsally than normally to allow for better screw purchase, given the bone void from the previous plate and screw construct medially. The second nonunion case was suspicious for infection; thus, this patient underwent hardware removal and bone biopsy. The bone biopsy did not reveal any microorganism growth and was deemed an aseptic nonunion. To date, the latter patient has remained minimally symptomatic and has not required revision of the arthrodesis.

The first IMA was measured and compared with a weightbearing radiograph both preoperatively and postoperatively once the patients were full weightbearing after their Lapidus fusion procedure. The mean preoperative first IMA was 19.73° (range 10.5° to 31°); postoperatively, it was 4.32° (range 0° to 6.5°; $p < .001$). The American Orthopaedic Foot and Ankle Society midfoot scoring system was used in the present study and demonstrated a mean preoperative score of 54.48 (range 37 to 78) and a mean postoperative score of 88.24 (range 72 to 95), and this improvement was statistically significant ($p < .001$). The overall change in the preoperative and postoperative scores was +33.76 (range 12 to 73). A total of 15 medial low-profile locking plates (17%) were removed at an average of 22.5 (range 12 to 32) months because of symptomatic prominence of the hardware in all 15 patients. Six patients (6.82%) displayed radiographic evidence of recurrent hallux valgus, defined as the hallux drifting laterally more than 20° postoperatively; however, none was clinically symptomatic or required additional surgery. Two patients (2.27%) developed hallux varus, 1 (1.14%) of whom underwent subsequent surgical revision. The other patient with hallux varus was asymptomatic and has not required additional surgery to date. Two patients (2.27%) developed nonunion of the arthrodesis site. One patient (1.14%) remained asymptomatic with a pseudoarthrosis and has not required additional surgical intervention. In the 1 patient (1.14%) who underwent revision surgery for nonunion of the Lapidus arthrodesis, the patient also had dorsiflexion malunion and transfer metatarsalgia that was addressed surgically during the revision procedure. No other patients in the present series developed transfer metatarsalgia symptomatic enough to require additional surgical intervention.

Discussion

Hypermobility of the first ray and medial column has been associated with the onset of hallux valgus and lesser metatarsal overload (6–8). Albrecht (9) was the first to describe a first tarsometatarsal arthrodesis in 1911. In 1934, Lapidus (10) described his technique for correcting hallux valgus through a wedge osteotomy of the first metatarsal and fusion into the medial cuneiform, with fusion of the first and second metatarsal bases without internal fixation. Since

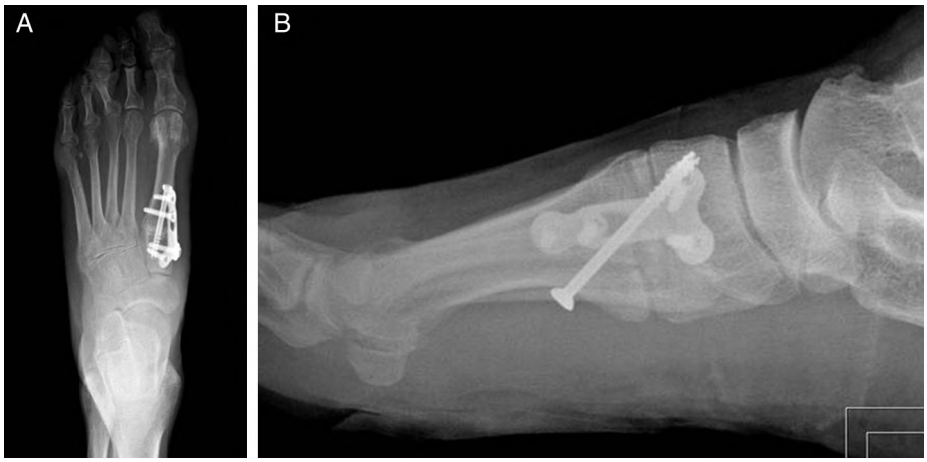


Fig. 5. (*A*) Anteroposterior radiograph showing excellent reduction of the first intermetatarsal angle with all hardware in good position. (*B*) Lateral view demonstrating placement of the plantar interfragmentary screw and plate fixation.

then, numerous modifications to the original Lapidus procedure have been introduced, including minimal bone resection and the addition of multiple screws and/or plates to assist fusion (7,9,11–17). Multiple fixation constructs have been well documented within published studies of first metatarsal–medial cuneiform arthrodesis. In 2010, Klos et al (6) reported on the stability of a medial locking plate with a dorsal to plantar compression screw versus fixation with 2 crossed screws. Eight pairs of fresh-frozen human specimens were used in a matched pair test. In the plate and screw group, an "X-plate" (X-locking plate 2.4/2.7 Synthes, Solothurn, Switzerland) was used. The plates were first secured into the first metatarsal by screws into the distal holes. Next, a 4-mm-diameter, cannulated, partially threaded, stainless steel screw was inserted dorsally into the first metatarsal and driven into the plantar aspect of the medial cuneiform. Then, screws were inserted into the proximal holes within the plate. In the crossed screw group, two 4-mm-diameter, cannulated, partially threaded, stainless steel screws were inserted, the first from dorsally to plantarly from the first metatarsal into the medial cuneiform and the second from dorsally to plantarly from the medial cuneiform into the proximal aspect of the first metatarsal. The screws crossed at a point on the longitudinal axis of the first metatarsal. The specimens were then tested in a 4-point bending test. The investigators found that during cyclic loading conditions, the construct using a medial locking plate with adjunct compression screw was superior to the construct using 2 crossed screws.

Saxena et al (18) compared the outcomes of the Lapidus procedure fixated with crossed lag screws versus a dorsal-medial locking plate with a plantar lag screw. A total of 40 patients were included in their retrospective study, with 19 patients in the crossed screw group and 21 in the plate with plantar lag screw group. In the plate group, a solid 3.5-mm screw was inserted plantarly from the base of the first metatarsal into the medial cuneiform with a Darco Modular Rearfoot System LPS Lapidus Plating System (Wright Medical Technology, Arlington, TN) locking plate. The plate was applied dorsomedially across the fusion site. This method was compared with 2 crossing 3.5-mm cortical fully threaded titanium screws applied in lag fashion. One was directed from the plantar–medial aspect of the first metatarsal into the medial cuneiform and the other from the dorsolateral aspect of the first metatarsal into the medial cuneiform. The investigators noted no statistically significant differences related to postoperative complications between the 2 groups but did note that the plate group allowed for earlier weightbearing (4 weeks versus 6 weeks in the screw group).

Scranton et al (17) reported on 10 matched pairs of cadaver feet that had either undergone the standard crossed 4.0-mm compression screw or fixation with a medial LPS locking Lapidus Plate (Arthrex). The cadaver constructs were stressed to failure using the INSTRON (Norwood, MA) and Wavemaker software (San Diego, CA) and noted that the load to failure was greater with the Lapidus plate and that the increased rigidity provided by these plates might minimize the risk of nonunion or malunion. A similar biomechanical study comparing the construct mentioned in our report and in the study by Scranton et al (17) was completed by 1 of us (J.M.C.). The study is pending publication in the "Journal of Foot and Ankle Surgery" and has demonstrated an increase in the strength of the fixation construct by 86.4%.

In 2008, Gruber et al (13) reported on 10 matched lower extremity pairs that either underwent a Lapidus procedure with 2 crossed, 4.0-mm, partially threaded, cannulated screws or a dorsomedial locking plate (Darco Modular Rearfoot System) LPS Lapidus Plating System (Wright Medical Technology), with a 4.0-mm, partially threaded, cannulated screw inserted from the dorsal aspect of the first metatarsal into the medial cuneiform. The specimens were then loaded in 4-point bend configuration until failure or 3 mm of deformation. The results demonstrated no difference in the load to failure or stiffness between the 2 groups, and the plate construct did not show different rigidity compared with the screw group.

Sorensen et al (8) reported on 21 patients who underwent a modified Lapidus procedure with a dorsomedial locking plate. Of the 21 patients, 19 had concomitant application of an interfragmentary screw, which was a partially threaded cannulated titanium screw. The investigators did not describe the orientation of the interfragmentary screw in their series. The locking plate was applied after screw fixation. They reported an average of 6.95 weeks to radiographic fusion, an average of 2 weeks to ambulation, a 9.52% rate of asymptomatic malunion, a 0% rate of delayed union or nonunion, and no revisions.

Klos et al (14) completed a cadaver study in 2011 to investigate the possible benefit of a compression screw combined with a plantarly applied, anatomically precontoured, plate versus a plate applied dorsomedially. Six pairs of human cadavers were randomized to receive either a dorsomedial H-shaped plate (Wright Medical Deutschland GmbH, Raisting, Germany) or a plantar Lapidus plate (Wright Medical Deutschland GmbH). In all samples, a 4-mm, cannulated, self-tapping, compression screw with a partial thread pattern was introduced first from the dorsal cortex of the first metatarsal into the medial cuneiform. The specimens were then loaded quasistatically, followed by cyclic loading to failure. The investigators noted in the static tests that the plantar plate construct was superior to the dorsomedial plate construct (14). They, therefore, concluded that plantar plating appears to offer a biomechanical benefit in the Lapidus arthrodesis (14).

We believe that the fixation construct we have described is a useful option for the Lapidus procedure. When a segment of bone is loaded vertically, there is congruent contact between the ends of the bone. During the stance phase of gait, potential disruptive distraction forces are created at the inferior aspect of the fusion site. Placement of a lag screw on the tension side of the arthrodesis can actually convert those forces into compression. Biomechanically, this should be a more stable and an inherently stronger fixation construct than the construct with a screw oriented across the dorsal aspect of the fusion site. Additional augmentation of plantar screw fixation with a medial locking plate might provide greater stability and strength to the fusion.

The present study had several limitations, primarily those inherent to all retrospective studies. First, just as with any radiographic evaluation, errors in patient positioning and rotation of the foot might account for some variability in radiographic measurements. We attempted to keep these errors to a minimum by having 1 of us (J.M.C.) perform all the measurements using a digital caliper. The small number of patients in the present series, the absence of a control group, and the relatively short follow-up period, all contributed to a less than perfect model. In addition, with the present study, we noted an increased rate of complications, most of the additional issues was related to the need for hardware removal only and were easily addressed once the hardware had been removed. We believe that hardware removal might be justified by the significantly lower percentage of nonunion and recurrence in deformity, which are more difficult to salvage, such as noted within our study.

The techniques described within the present report are additional modifications to the Lapidus procedure and provide a rigid internal fixation construct. In addition, this method has allowed early weightbearing with reproducible and reliable results. The traditional concept of the Lapidus procedure as a technically challenging procedure with high risks, prolonged non-weightbearing, and extensive postoperative recovery can perhaps be mitigated by this rigid construct design.

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Exhibit 1016

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ORIGINAL ARTICLE

Proximal abduction–supination osteotomy of the first metatarsal for adolescent hallux valgus: a preliminary report

Ryuzo Okuda · Toshito Yasuda · Tsuyoshi Jotoku · Hiroaki Shima

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Abstract
Background Surgical treatment of adolescent hallux valgus has been a challenging intervention because of high rates of postoperative recurrence. The purposes of this study were to describe a proximal abduction–supination osteotomy of the first metatarsal and prospectively review preliminary results of this procedure for correction of adolescent hallux valgus.
Methods Eleven patients (12 feet) who had had a proximal abduction–supination osteotomy of the first metatarsal combined with a distal soft-tissue procedure to correct an adolescent hallux valgus deformity were prospectively reviewed clinically and radiologically. The average duration of follow-up was 22 months. The average age at the time of surgery was 17 years.
Results The mean score on the Japanese Society for Surgery of the Foot standard rating system for hallux improved significantly, from 62.0 points preoperatively to 99.2 points postoperatively ($p = 0.002$). All patients were satisfied and would choose to have the same procedure again. The mean hallux valgus angle decreased significantly, from 32.3° preoperatively to 12.2° postoperatively ($p = 0.002$); mean intermetatarsal angle decreased significantly from 14.0° preoperatively to 6.2° postoperatively ($p = 0.002$). No feet had postoperative recurrence of hallux valgus (a hallux valgus angle ≥20°). There were no occurrences of nonunion or transfer lesions.
Conclusions The clinical and radiological results of this study demonstrate that a proximal abduction–supination osteotomy with a distal soft-tissue procedure, which described in this study, achieved significant correction of an adolescent hallux valgus deformity, significant improvement in pain and function, and reduction in rate of recurrence.

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Introduction

Adolescents with a mild hallux valgus deformity have been managed with nonoperative treatment, including modification of shoe wear or orthoses [1, 2]. Surgical treatment had been indicated for patients who have symptomatic moderate-to-severe hallux valgus when conservative treatment had failed. Many surgical procedures for correction of adolescent hallux valgus have been described in the literature, and surgical outcomes have been reported with various success rates [3–15]. However, surgical treatment of adolescent hallux valgus has been a challenging intervention because of the high rate of postoperative recurrence [5–9, 11]. Risk factors for recurrence following a proximal crescentic metatarsal osteotomy include uncorrected pronation deformity of the first metatarsal and incomplete reduction of the sesamoids [16, 17]. Therefore, we devised a proximal abduction–supination osteotomy of the first metatarsal in order to reduce these risk factors for recurrence. The purposes of this study were to describe the surgical technique and to prospectively review the results of this procedure for treatment of symptomatic adolescent hallux valgus.

Patients and methods

Our institutional review board approved this study, and informed consent was obtained from each patient. Between

March 2007 and July 2011, 11 consecutive female patients (12 feet) who had symptomatic adolescent hallux valgus deformity were treated with a proximal abduction–supination osteotomy of the first metatarsal combined with a distal soft-tissue procedure. Adolescent hallux valgus was defined as the onset of deformity in the teen years or earlier, and hallux valgus surgery at the age of ≤22 years. The average age at surgery was 17 (range 13–22) years. In two patients (two feet) who had surgery at the age of 20 and 22 years, onset of deformity occurred at the age of ≤12 years. Therefore, these two patients were considered as having adolescent hallux valgus. All feet had the closed epiphysis of the first metatarsal at the time of surgery. In two feet, a medial closing-wedge osteotomy of the proximal phalanx (Akin procedure [18]) was added. All procedures were performed by one of the authors. The average duration of follow-up was 22 (range 12–36) months. No patients were lost to follow-up. All patients underwent clinical and radiological assessment preoperatively and at the time of the most recent follow-up.

Indication for a proximal abduction–supination osteotomy combined with a distal soft-tissue procedure was symptomatic hallux valgus deformity (hallux valgus angle ≥30° or an intermetatarsal angle ≥12°). Conservative treatment, including modification of shoe wear, nonsteroidal anti-inflammatory medications, or arch supports, had failed for all patients. Patients were excluded from the study if they had rheumatoid arthritis, osteoarthritis of the first metatarsophalangeal joint, or other inflammatory diseases or if they had had an operation on the affected foot.

Surgical technique

Surgical technique consisted of releasing the distal soft tissues, excising the medial eminence of the first metatarsal head, plicating the medial part of the capsule, and a proximal crescentic osteotomy of the first metatarsal [19]. The medial eminence was excised minimally to preserve the distal articular surface of the first metatarsal head. The adductor hallucis tendon was then dissected from its insertion. The transverse metatarsal ligament was released, and a longitudinal incision was made in the dorsolateral capsule of the first metatarsophalangeal joint. The crescentic osteotomy was performed 1.5 cm distal to the metatarsocuneiform joint. The osteotomy was curvilinear, and the concavity of the cut was directed distally. The proximal fragment was moved medially with a elevator, and the distal fragment was abducted to achieve parallelism between the first and second metatarsals; then, the distal fragment of the first metatarsal was manually supinated (Fig. 1) so that a round, lateral edge of the first metatarsal head (a positive round sign [18]) on the dorsoplantar fluoroscopic view of the foot changed to an angular- or intermediate-shaped lateral edge (a negative round sign) (Fig. 2). After the desired correction was confirmed fluoroscopically, two or three crossed 1.5-mm Kirschner wires were used to fix the osteotomy site. The medial part of the capsule and the abductor hallucis tendon were plicated. If correction of the hallux valgus interphalangeus was necessary, a medial closing-wedge osteotomy of the proximal phalanx was added. Intraoperative dorsoplantar and lateral radiographs of the foot were made to evaluate the hallux

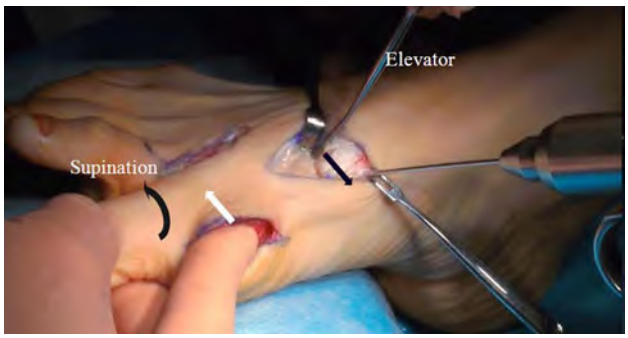


Fig. 1 Intraoperative correction of the metatarsus primus varus and pronation of the first metatarsal at the osteotomy site. The proximal fragment was pushed medially (*black arrow*) with a elevator, the distal fragment was abducted (*white arrow*) with a finger pressure applied to the medial aspect of the first metatarsal head, and the great toe, which was held with thumb and finger, was manually supinated (*curved arrow*)



Fig. 2 Intraoperative dorsoplantar fluoroscopic views. **a** Lateral edge of the first metatarsal head appearing to be round before supination of the distal fragment of the first metatarsal (*arrow*). **b** Lateral edge of the first metatarsal head appearing to be angular after supination of the distal fragment of the first metatarsal (*arrow*)

valgus angle, intermetatarsal angle, sesamoid position, and a round sign and sagittal alignment of the first metatarsal.

Postoperatively, a short-leg cast and nonweightbearing were continued for 2 weeks. Partial weightbearing in a short-leg plaster shell and active and passive extension and flexion exercises of the first metatarsophalangeal joint were then encouraged. Three weeks after surgery, patients were instructed to wear ready-made shoes with an arch support, and full weightbearing was encouraged.

Clinical assessment

Clinical assessment consisted of the Japanese Society for Surgery of the Foot standard rating system for hallux (JSSF scale) [20], metatarsalgia, range of motion of the first metatarsophalangeal joint, and patient satisfaction. The JSSF scale is a validated foot-rating system and assigns 40 points for pain, 45 points for function, and 15 points for alignment, with a possible maximum score of 100 points. The range of motion of the first metatarsophalangeal joint was measured by placing one goniometer arm parallel to the hallux and the other goniometer arm parallel to the long axis of the first metatarsal, then passively moving the first metatarsophalangeal joint from maximum flexion to maximum extension. Patient satisfaction was assessed with a questionnaire at the time of the most recent follow-up. Patients were asked whether they were satisfied or dissatisfied with the overall result of the surgery and were asked whether they would choose the same procedure again.

Radiographic examination

Dorsoplantar and lateral weightbearing radiographs were made preoperatively and at the time of the most recent follow-up. The hallux valgus angle (the angle between the longitudinal axes of the first metatarsal and the proximal phalanx) and the intermetatarsal angle (the angle between the longitudinal axes of the first and second metatarsals) were measured on the dorsoplantar weightbearing radiograph. The longitudinal axis of the first metatarsal was defined as the line connecting the center of the metatarsal head with the center of the proximal articulation according to the method proposed by Shima et al. [21]. The longitudinal axis of the proximal phalanx was defined as the line connecting the center of the proximal end of the diaphysis with the center of the distal end. The longitudinal axis of the second metatarsal was defined as a line connecting the center of the proximal end of the diaphysis with the center of the distal end. Postoperative recurrence was defined as a hallux valgus angle of $\geq 20^\circ$ at the time of the most recent follow-up.

The shape of the lateral edge of the first metatarsal head was classified as one of three types: round (type R), angular (type A), and intermediate (type I) with the measurement system [16]. We defined the round sign as being positive when the shape of the lateral edge was classified as type R as being negative when the shape of the lateral edge was classified as either type I or type A.

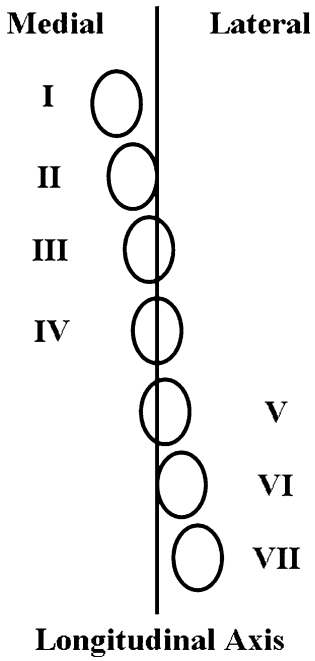


Fig. 3 Position of the medial sesamoids was classified as grade I, II, III, IV, V, VI, and VII on the basis of its relationship to the longitudinal axis of the first metatarsal

The position of the medial sesamoid in relation to a line drawn along the longitudinal axis of the first metatarsal on the dorsoplantar weightbearing radiograph was evaluated and classified as grades I, II, III, IV, V, VI, and VII according to the measurement system proposed by Hardy and Clapham [22] (Fig. 3).

The inclination angle of the first metatarsal was measured on the lateral weightbearing radiograph. The inclination angle was the angle between the longitudinal axis of the first metatarsal and the floor [16]. The longitudinal axis of the first metatarsal was defined as a line connecting the center of the proximal articular surface with the center of the distal end of the diaphysis.

Statistical analysis

Preoperative and postoperative radiological and clinical data were compared using the Wilcoxon signed-rank test. Differences with a p value <0.05 were considered significant.

Results

The mean total JSSF score improved significantly from 62.0 points (range 49–75)) preoperatively to 99.2 points

Table 1 Clinical evaluation

	Preoperative	Most recent follow-up	*p* value
JSSF score			
Pain	27.5 [30] (20–30)	39.2 [40] (30–40)	0.002
Function	32.5 [32] (29–37)	45 [45]	0.002
Alignment	1.3 [0] (0–8)	15 [15]	0.001
Total	62.0 [62] (49–75)	99.2 [100] (90–100)	0.002
ROM of the 1st MTP joint			
Extension (°)	70.4 (55–90)	67.1 (50–80)	0.526
Flexion (°)	27.1 (10–45)	21.7 (10–40)	0.219

Values are mean [median] (range)

JSSF Japanese Society for Surgery of the Foot standard rating system for hallux, *ROM* range of motion, *MTP* metatarsophalangeal

Table 2 Pre- and postoperative radiographic measurements

	Preoperative	Most recent follow-up	*p* value
Hallux valgus angle (°)	32.3 (28–38)	12.2 (9–17)	0.002
Intermetatarsal angle (°)	14.0 (11–18)	6.2 (3–9)	0.002
Inclination angle (°)	16.9 (13–21)	16.9 (10–21)	0.886

Values are given as the mean (range)

(range 90–100) at the most recent follow-up ($p = 0.002$) (Table 1). Three patients (three feet) had had metatarsalgia preoperatively. There were no feet with metatarsalgia at the most recent follow-up.

Mean extension and flexion of the first metatarsophalangeal joint are shown in Table 1. There were no significant difference in mean extension and flexion between preoperative and the most recent follow-up evaluations ($p = 0.526$ and 0.219, respectively). All patients were satisfied with the overall results of this procedure and stated they would have the same procedure again. Results of the radiographic measurements are shown in Table 2. Preoperative hallux valgus and intermetatarsal angles significantly decreased at the most recent follow-up ($p = 0.002$, $p = 0.002$). All feet had a hallux valgus angle of $\leq 17°$ and an intermetatarsal angle $<10°$ at the most recent follow-up. No significant difference was observed in mean inclination angle of the first metatarsal between preoperative and the most recent follow-up evaluations ($p = 0.886$).

Distribution of the position of the medial sesamoids is shown in Table 3. All feet were classified as grade V or greater preoperatively. Ten feet (83 %) were classified as grade IV or less, and the remaining two as grade V at the most recent follow-up. The mean sesamoid position improved significantly from 5.8 (median 6, range 5–7) preoperatively to 3.3 (median 3, range 2–5) at the most recent follow-up ($p = 0.002$).

Table 3 Distributions of sesamoid position and shape of the lateral edge of the first metatarsal head

	Preoperative	Most recent follow-up
Sesamoid position		
Grade II	0	2
Grade III	0	6
Grade IV	0	2
Grade V	5	2
Grade VI	4	0
Grade VII	3	0
Shape of the lateral edge		
Type A	0	7
Type I	1	4
Type R	11	1

Distribution of the shape of the lateral edge of the first metatarsal is shown in Table 3. Preoperatively, the round sign was positive for 11 feet and negative for one foot (type I). At the most recent follow-up radiographs, the round sign was positive for one foot and negative for 11 (type A or I) (Fig. 4).

There was no recurrence of hallux valgus in any patients. There were no occurrences of nerve injury, infection, delayed wound healing, delayed union, or nonunion. At the most recent follow-up, no painful transfer lesions and no hallux varus developed in any patient.

Discussion

Many authors reported on the results of a distal metatarsal osteotomy for correction of mild-to-moderate hallux valgus deformity with various success rates in adolescents [3, 4, 7, 9, 11]. Canale et al. [9] reviewed the long-term results of the Mitchell procedure for treating adolescent hallux valgus and reported that a poor result in ten (20 %) of 51 feet were associated with recurrence of the hallux valgus deformity. Zimmer et al. [7] reported the results of chevron osteotomy for correction of adolescent hallux valgus and found that five (14 %) of 35 feet had subjective recurrence postoperatively. Peterson et al. [10] reviewed the results of a double osteotomy of the first metatarsal for adolescent moderate-to-severe hallux valgus and reported a satisfactory result in 13 (87 %) of 15 feet, although the two failures occurred due to technical problems that resulted in a postoperative hallux varus deformity. There is little available information on the results of a proximal osteotomy of the first metatarsal for correction of a hallux valgus deformity in adolescents [11, 14]. In this study, we describe a proximal abduction–supination osteotomy to correct adolescent hallux valgus and prospectively review the results of this procedure.



Fig. 4 A 17-year-old girl with a moderate hallux valgus deformity. **a** Preoperative dorsoplantar weightbearing radiograph demonstrating a hallux valgus angle of 33°, an intermetatarsal angle of 13°, a grade VI position of the medial sesamoids, and a round-shaped lateral edge of the first metatarsal head (a positive round sign). **b** Preoperative lateral weightbearing radiograph demonstrating an inclination angle of the first metatarsal of 18°. **c** At the 27-month follow-up, dorsoplantar weightbearing radiograph demonstrating a hallux valgus angle of 9°, an intermetatarsal angle of 5°, a grade III position of the medial sesamoids, and an intermediate-shaped lateral edge of the first metatarsal head (a negative round sign). **d** Lateral weightbearing radiograph demonstrating an inclination angle of the first metatarsal of 17°

Our radiological results show that postoperative hallux valgus angle was <17° and postoperative intermetatarsal angle <10° in all feet; there was no recurrence of hallux valgus. Therefore, our surgical procedure could provide satisfactory correction for adolescent hallux valgus.

Several authors have reported that the rate of the excellent and good results has ranged from 69 to 93 % following a distal osteotomy, a proximal osteotomy, or a double osteotomy of the first metatarsal for adolescent hallux valgus, although there were various assessment tools among the literature [3, 4, 7, 9, 10, 13–15]. In our study, all patients were assessed using JSSF scale as a validated foot-rating system [20] preoperatively and at the time of the most recent follow-up. The mean total JSSF score improved significantly from 62.0 points preoperatively to 99.2 points postoperatively ($p = 0.002$); postoperative JSSF score was ≥90 points in all patients. Therefore, clinical results of our study are comparable with previously reported clinical results.

The distal metatarsal articular angle is a radiographic measurement of the orientation of the articular surface of the first metatarsal. Coughlin [11] found an increased distal metatarsal articular angle in 48 % of 60 feet with adolescent hallux valgus. However, the distal metatarsal articular angle is not thought to be as valuable in the study of hallux valgus because the medial and/or lateral extent of the distal articular surface of the first metatarsal head is often not clearly defined on radiographs [23]. In addition, there is controversy regarding the reliability in the distal metatarsal articular angle measurement [24–27]. In our study, all but one foot had a round-shaped lateral edge of the first metatarsal head on preoperative radiographs, and the lateral articular margin of the first metatarsal head was not distinct. The rate of a round-shaped lateral edge of the first metatarsal head was 1.7 % (1/60 feet) in normal adult females and 78.3 % (47/60 feet) in adult females with hallux valgus [16]. Eleven of 12 feet (91.6 %) in adolescent hallux valgus had a round-shaped lateral edge. Therefore, a round-shaped lateral edge of the first metatarsal head may be the defining characteristic of adolescent hallux valgus. The difficulty of defining the lateral articular margin due to a round-shaped lateral edge of the first metatarsal head might have resulted in controversy regarding the reliability of the distal metatarsal articular angle measurement.

Mizuno et al. [28] described that pronation of the first metatarsal is one of the essential features of hallux valgus based on their clinical observation, and they proposed distal detorsion osteotomy of the first metatarsal. Eustace et al. [29], in a study of first metatarsal rotation and the role of pronation in hallux valgus, found that the amount of first metatarsal rotation increases as the intermetatarsal angle increases. They concluded that pronation and varus deviation of the first metatarsal are intimately related and appear to contribute to development of hallux valgus. The prevalence of the round-shaped lateral edge of the first metatarsal head (a positive round sign) was significantly greater in feet with hallux valgus than it was in normal feet [16]. From an anatomical point of view, the pronation of the first metatarsal in feet with hallux valgus may cause the shape of the lateral edge to appear round on the dorsoplantar radiograph [16]. In our study, a preoperative round sign was positive in all but one foot. However, we found that the apparent shape of the lateral edge changed from type R to type A or I under intraoperative fluoroscopy when the distal fragment was supinated after a proximal metatarsal osteotomy. In addition, a round sign was negative in most feet at the time of the most recent follow-up. Therefore, we believe that the round-shaped lateral edge of the first metatarsal head in adolescent hallux valgus might be produced on the radiograph by pronation of the first metatarsal head.

Recurrence of hallux valgus is the common complication following surgical correction for an adolescent hallux valgus deformity. The reported prevalence of recurrence deformity ranged from 0 to 61 % [3–9, 11, 12, 15]. Canale et al. [9] investigated the long-term results of the Mitchell procedure for adolescent hallux valgus and stated that the poor results were secondary to recurrence of the deformity, technical problems associated with the operation, stiffness, or an unsightly scar. Risk factors for postoperative recurrence in adult hallux valgus included postoperative round-shaped lateral edge of the first metatarsal head, postoperative incomplete reduction of the sesamoids, and a postoperative round sign can be positive when the pronation of the first metatarsal presents or recurs after surgery [16, 17]. Pronation of the first metatarsal may be a possible component of lateral displacement of the sesamoids because pronation of the first metatarsal brings dorsolateral displacement of the sesamoids at the same time. Therefore, we devised a proximal abduction–supination osteotomy in which pronation deformity of the first metatarsal can be corrected. Our radiological results showed a negative round sign and complete reduction of the sesamoids, defined as grade IV or less [17], in most patients at the most recent follow-up. We believe that these factors led to no recurrence in our study.

Our study has some limitations, including small number of patients and relatively short duration of follow-up. Surgical treatment of adolescent hallux valgus is relatively rare and has been a challenging intervention due to the high rate of complications [5–9, 11, 12]. Results of our study suggest that our surgical procedure, which can correct pronation of the first metatarsal as well as the metatarsus primus varus, has considerable potential for treating hallux valgus in adolescents. Therefore, we report the preliminary results of this procedure. Further investigations involving large number of patients, severe hallux valgus deformity (angle $\geq 40°$), and longer follow-up are required to demonstrate the reliability and durability of this procedure.

In conclusion, our clinical and radiological results indicate that a proximal abduction–supination osteotomy is an effective procedure for correcting hallux valgus deformity in adolescents and could provide satisfactory correction and a low rate of recurrence.

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Exhibit 1022

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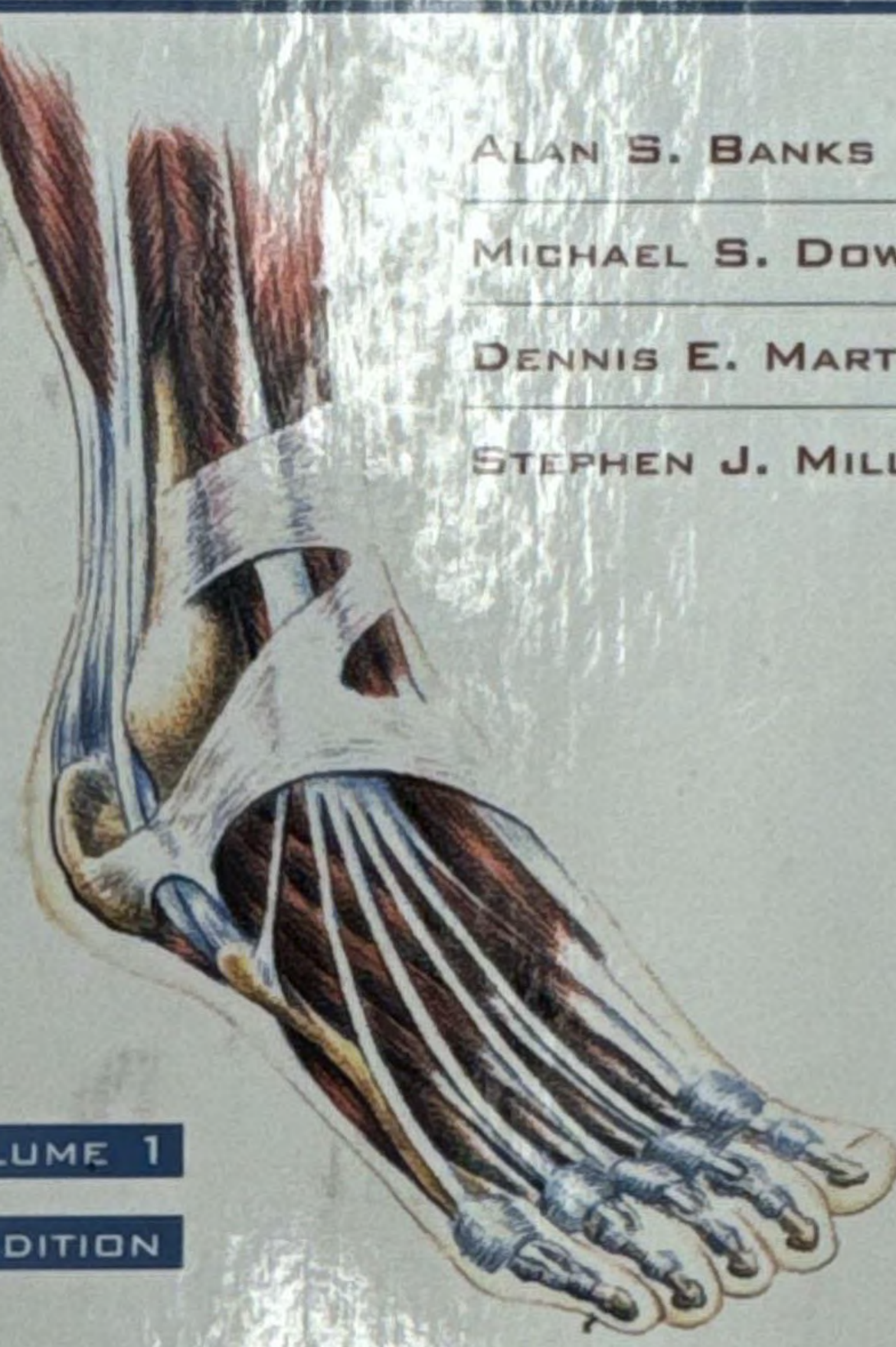
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Third Edition

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CHAPTER 16

Proximal Procedures of the First Ray

PART 1

Osteotomies of the First Metatarsal Base

Robb A. Mothershed

Metatarsus primus adductus, or an increase of the first intermetatarsal angle, has long been recognized as a major contributing factor in the deformity of hallux abducto valgus. This component of hallux abducto valgus has been addressed by proximal osteotomies for decades. A transverse plane osteotomy of the first metatarsal base for the repair of hallux abducto valgus deformity was first described in 1901 by Loison (1), and it was performed in 1903 by Balacescu (2). However, not until the late 1960s and early 1970s did the base wedge osteotomy became popular and widely used. Over the intervening years, this particular procedure has been performed with less frequency because of several factors. First, certain complications were believed to be inherent to the procedure, including first metatarsal elevatus, shortening of the metatarsal, failure of the fixation, and delayed union (3–7). However, surgeons subsequently began to appreciate that most of these problems resulted from surgical technique, inadequate fixation, and insufficient postoperative protection, as opposed to a deficiency of the procedure itself. The perceived complications associated with the closing base wedge osteotomy also led surgeons to consider other forms of proximal osteotomies such as the crescentic and chevron configurations. In addition, other surgeons have employed more distal procedures for the correction of hallux abducto valgus deformity such as the Austin or Scarf osteotomies whenever possible. These latter procedures may prove technically easier to perform, and the patient can remain weight bearing during the postoperative period. However, the proximal osteotomies still are effective, particularly in patients with severe deformities and in patients with high intermetatarsal angles. The technical advances in surgical technique, rigid internal fixation, and the institution of a non–weight-bearing interval in the postoperative recovery have demonstrated that these procedures can provide consistently good results.

INDICATIONS

Large Intermetatarsal Angles

The traditional indication for a transverse plane base osteotomy of the first metatarsal was a hallux abducto valgus deformity with a high intermetatarsal angle, typically exceeding 15 degrees. This is still a reasonable criterion for employing this type of procedure, although in some instances adequate correction of severe deformities can be accomplished with other approaches as well.

The base wedge procedure may be more effective in reducing a high intermetatarsal angle than a distal procedure, particularly in rigid deformities, because of the geometric principles of placement of the osteotomy (8). The oblique orientation of the base wedge osteotomy is angled from proximal-medial to distal-lateral. This design allows the axis and hinge of the osteotomy to be placed in close proximity to the base of the first metatarsal. The effect creates the longest distance possible between the hinge and the distal end of the bone while keeping the osteotomy within the first metatarsal. This distance is the radius arm. A longer radius arm creates greater lateral movement at the end of the arm for each degree of rotation around the arc of the circle. Therefore, the base wedge osteotomy allows greater lateral movement of the head of the metatarsal for every degree of wedge resected and thereby provides a more effective procedure.

In addition, the more proximal the apex of the osteotomy,

the more lateral is the axis of rotation in relation to the position of the second metatarsal. Therefore, a more proximal hinge provides a more lateral overall position of the first metatarsal head once the distal segment has been reduced into a parallel relationship with the second metatarsal. In effect, the more proximal hinge allows the first metatarsal head to come closer to the second metatarsal without creating a negative intermetatarsal angle in the distal segment of the bone (8).

The crescentic osteotomy also offers a more proximal location for rotation of the metatarsal. Although the proximal chevron procedure is typically transposed, it may also be rotated to enhance the reduction of the intermetatarsal angle. In each instance, more effective correction of large intermetatarsal angles may be obtained as compared with distal osteotomies.

Rigid First Ray

Flexibility of the first ray is an important factor to consider when evaluating the patient with hallux abducto valgus deformity. The success of a distal metatarsal osteotomy in the repair of hallux abducto valgus deformity associated with high intermetatarsal angles requires good transverse plane flexibility. This feature may be evaluated preoperatively by assessing the sagittal plane mobility of the first ray. If the first ray demonstrates good mobility in the sagittal plane, then it will almost always have good mobility in the transverse plane as well. In addition, one may assess the flexibility by applying medial to lateral compression to the first metatarsal head. However, if the sesamoids are significantly displaced within the first intermetatarsal space, then lateral shift of the metatarsal head may be difficult to accomplish.

Radiographic evaluation may also render helpful information. Some patients may actually have an enlarged articular facet between the metatarsal bases and a rudimentary os intermetatarsia, both of which are typically associated with less mobility of the first ray (Fig. 1). When distal osteotomies are employed for the correction of greater degrees of hallux abducto valgus deformity, the correction is accomplished by a combination of the release of soft tissue tension about the first metatarsal phalangeal joint and the translocation of the metatarsal head. If a distal osteotomy is performed in a rigid deformity, then the release of the soft tissues at the first metatarsophalangeal joint will generally result in little if any ability to reduce the intermetatarsal splay significantly. As such, it becomes more difficult to achieve a desirable permanent correction with a distal procedure. Therefore, a proximal osteotomy may be appropriate for correction of the hallux abducto valgus deformity in patients with reduced mobility of the first ray with only moderate amounts of intermetatarsal splay.

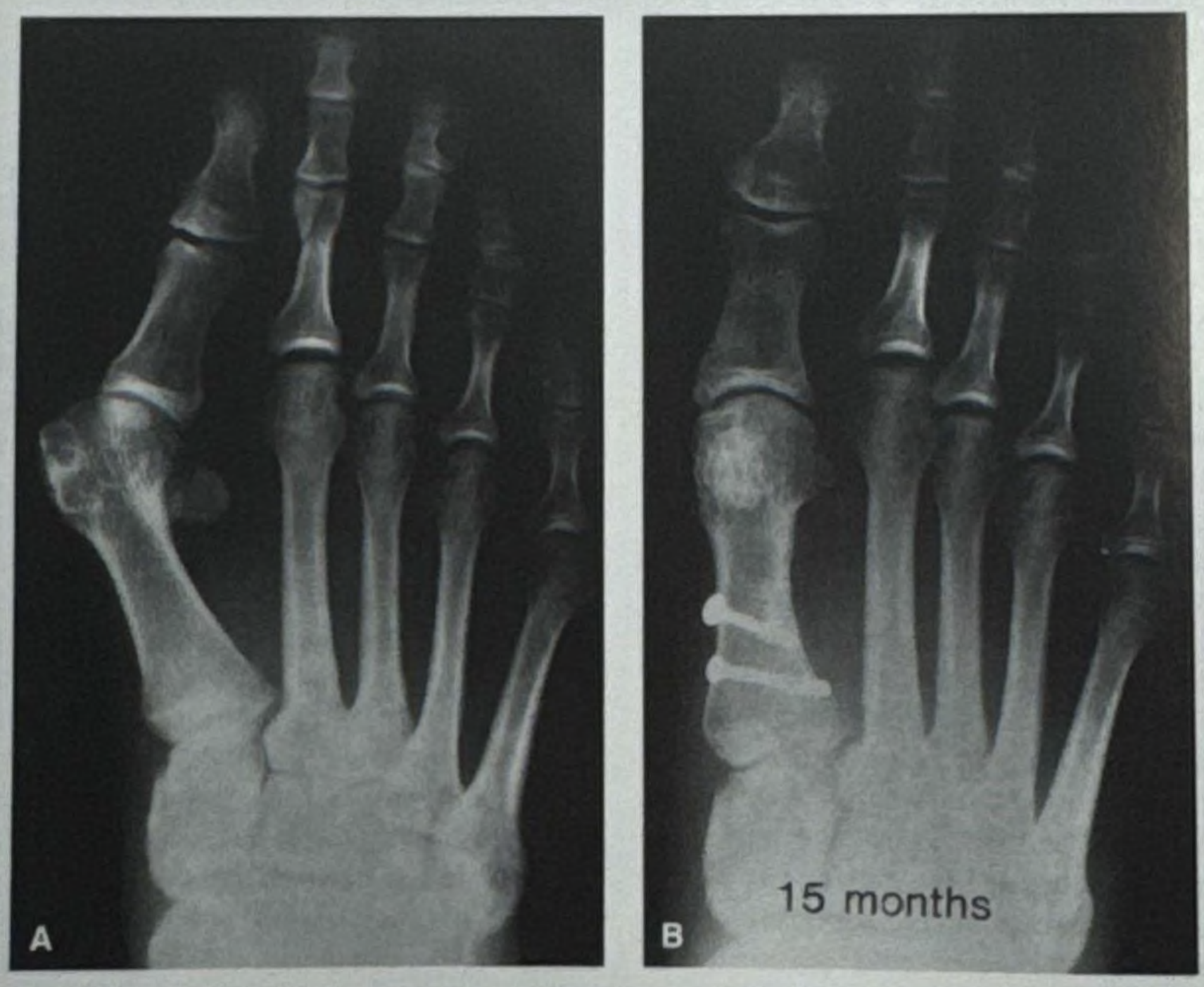


FIG. 1. A: Preoperative radiograph of a patient with severe hallux abducto valgus and a rigid first ray secondary to the articular relationship of the first and second metatarsal bases. **B:** Postoperative appearance 15 months after a closing base wedge osteotomy and fibular sesamoidectomy.

Sagittal Plane Abnormalities of the First Ray

Proximal osteotomies may also be helpful in addressing significant sagittal plane deformity or disease in patients with hallux abducto valgus deformity. The presence of a callus or pain plantar to the second metatarsal head generally indicates a hypermobile first ray, and patients may benefit from simultaneous plantarflexion of the metatarsal with reduction of the intermetatarsal angle. Proximal osteotomies are well suited to correction of this type of combined deformity.

An abnormally large sagittal plane deviation of the metatarsal can be more effectively corrected with an osteotomy of the first metatarsal base. An elevated first metatarsal may be effectively addressed at the base of the metatarsal because there will be more effective plantarflexion of the metatarsal as the resection of a small amount of bone wedge at the base translates into a larger amount of plantar deflection of the metatarsal when compared with resection of a distal wedge of bone. If a similar amount of plantarflexion could be achieved with a distal metatarsal osteotomy, it would more abruptly change the vectors of the flexor and extensor tendons crossing the joint. This change in vectors would potentially have a greater disruption of the muscular balance of the first metatarsal phalangeal joint, which could lead to a propurchasing or cock-up hallux.

Hallux Abducto Valgus with Metatarsus Adductus

Some investigators have described the association of hallux abducto valgus with metatarsus adductus. LaReaux and Lee found that 35% of their patients with hallux abducto valgus had a metatarsus adductus deformity, compared with only 13% in a control group (9). Measurements of radiographs in 115 feet without evidence of hallux abducto valgus demonstrated a statistically significant and direct relationship between an increasing metatarsus adductus angle and an increasing hallux abductus angle (10). Banks et al. noted, in their series of patients with juvenile hallux abducto valgus, that 48 of the 72 cases had a metatarsus adductus angle greater than 15 degrees (11). Furthermore, an association was noted between an increasing metatarsus adductus angle and increasing amounts of hallux abductus.

The initial radiographic evaluation of hallux abducto valgus in patients with a concomitant metatarsus adductus is often misleading. Significant abduction of the hallux may be noted, yet with little intermetatarsal splay (Fig. 2). However, one must consider that the generalized adductus of the forefoot results in a greater functional value of the intermetatarsal angle. In this situation, the true intermetatarsal angle may best be estimated by the following formula (12):

True intermetatarsal angle = (Metatarsus adductus angle − 15 degrees) + Intermetatarsal angle

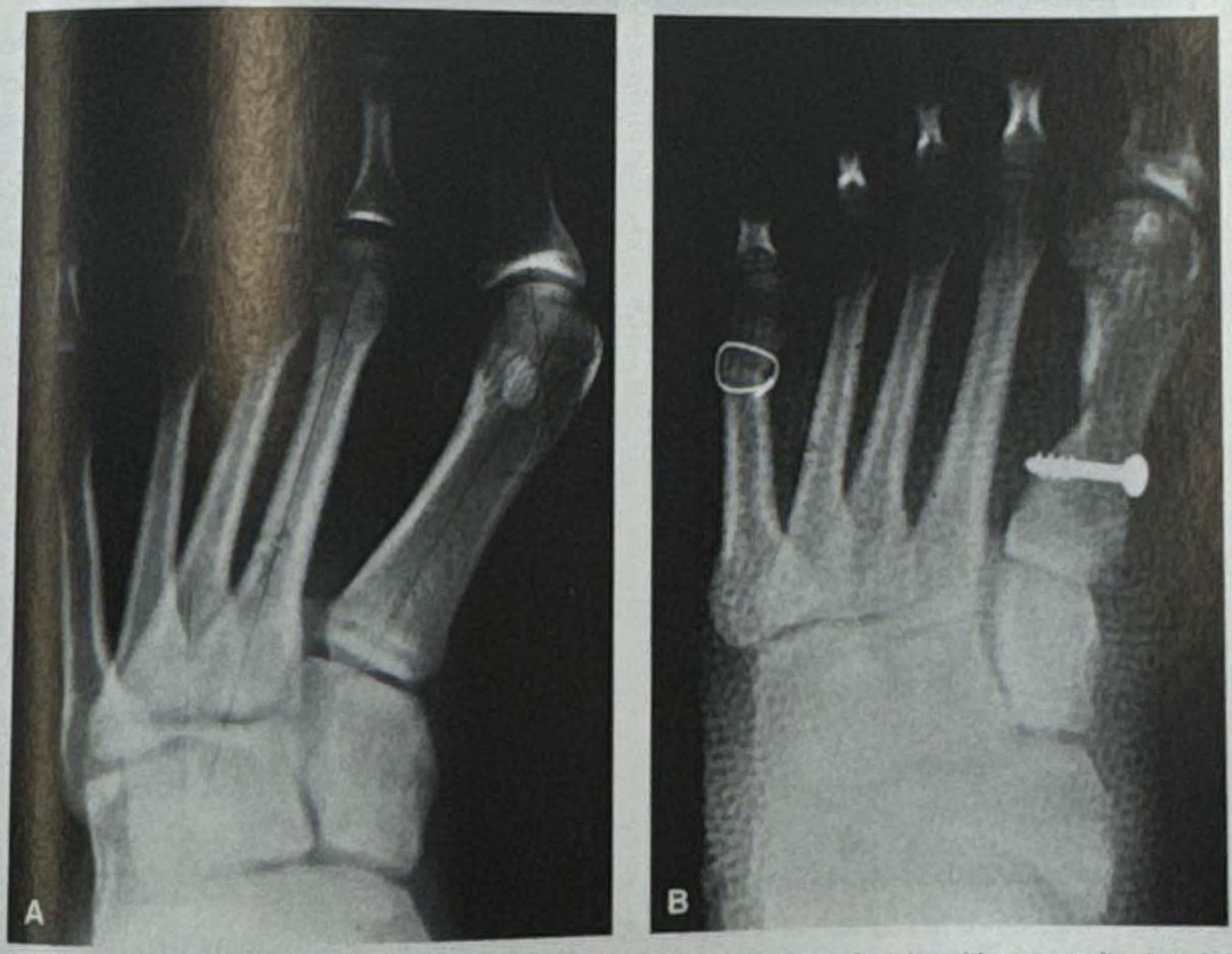


FIG. 2. **A:** A preoperative radiograph of a patient with hallux valgus deformity with concomitant metatarsus adductus. **B:** A closing base wedge osteotomy was performed to reduce the first intermetatarsal space.

This formula provides a better determination of the actual intermetatarsal angle being treated.

When repairing a hallux abducto valgus deformity in a patient with metatarsus adductus, the surgeon should reduce the intermetatarsal angle to 0 degrees or a slightly negative value to minimize the chance of recurrence of hallux abducto valgus (12). Despite excellent correction, the hallux may not remain perfectly rectus, but it may resume a slightly abducted alignment postoperatively. The longer radius for correction with a proximal osteotomy is well suited to achieve the degree of correction that is desirable.

Juvenile Hallux Abducto Valgus Deformity

The development of a hallux abducto valgus deformity in young patients represents significant deforming forces acting on the foot. Patients with juvenile hallux abducto valgus often present with other significant deformities. Banks et al. found that 66.7% of their patients with juvenile hallux abducto valgus deformity possessed a metatarsus adductus angle greater than 15 degrees (11). Pes valgus deformity and ankle equinus have also been associated with juvenile hallux abducto valgus (12–15).

In the younger patient, correction of hallux abducto valgus deformity must be maintained over decades. Studies have shown that the incidence of recurrence of the deformity is higher in young patients undergoing a soft tissue procedure or distal osteotomy (16–18). The intermetatarsal angle in juvenile and adolescent patients is best reduced to 0 degrees or closely approximating that value to minimize the possibility of recurrence. In most patients, this goal can be more effectively accomplished with a proximal osteotomy.

Iatrogenic Deformities

Correction of a recurrent hallux abducto valgus deformity often represents a difficult challenge. The metatarsal head is typically narrowed from the previous surgical procedure, and this configuration may make the use of a capital osteotomy difficult for the degree of correction required (Fig. 3). Furthermore, the presence of any retained fixation devices may compromise the integrity of the bone, so additional osteotomies at this level may pose more of a risk relative to fixation. In these instances, a proximal osteotomy may prove the best alternative, even if the intermetatarsal angle is low.

ANATOMIC CONSIDERATIONS

The choice of incisions for proximal osteotomies has been debated, but an effective incision may be placed dorsally

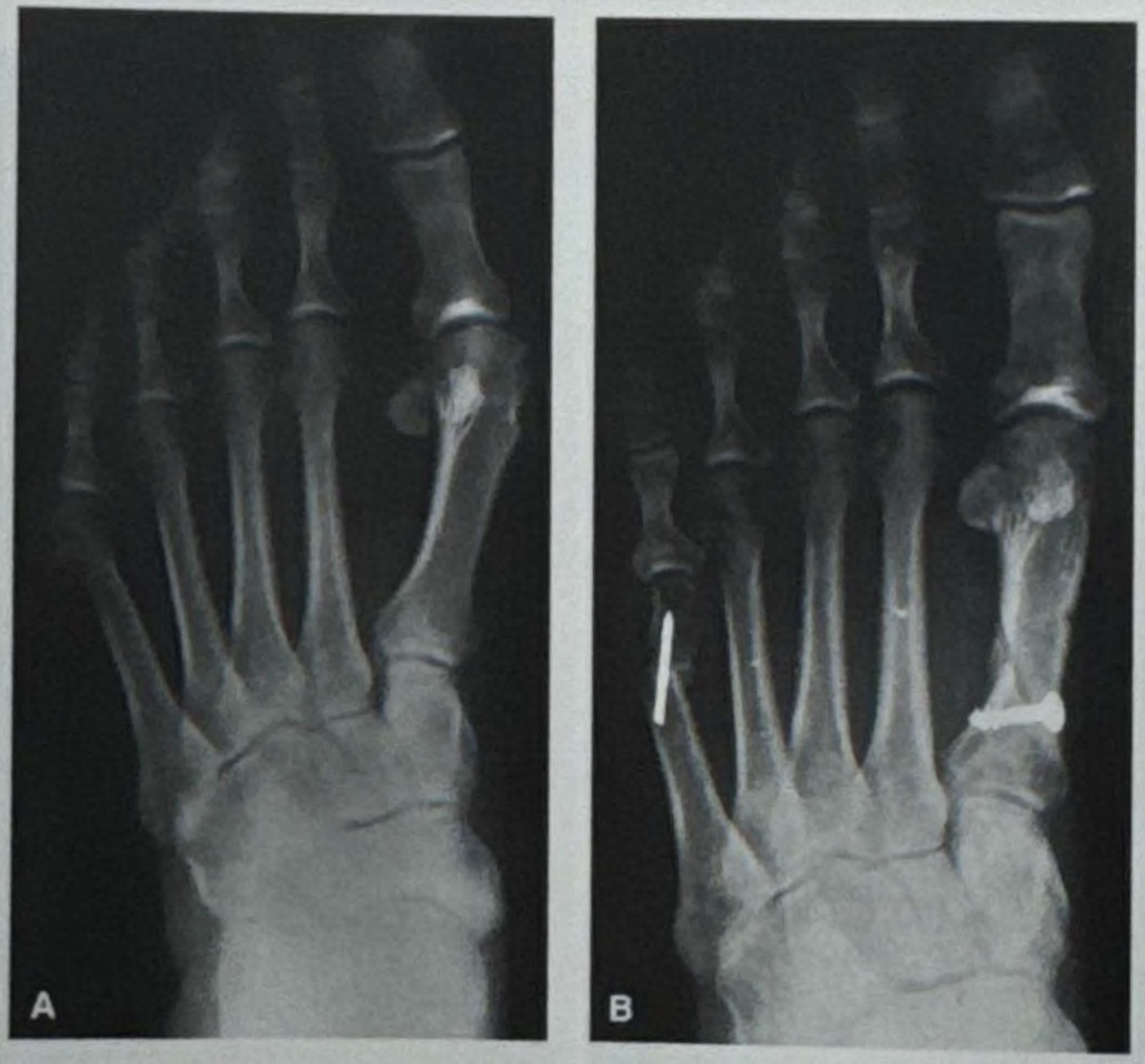


FIG. 3. A: Preoperative radiograph of a patient after a simple Silver bunionectomy with narrowing of the metatarsal head. This may preclude the use of a capital osteotomy for subsequent repair. **B:** Radiograph after a closing base wedge osteotomy.

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NSIDERATIONS

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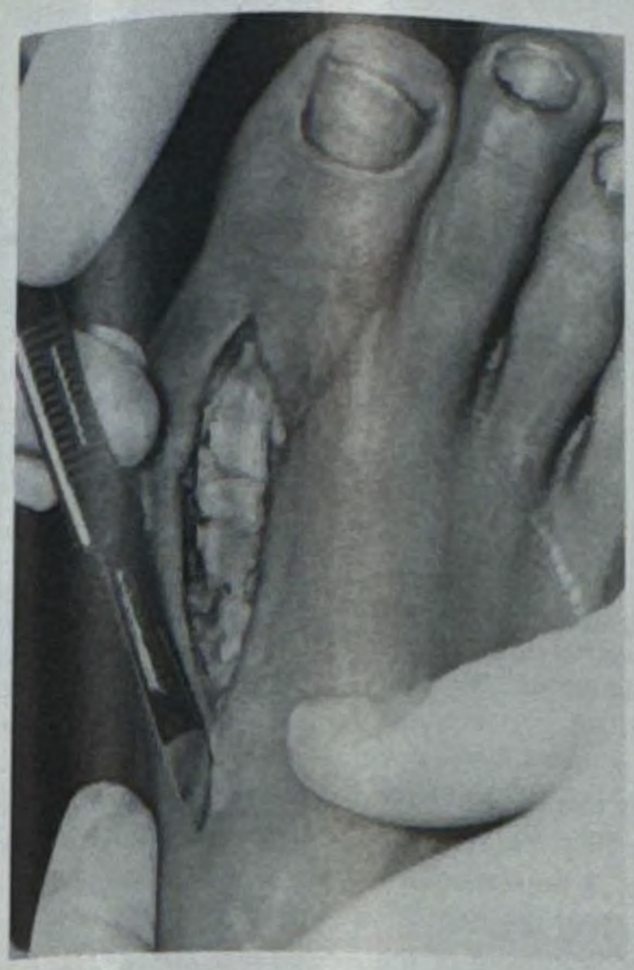


FIG. 4. Once the first metatarsophalangeal joint dissection has been accomplished, the skin incision is extended proximally for execution of the base osteotomy.

along the first ray slightly medial to the extensor hallucis longus tendon. The incision commences proximal to the first metatarsocuneiform joint and extends distally to the proximal phalanx. Typically, the distal segment of the incision is initiated and the metatarsophalangeal joint is released, and then the incision is extended proximally to provide access for the osteotomy (Fig. 4). The single-incision approach has been employed for decades without deleterious sequelae (8).

Once the skin incision is completed, dissection is carried through the relatively thin subcutaneous tissues. The previously defined tissue planes may be followed from the more distal aspect of the wound into the proximal metatarsal area. At the proximal aspect of the incision, one typically encounters a branch of the medial dorsal cutaneous nerve. This nerve is easily retracted into the medial subcutaneous tissues. Once the superficial fascia has been cleared from the deeper structures, the deep fascia is incised along the medial aspect of the extensor hallucis longus tendon. This provides for effective retraction of the tendon and better exposure of the base and shaft of the metatarsal. The periosteum is then incised and reflected from the base of the metatarsal. Additional dissection of this layer may be required both medially and laterally to allow satisfactory clearance for the saw blade during the performance of the osteotomy as well as the insertion of internal fixation.



FIG. 5. The transverse closing base wedge osteotomy.

TECHNIQUES

Closing Base Wedge Osteotomy

The closing wedge osteotomy has been the standard technique for base procedures for many years. Traditionally, the procedure was performed in a transverse orientation, and fixation was provided by Kirschner wires (K-wires), intraosseous wire loops, or other methods (Fig. 5). The transverse wedge osteotomy was modified to an oblique orientation to accommodate screw fixation (8) (Fig. 6). In addition, the oblique orientation allows the surgeon to place the apex of the osteotomy further proximally, thus providing a longer radius arm for correction. More freedom was obtained in



FIG. 6. The oblique closing base wedge osteotomy.

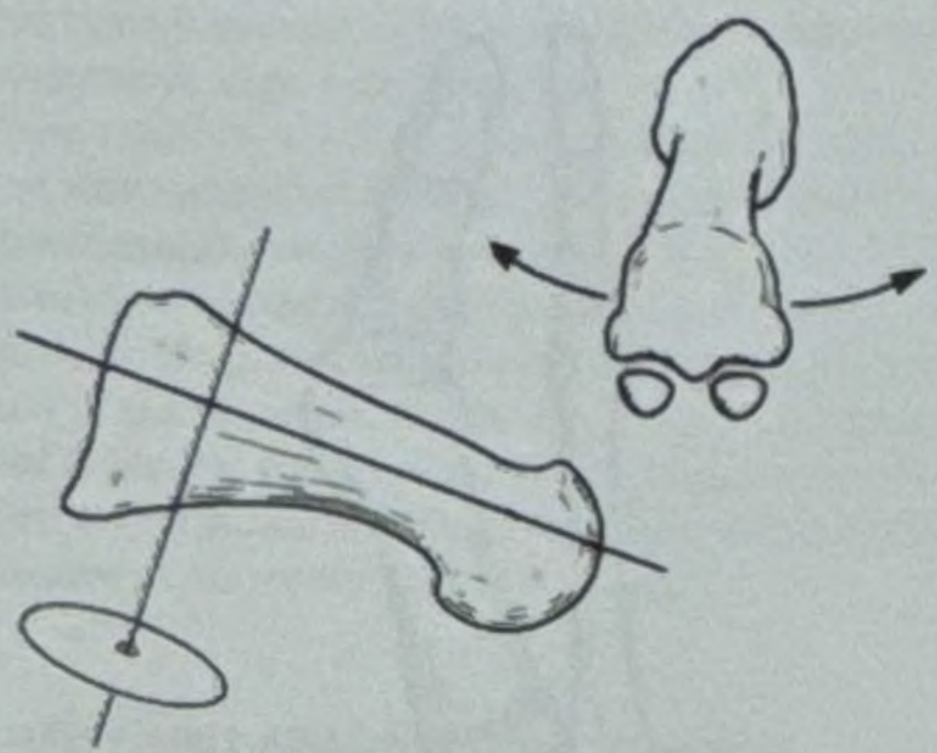


FIG. 7. Traditional axis of the base wedge osteotomy. If the osteotomy is made perpendicular to the metatarsal, subsequent lateral displacement of the distal metatarsal will result in sagittal plane dorsiflexion as well. Such may be the cause of a short first metatarsal.

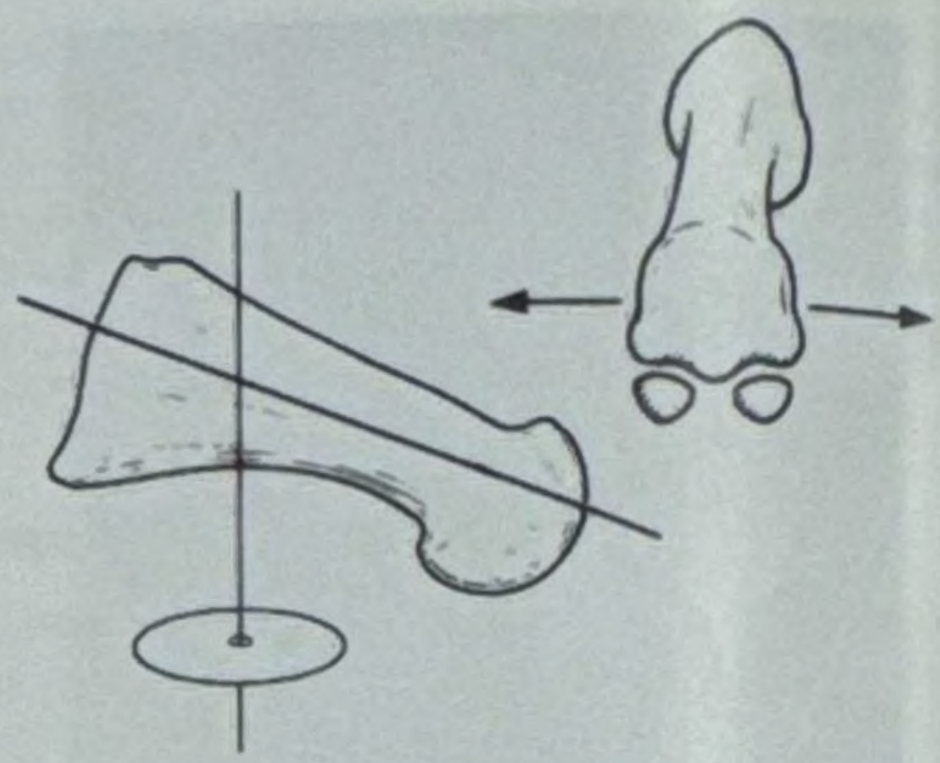


FIG. 8. If the osteotomy is made perpendicular to the weight-bearing surface, then lateral displacement of the distal metatarsal will not dorsiflex or plantarflex the metatarsal head, and it should remain parallel with the weight-bearing surface.

maneuvering the oscillating saw for performance of the procedure. With this technique, the handle of the saw is directed medially away from the foot and is free from the interference and contact of the foot itself. Therefore, the surgeon need not worry that the saw may be misdirected during the osteotomy.

Regardless of which orientation is employed, the use of an axis guide may facilitate the performance of the osteotomy. The axis guide also provides an accurate means of assessing and implementing concomitant dorsiflexion or plantarflexion of the distal metatarsal with closure of the osteotomy. During the base wedge osteotomy of the first metatarsal, an intact cortical hinge acts as an axis of rotation (8). The traditionally perceived axis for a hinged osteotomy of the first metatarsal was perpendicular to the long axis of the bone. Because of the anatomic declination of the first metatarsal in the human foot, rotation of the distal segment of the first metatarsal around this axis after a closing base wedge osteotomy would tend to create elevation of the metatarsal head from the weight-bearing surface (Fig. 7). However, designing the osteotomy so the axis is perpendicular to the weight-bearing surface allows for full rotation of the distal segment of the metatarsal without elevating or plantarflexing the metatarsal head in relation to the weight-bearing plane (Fig. 8).

The previous description of the sagittal plane orientation of the axis is based on the given relationship that the axis is perpendicular to the transverse plane when viewed in the frontal projection. Logically, manipulation of the axis in the frontal plane may influence the ultimate position of the metatarsal head in relation to the weight-bearing surface. Manipulation of the axis in the frontal plane is based on the presumption that the axis remains perpendicular to the weight-bearing surface in the sagittal plane.

With the axis perpendicular to the weight-bearing surface in the frontal plane, lateral rotation of the distal metatarsal segment maintains the metatarsal head on the weight-bearing surface (Fig. 9). When the superior pole of the axis is tilted laterally, a dorsomedial hinge is created, and plantarflexion of the distal segment of the metatarsal occurs with lateral rotation or closing of the wedge osteotomy (Fig. 10). Conversely, when the superior pole of the axis is tilted medially, a plantar medial hinge is created, and dorsiflexion of the distal segment occurs with closing of the wedge osteotomy (Fig. 11).

The concept of the axis relationship just described may be directly applied to the actual execution of the closing base wedge osteotomy of the first metatarsal. A 0.045-inch K-



FIG. 9. Proper frontal plane orientation must be observed as well. Same perpendicular relationship of the axis is essential if the distal segment is to remain on the weight-bearing surface after closure of the osteotomy.



FIG. 10. Altering the position of the axis may be used to the surgeon's advantage. If the axis is tilted laterally, then a dorsomedial hinge is created. When the osteotomy is closed, plantarflexion of distal segment occurs.

wire can be drilled through the base of the first metatarsal to represent the functional hinge of the intended osteotomy. The K-wire should penetrate the dorsal cortex just short of the apex of the intended osteotomy, to allow for additional feathering of the hinge. The wire is then drilled to penetrate the metatarsal at the appropriate angle, which affects manipulation of the distal metatarsal as required for each individual case.

With the K-wire in place, the relationship of the axis with the weight-bearing surface is evaluated from a medial and frontal perspective. The position of the axis may easily be changed before the osteotomy by simply removing and reinserting the K-wire.

The wedge osteotomy is then cut by keeping the plane of the saw blade in line with the axis guide so the planes of the two cuts converge at the K-wire. The medial cortex of the metatarsal remains intact as a physical hinge that coincides with the axis and planes of the intersecting wedge osteotomies. The osteotomy may be feathered to create a flexible yet intact hinge that bends but does not fracture with manual reduction. Christensen et al. showed that the intact medial hinge provides stability to the osteotomy and functions as another point of fixation (19). If the hinge fractures, the stability of the osteotomy will be reduced, and fixation may prove more difficult.



FIG. 11. Should dorsiflexion of the distal segment be necessary, then the axis should be tilted medially.

Various forms of fixation have been employed with the closing base wedge osteotomy, and studies have been conducted in an attempt to determine which form of fixation is more stable (20,21). An important factor for a successful closing base wedge osteotomy is the presence of two points of fixation. An intact medial cortical hinge may be considered one point of fixation. The transverse wedge osteotomy is more commonly stabilized with crossed K-wires or cerclage wire. Evidence seems to indicate that when a K-wire is used, the osteotomy is more stable if the wire crosses the metatarsal-cuneiform joint (21). Cerclage wire appears to provide the most stability when it is applied at the plantar aspect of the metatarsal, such that it prevents disruption by the weight-bearing forces (20).

Although K-wires and cerclage wire are commonly used for fixation, the technique I favor is the use of two 4.0-mm partially threaded cancellous screws to secure the osteotomy. This has provided effective fixation and a high rate of success. The first screw is placed distal to the medial hinge and is oriented perpendicular to the metatarsal. The second screw is positioned distal to the first and is oriented perpendicular to the osteotomy (Fig. 12). Alternatively, crossed-screw fixation of the base wedge has been described, with favorable results (22). The cancellous screws are employed more often because they provide rigid fixation of the osteotomy, regardless of the integrity of the bone. However, provided non–weight-bearing is instituted after surgery, both crossed 0.062 K-wires and a single screw may provide good results that are comparable (23). Cortical bone screws also provide good stabilization.

The closing base wedge osteotomy has always been an effective means of reducing the intermetatarsal angle, although early reviews noted that shortening of the first metatarsal was a common occurrence after a transverse base wedge osteotomy (3–7). As a consequence, metatarsalgia, painful plantar callosities, and stress fractures of the lesser metatarsals developed in some patients. However, the base wedge osteotomy was not totally abandoned because it provided a much needed alternative in patients with severe deformities with high intermetatarsal angles. A few workers persisted in the investigation of the procedure (24), and the technical aspects were further advanced by the application of rigid internal fixation across angulated osteotomies. However, elevation of the first metatarsal continued to develop even with the use of the new fixation

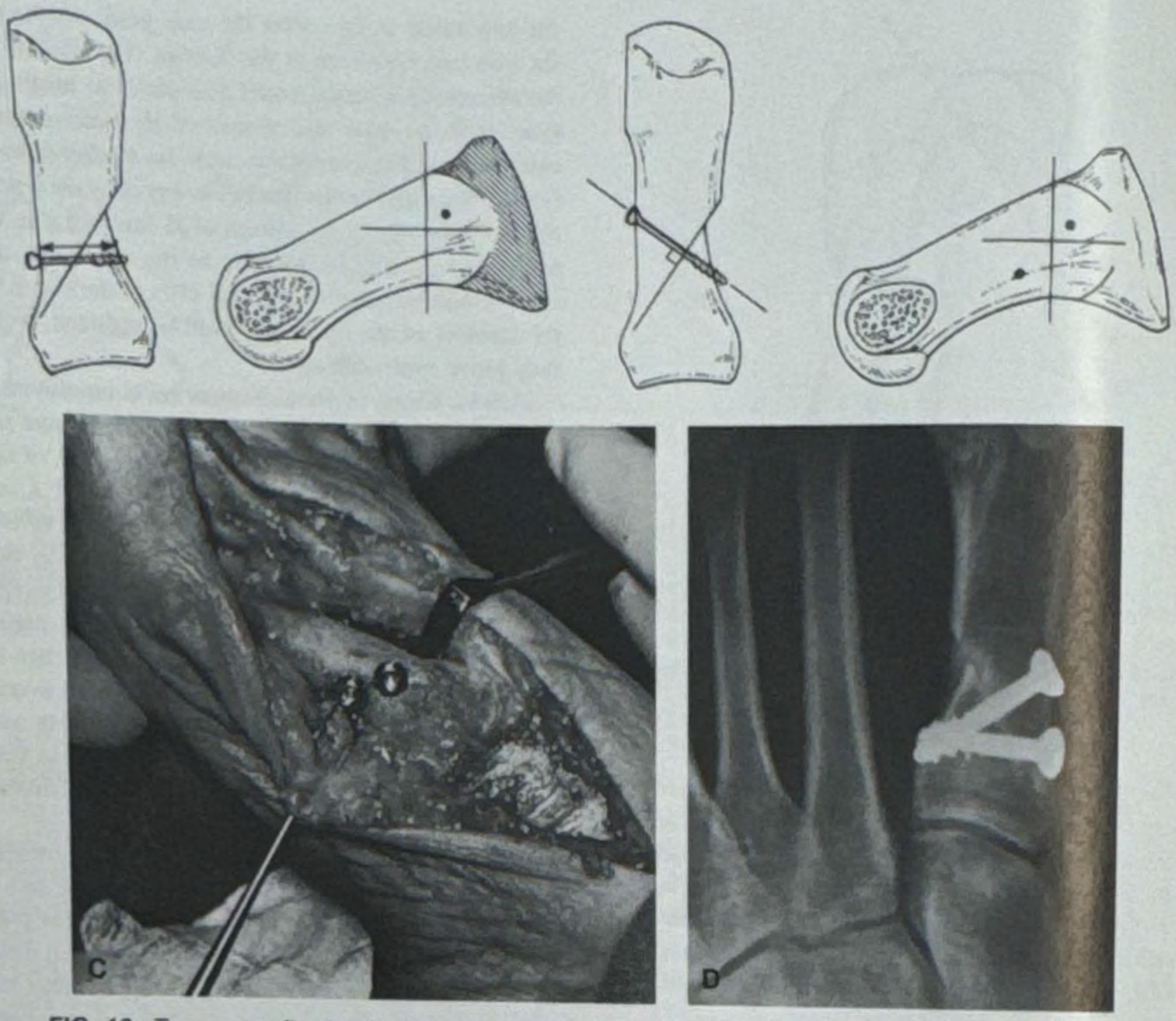


FIG. 12. Two-screw fixation for the oblique closing base wedge osteotomy. **A:** The anchor screw is oriented perpendicular to the medial cortex or long axis of first metatarsal. **B:** Compression screw perpendicular to the plane of the osteotomy. **C:** Medial orientation of the two-screw technique. **D:** Compression and anchor screws.

techniques. Although some authors proposed that the change in metatarsal declination was related to the removal of excessive amounts of bone from the dorsal aspect of the osteotomy (6), Schuberth et al. attributed this phenomenon to weight bearing in the postoperative period before osseous healing had occurred, as opposed to its being a primary complication of the procedure itself (7). Furthermore, the radiographic appearance of a shortened metatarsal could largely be explained by the elevation of the distal fragment, which could be overcome by geometrically correct osteotomy and an appropriate interval of non–weight-bearing during the healing process (8). Later investigators proved that the shortening associated with the oblique base wedge osteotomy was less than actually perceived. Using both mathematic and bone models, investigators determined that the average oblique base wedge osteotomy would result in less than 2 mm of shortening, comparable to most other osteotomies (25). Therefore, elevation of the first metatarsal would be a primary means of creating the appearance of a "shortened" metatarsal on dorsoplantar radiographs. Other investigators noted that early weight bearing in the postoperative period either contributed to or directly caused failure of the fixation (26).

However, later authors who instituted at least 6 weeks of non–weight bearing after the closing base wedge osteotomy continued to find evidence of first metatarsal elevatus, although of far less magnitude and with few associated problems (19,27,28). Nonetheless, patient satisfaction rates were high, and evaluations of the results by the investigators were similar. The problems of transfer lesions or other symptoms related to the alignment of the first ray were minimal. In one study, 44% of patients admitted to premature weight bearing on the extremity (28). Whether this is a consistent finding in other patient groups or whether this accounts for the small degree of metatarsal elevation is unknown. In addition, an inconsistency is noted in the means by which first metatarsal elevation has been measured on radiographs, and

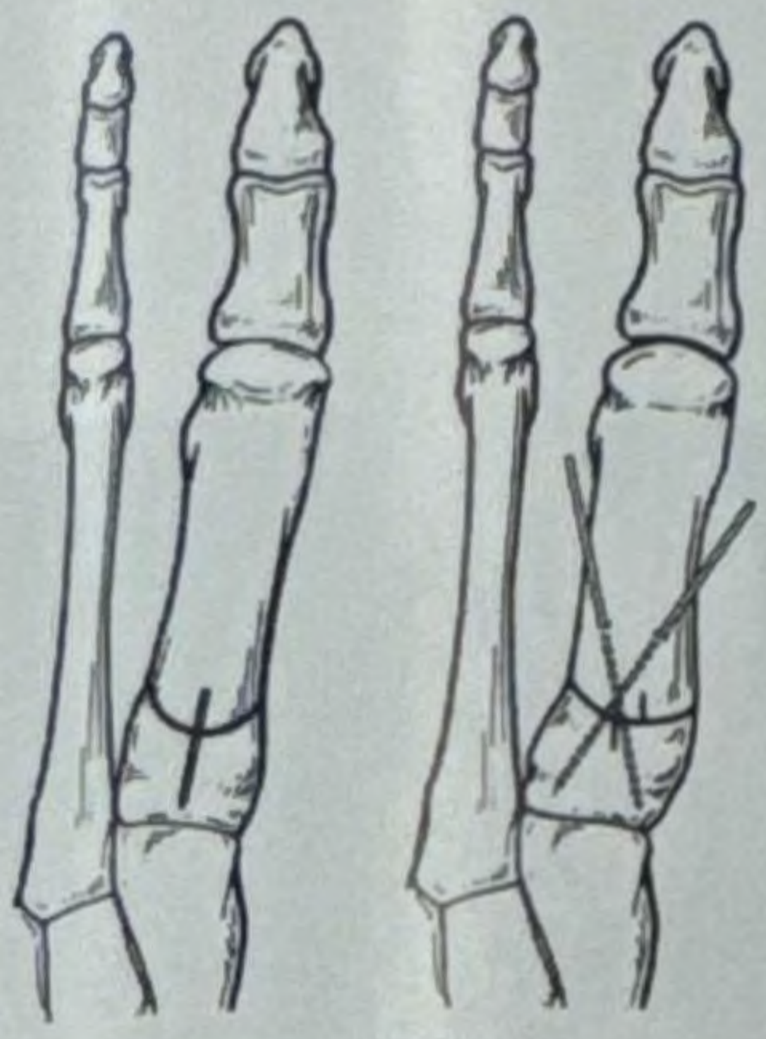


FIG. 13. A,B: The crescentic first metatarsal osteotomy. A notch may be made on each side of the osteotomy before rotation to help assess the amount of correction achieved.

al times the values could have been affected by the position of the foot. Therefore, it appears that at the current levels of elevation noted with non–weight bearing in the postoperative setting, this phenomenon is clinically inconsequential. Good correction can be achieved with restoration of function.

Crescentic Osteotomy

The crescentic osteotomy is another popular technique for achieving reduction of the intermetatarsal angle at the proximal aspect of the first metatarsal. This procedure may provide correction of deformity in all three planes (Fig. 13). Because no bone is resected, this procedure theoretically produces little shortening (29), so it may be a good alternative in the patient who has a significantly short first metatarsal. However, the performance of any osteotomy creates some amount of shortening, typically in the range of 1 to 2 mm. The osteotomy has been modified to include a plantar shelf in an attempt to provide more stability (30).

A special crescentic blade is necessary to perform the procedure. The saw blade is oriented with the concavity directed proximally, so there is more excursion of the bone segments to allow for correction of the intermetatarsal angle. This also allows for better bone contact once the osteotomy is rotated (31). Cohen et al. and Kay et al. demonstrated how the orientation of the blade directs the correction in each plane (29,30). As in the closing base wedge osteotomy, the cut should be oriented so the saw is perpendicular to the weight-bearing surface to prevent dorsiflexion of the distal metatarsal with lateral rotation. If the blade is oriented laterally, then plantarflexion of the distal segment will occur, with reduction of the intermetatarsal angle. If the blade is oriented medially, then dorsiflexion will occur with translation of the osteotomy.

The osteotomy is best performed distal to the plantar flare of the metatarsal; otherwise, the cut will be difficult to complete. A small notch may be made at the intended osteotomy site, to provide a better determination of the amount of correction that is achieved with rotation of the distal segment (Fig. 14). However, care must be taken not to produce significant plantarflexion and inversion during correction of more severe deformities. It appears that the best correction of the intermetatarsal angle may be achieved when the saw diameter is larger than the diameter of the osteotomy site (31).

Although the crescentic osteotomy does provide good correction, it has some disadvantages. Because there is no fixed hinge, the osteotomy is unstable, and this feature may make it difficult to achieve solid, reliable fixation across the osteotomy site. The cannulated screw system has facilitated this process (32). Fixation may consist of one screw (33,34), two screws (32), one screw and one K-wire (35), crossed K-wires, or Steinmann pins. The screws can become prominent at a later time and may require removal (33).

Cohen et al. described a modification of the crescentic procedure that incorporated a plantar shelf to enhance overall stability (30). A K-wire was introduced medially at the apex of the osteotomy, and the plantar shelf was created initially with a sagittal saw. The dorsal crescentic cut was then performed. Good results were noted without sagittal plane deviation of the first metatarsal. Later studies comparing the crescentic shelf and standard crescentic procedures indicated that, by using the shelf procedure, one could produce slightly greater reductions in the intermetatarsal angle and enhanced plantarflexion of the distal metatarsal, although the differences were not statistically significant. Overall, both procedures possessed similar mechanical properties, although investigators believed that the shelf osteotomy may be easier to fixate (36).

Favorable results have generally been reported with the procedure (30,32–35,37). Although the crescentic osteotomy may tend to resist sagittal plane disruptive forces more effectively than a base wedge osteotomy (38), weight bearing cannot be recommended before osseous consolidation. Unrestricted weight bearing has been associated with metatarsal elevation (33–35), although most authors have apparently not altered their postoperative regimen to prevent this potential problem.

Chevron Osteotomy

The procedure was first described by Kotzenberg in 1929 as a horizontal "V" in Schotte's article (39). The osteotomy is performed 1 to 1.5 cm from the metatarsal cuneiform joint. The apex of the osteotomy can be oriented either distally or proximally, although most surgeons appear to favor a distal

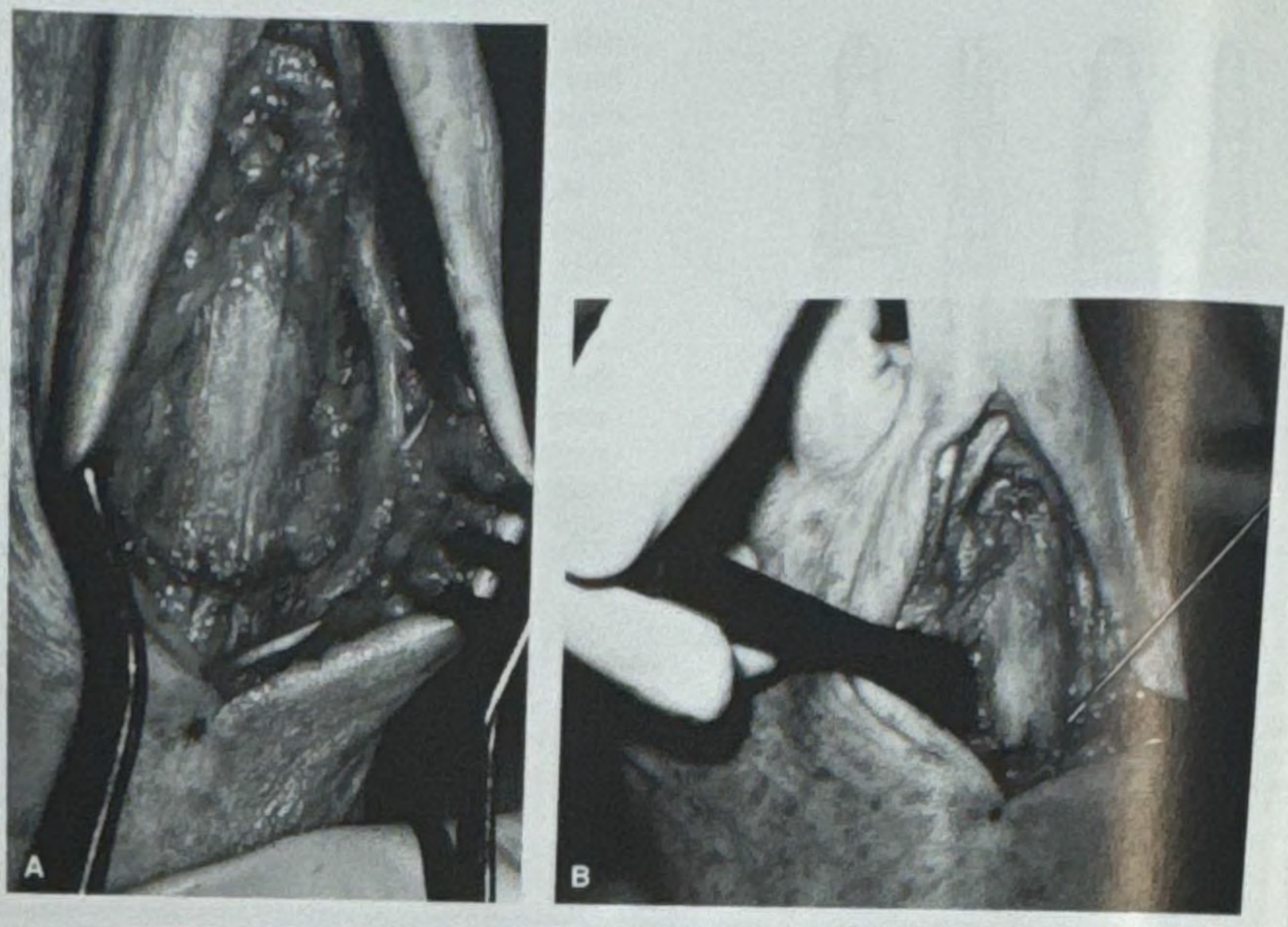


FIG. 14. A: The crescentic osteotomy is performed with the concavity directed proximally. **B:** A crescentic osteotomy is temporarily fixated with a guidewire for a cannulated screw. **C:** A preoperative radiograph of a patient with a high intermetatarsal angle. **D:** After the crescentic osteotomy and fixation with two cannulated screws. (Courtesy of Ira Fox, D.P.M.)

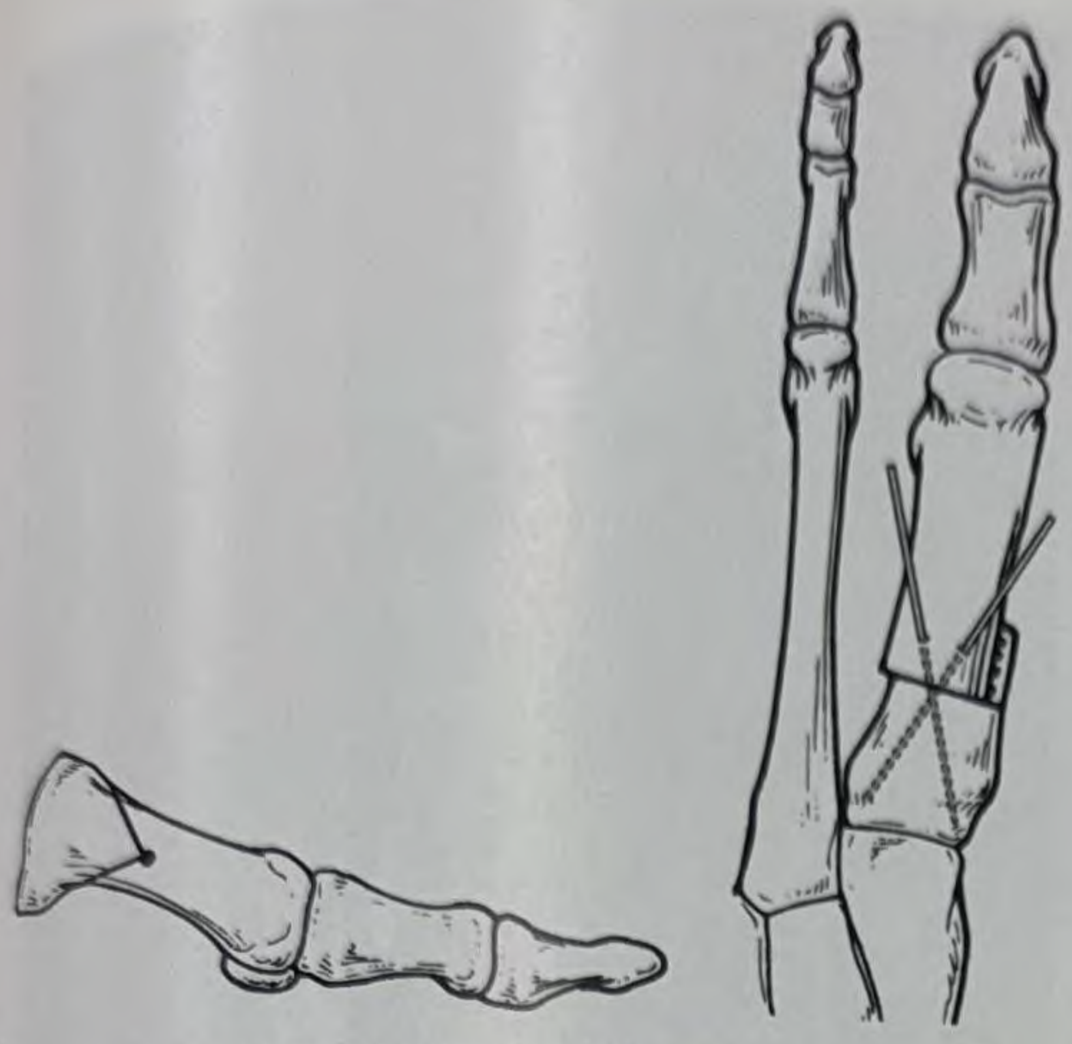


FIG. 15. **A,B:** The proximal chevron osteotomy.



FIG. 16. The opening wedge osteotomy. A laterally based hinge is necessary for this procedure.

apex. In either instance, care should be taken to avoid compromise of the first metatarsal cuneiform joint (Fig. 15). The same axis guide techniques described for osteotomies of the metatarsal head may be incorporated into the proximal procedure to shorten, lengthen, dorsiflex, or plantarflex the distal metatarsal with lateral transposition. However, because the osteotomy is primarily transpositional, it does not appear to provide any advantage over the more distally based Austin procedure. Regardless of the location of the osteotomy, similar amounts of lateral shift result in similar reductions in the intermetatarsal angle. Improved correction may be achieved with the proximal chevron procedure if the distal segment is swiveled laterally before fixation. The design of the osteotomy affords good stability in the sagittal plane.

One may experience some difficulty in securing fixation. The V-osteotomy may be stabilized with one (40) or two screws, or a single (34) or crossed K-wires (35). In some instances, the screw may have to traverse the tarsometatarsal joint to achieve adequate stability (40).

Favorable experiences have been reported with the procedure, and few complications have been noted (34,40). Dorsal angulation of the first metatarsal has been noted in some patients (34). Although weight bearing has been allowed in the postoperative setting, it cannot be recommended.

Opening Base Wedge Osteotomy

The opening base wedge osteotomy is seldom performed today because of the increased technical demands of the procedure. A primary indication is an excessively short first metatarsal resulting from iatrogenic or congenital causes. The hinge is laterally based, and a bone graft is placed in the osteotomy site to achieve correction by expanding the medial side of the metatarsal (Figs. 16 and 17). Graft can be harvested from many possible donor sites in the foot, leg, or hip. The medial eminence from the metatarsal head is often used because it is readily accessible (41). However, in some instances, the quality of bone from this area is not optimal and has been associated with loss of correction with time (42).

The opening base wedge osteotomy has an increased healing time because of the time required for the graft to incorporate into the metatarsal. The use of a graft also increases the risk of delayed union or nonunion. Furthermore, at times one may note a delayed shift in the alignment of the distal metatarsal. Fixation may be provided with crossed K-wires, cerclage wire, plates and screws, staples (41), or external fixation (43), although originally this osteotomy was not fixated (44), and other surgeons have allowed weight bearing in a cast without fixation (42). Youngswick recommended that the osteotomy be performed, the metatarsal rotated to the corrected position, and staple fixation applied prior to the insertion of the bone graft (41).

The purpose of the opening wedge osteotomy is either to lengthen or to prevent shortening of the metatarsal, although this may predispose the patient to developing a hallux limitus or hallux rigidus deformity by increasing tension at the metatarsophalangeal joint. Curiously, few studies have actually evaluated the change in length after the procedure, although one series noted no significant change in the relative lengths of the first and second metatarsals at postoperative follow-up (42). If this finding is accurate, then it would appear to obviate the specific indication for the opening wedge osteotomy compared with other proximal procedures, especially considering the additional risks and complexities of the former.

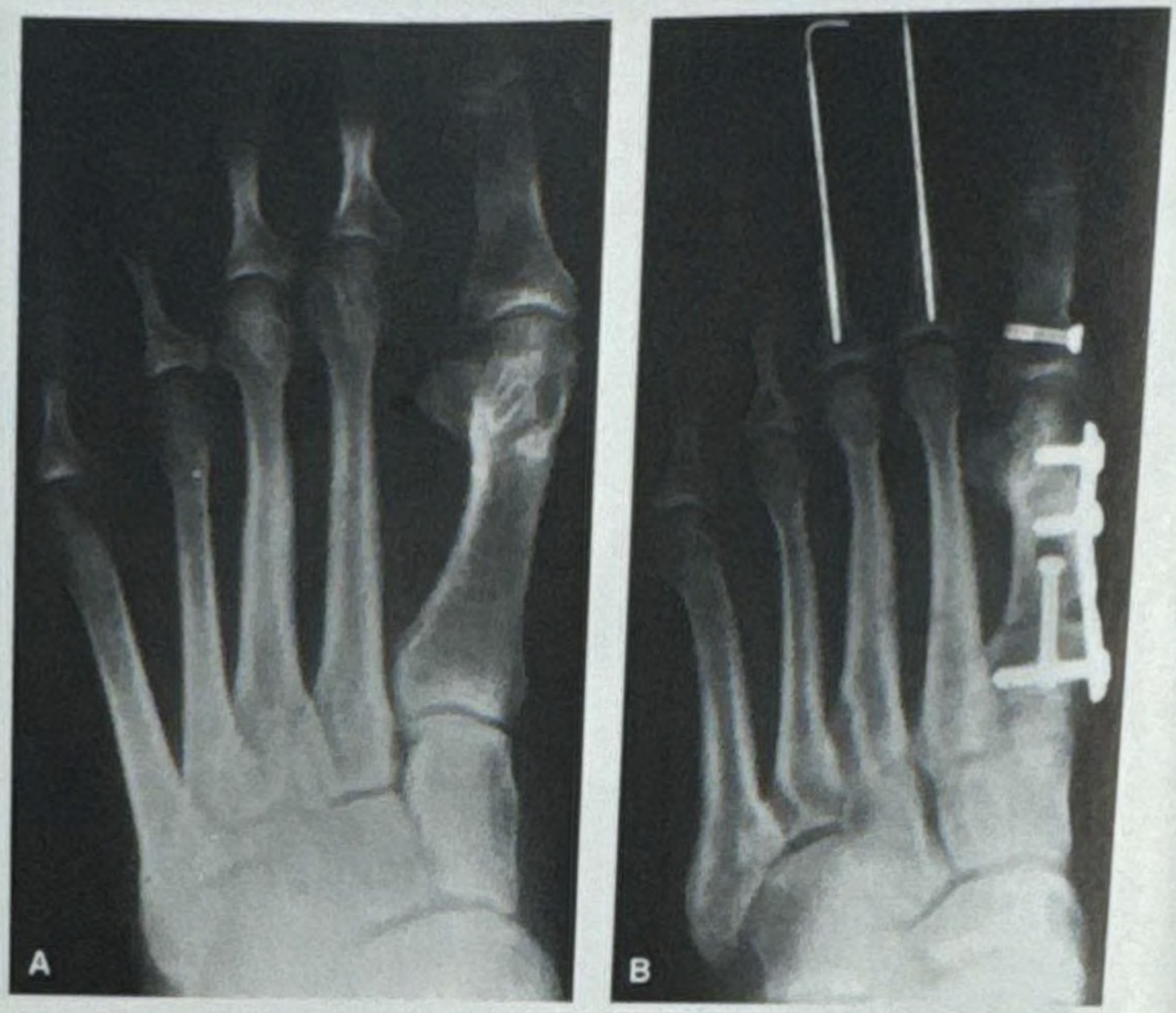


FIG. 17. A: A patient with recurrent hallux abducto valgus deformity and a short first metatarsal. **B:** After an opening base wedge osteotomy. Stabilization was achieved with a plate and screw.



FIG. 18. A,B: Elevation of the first metatarsal may develop after any proximal first metatarsal if weight bearing is allowed before healing.



FIG. 19. **A,B:** Nonunion of the first metatarsal base resulting in part from early weight bearing. **C:** The nonunion was resected, and a bone graft was obtained from the patient's iliac crest to preserve length to the metatarsal.

POSTOPERATIVE COURSE

Proximal osteotomies must be protected against the disruptive forces of weight bearing, regardless of the procedure or fixation. Although most distal osteotomy designs can withstand the forces of weight bearing, the base osteotomy can be easily disrupted by the forces transmitted through the longer lever arm (Fig. 18). Once the internal fixation is compromised, instability of the osteotomy will occur, producing motion and ultimately elevation of the first metatarsal. If the disruptive forces continue across the osteotomy site, a delayed union or nonunion can develop (Fig. 19). Non–weight bearing is maintained for a minimum of 6 weeks and until evidence of bone healing is sufficient. The patient is placed in a below-knee non–weight-bearing cast, and ambulation is assisted with crutches, walker, or a knee walker. Early passive range of motion of the first metatarsal phalangeal joint can begin even during the casting period. The range-of-motion exercises can also be performed at the lesser metatarsal phalangeal joints and the knee. After 6 weeks, the patient can usually progress to protective weight bearing, provided the patient has radiographic evidence of osseous healing and satisfactory clinical evaluation.

SUMMARY

Base osteotomy of the first metatarsal can be a successful and rewarding component of hallux valgus surgery. Many advances have been made in the technical aspects of these procedures, such as precise resection of bone and stable fixation techniques that have accounted for fewer complications and improved results. The use of the hinge-axis concept can aid in the proper orientation of the osteotomy. Once the osteotomy is temporarily fixated, one should evaluate the patient's foot to ensure that the proper amount of correction

has been achieved. It appears that subsequent elevation of the first metatarsal has been noted with all these procedures, although the outcomes achieved would lead one to believe that this is not a functional problem with the amount of displacement currently observed.

In all osteotomies of the first metatarsal base, stable fixation is important to ensure a successful result. Although studies may indicate that one form of fixation is superior to another for any given procedure, in actual clinical practice, these differences often prove insignificant, provided good correction is achieved and appropriate measures are instituted after surgery. Regardless of which procedure is performed, the patient must remain non–weight bearing for a minimum of 6 weeks and until bone healing is sufficient. Osteotomy of the first metatarsal base provides predictable long-term results in a reliable manner in the compliant patient, especially when careful attention is paid to the technical aspects of its execution.

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PART 2

Metatarsal Cuneiform Procedures

Alan R. Catanzariti and Edwin L. Blitch IV

FIRST METATARSOCUNEIFORM ARTHRODESIS

Procedures involving the first metatarsocuneiform joint have been advocated since the earliest stages of hallux valgus repair. The initial impetus for surgical intervention at this site was based on what was believed to be the primary cause of hallux abducto valgus (1–3). Truslow described hallux abducto valgus as secondary to a "metatarsus primus varus," which would need to be addressed for surgical treatment to be successful. To accomplish this purpose, he favored a wedge resection from the first metatarsocuneiform joint (2). Kleinberg believed that the most remarkable finding on a dorsoplantar radiograph in patients with hallux abducto valgus was the adduction of the first metatarsal. He noted that whereas the remaining tarsometatarsal joints were transverse, the first metatarsocuneiform joint was oriented in a more oblique manner. To correct the primary cause of the hallux abducto valgus, Kleinberg believed that one would be required to address the tarsometatarsal joint. Truslow's procedure was thought inadequate to reduce the deformity, and Kleinberg proposed a double wedge resection of the joint that would allow the first and second metatarsals to be oriented parallel to one another (3). Later, Lapidus described metatarsus primus varus as an atavistic foot type that had not fully developed over previous phylogenetic forms. Again, this increased separation between the first and second metatarsals was deemed the most frequent cause of hallux abducto valgus, and resection of the first metatarsocuneiform joint was advocated (4).

As the decades passed, the philosophies regarding the origin of hallux abducto valgus changed, yet resection of the first metatarsocuneiform joint remained an accepted procedure, albeit with a different perspective. Other indications have evolved, so arthrodesis of the first metatarsocuneiform joint remains a viable option in patients with hallux abducto valgus (Fig. 20).

Indications

In numerous instances, arthrodesis of the first metatarsocuneiform joint may prove an acceptable choice in the repair of hallux abducto valgus. Correction of large intermetatarsal angles may be readily accomplished; an intermetatarsal angle greater than 15 degrees has been an arbitrary level at which the procedure was deemed appropriate (5–7). However, the procedure may also be employed in patients with lower intermetatarsal angles and concomitant metatarsus adductus or a long first metatarsal, to enhance first ray stability, in cases of revisional surgery, or in patients with degenerative change or symptoms at the first metatarsocuneiform joint. Arthrodesis at this level may also be helpful in addressing hallux rigidus secondary to metatarsus primus elevatus. The procedure permits repositioning of the first metatarsal in the sagittal plane and is particularly effective if the first metatarsal is long.

A common use that has evolved for the procedure has been in conjunction with a hypermobile first ray or in patients with ligamentous laxity. Hypermobility of the first ray has classically been noted as a precursor to hallux abducto valgus deformity (8). However, exactly what constitutes abnormal motion within the medial column has not been firmly established. First ray motion involves two distinct joints: the medial naviculocuneiform joint and the first metatarsocuneiform joint. The primary source of motion in a normal first ray is at the medial naviculocuneiform joint (9,10). Specifically, an average of 12.3 degrees of motion has been noted at the medial naviculocuneiform joint and 5 degrees at the first metatarsocuneiform joint (10). Gellman et al. found that the first metatarsal itself could dorsiflex about 5.0 degrees (11). Wanivenhaus and Pretterdklieber described the dorsal shift from neutral at the base of the first metatarsal as measuring about 2.6 mm (12). Furthermore, the actual shape of the first metatarsocuneiform joint has been proposed to have an influence on the range of motion as well (13,14). However, the contribution of each component joint to the total range of first ray motion and the amount of motion available as a whole will vary, in some instances to a significant degree (10,15).

Clinical studies have appeared to support the values derived from the laboratory and have demonstrated that patients with hallux abducto valgus deformity may possess a greater degree of first ray mobility compared with control patients (16). Additional studies have shown an association between a hypermobile first ray and generalized ligamentous laxity. An evaluation of 50 patients presenting with various foot problems revealed a marked increase in the intermetatarsal and hallux abductus angles when hypermobility was present (17). Hyperflexibility of the thumb has been associated with first ray hypermobility, yet no correlation was found between first ray motion and sex, age, intermetatarsal angle, size, skin stretch, hyperextension of the knee, or shape

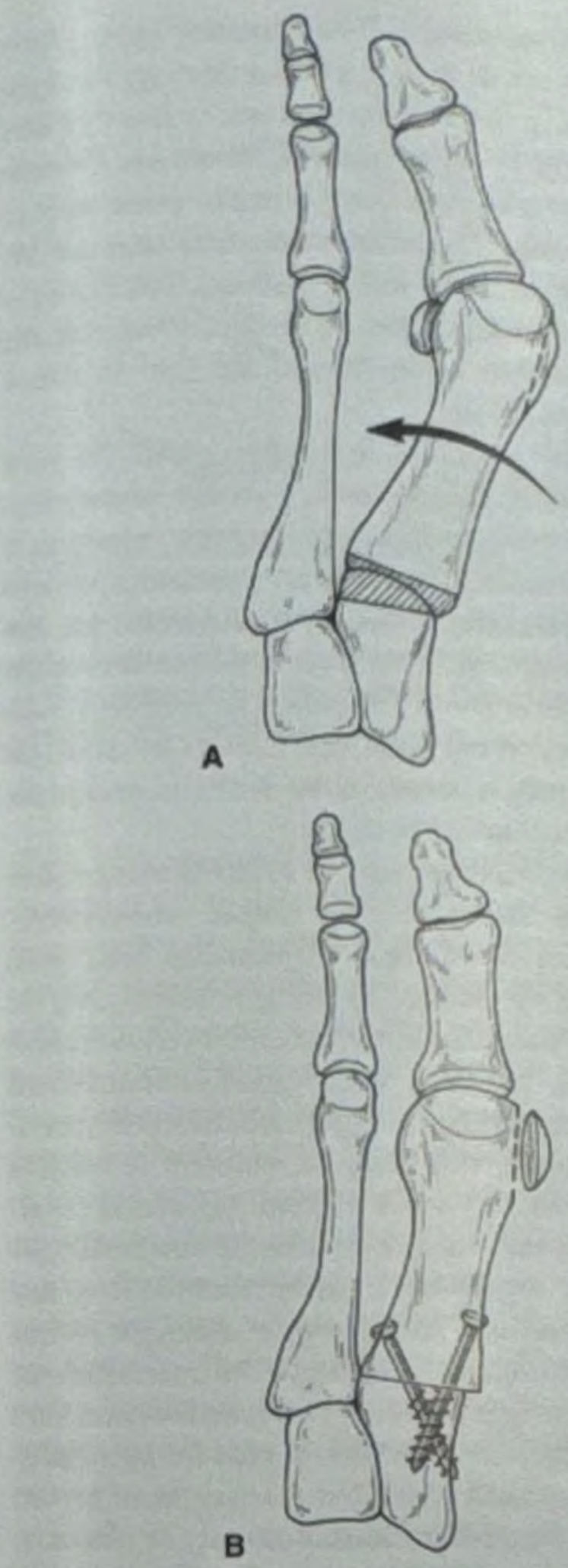


FIG. 20. A,B: The first metatarsocuneiform arthrodesis for correction of hallux abducto valgus deformity.

of the distal cuneiform (14). In female patients with symptomatic hallux abducto valgus, a statistically significant correlation was found with mild generalized hypermobility when compared with a similar control patient group (18).

Radiographic features associated with hypermobility are difficult to assess and are generally nonspecific. Most radiographic findings are secondary to structural changes that develop over time. A modified Coleman block test has been recommended to produce maximum dorsiflexion and plantarflexion of the first ray to assess motion at the first metatarsocuneiform joint with a lateral radiograph. Although this test may demonstrate the motion available at the joint, no objective studies have been conducted to demonstrate its reliability (19). Cortical thickening of the second and possibly third metatarsals on an anteroposterior radiograph may provide indirect evidence of a hypermobile first ray.

Hallux abducto valgus deformity resulting from hypermobility of the first ray has been described as a prime indication for arthrodesis of the first metatarsocuneiform joint (5,20–25). This procedure can indirectly restore functional stability to the medial column by allowing the peroneus longus muscle to have a greater mechanical advantage at the medial naviculocuneiform joint, where the majority of first ray motion occurs. Furthermore, this procedure has also been recommended in patients with concomitant hallux abducto valgus deformity associated with a hypermobile flatfoot (24,25).

However, a hypermobile first ray is a relative, but not an absolute, indication for first metatarsocuneiform arthrodesis. Numerous procedures have proven successful in the repair of bunion deformities, many in patients who undoubtedly possessed a hypermobile first ray. Most first ray mobility occurs at the naviculocuneiform level (9). Although arthrodesis at the more distal joint may enhance stability, other methods such as a modified Young procedure or naviculocuneiform joint arthrodesis may also prove suitable. Furthermore, orthotic devices may be employed to address medial column instability postoperatively. The actual selection of the procedure is based on the knowledge, skill, training, and experience of the surgeon and on the specific clinical findings and concerns unique to the patient. Numerous options may be suitable for any given situation.

First metatarsocuneiform arthrodesis has also been recommended for adolescents with hallux abducto valgus deformity. Several studies in this patient population have demonstrated good results (21,24). Although this procedure has been recommended for adolescents with a closed epiphysis, the procedure may be used in adolescents with an open growth plate with no complications. Smooth wires or pins are used for fixation in this setting. Temporary use of smooth pins has not been found to damage an open growth plate (5,26). However, because growth plate damage may develop secondary to periosteal dissection (7), one must be careful to avoid unnecessary stripping of the soft tissues away from the physis. Myerson et al. found that in adolescents with a hypermobile first ray, realignment could be accomplished with a first metatarsocuneiform arthrodesis without distal soft tissue release or exostectomy (24). Avoiding surgery at the metatarsophalangeal joint may be an option in juvenile or adolescent patients who have no joint adaptation, but once lateral contracture has developed, then release of the joint appears prudent.

Salvage of previously failed hallux abducto valgus surgery with recurrent or residual metatarsus primus adductus is another indication for first metatarsocuneiform arthrodesis, especially if recurrence is secondary to hypermobility or ligamentous laxity. However, in many instances, the previous operation may have shortened the first metatarsal, so a bone graft may be necessary to prevent any additional shortening or to restore more functional length.

Arthrodesis of the first metatarsophalangeal joint has been recommended when the first metatarsocuneiform angle is medially deviated more than 30 degrees (26). However, variations in the angular relationships at this level have been found based on the position of the foot in addition to the orientation of the x-ray beam (17,27). Furthermore, ligamentous laxity was noted to have little to no effect on the metatarsocuneiform angles (17). This finding suggests that angular deviation should not be used as a sole criterion for tarsometatarsal arthrodesis. In some instances, a lateral weight-bearing radiograph may demonstrate sagittal plane subluxation with plantar gaping of the metatarsocuneiform joint.

Surgical Technique

The surgical incision is placed dorsally or medially over the first metatarsocuneiform joint. This may be a proximal extension from the incision used for exposure of the first metatarsophalangeal joint or a separate second incision. The medial dorsal cutaneous nerve is usually encountered in the subcutaneous tissue and should be retracted. Once the deep fascia is incised, the extensor hallucis longus is easily retracted to access the dorsal aspect of the joint. Medially, the tibialis anterior is freed from its distal fascial investments, so the tendon may be retracted dorsally to access the plantar aspect of the joint better and to facilitate fixation when a medial plate is used. The location of the joint may then be identified.

A linear incision is then made over the capsule and periosteum, which are carefully reflected. Caution is warranted during dissection of the lateral portion of the joint in an effort to avoid damage to the deep peroneal nerve and the first perforating branch of the dorsalis pedis artery. Plantarly, one needs to release the thick tarsometatarsal ligaments. Attachments of the posterior tibial and peroneus longus tendons, as well as Lisfranc's ligament, frequently hinder removal of the joint surfaces because of their extensive attachments in this location. Full joint mobilization facilitates later débridement of the cartilaginous surfaces. Dissection is generally extended distally to the junction of the proximal and middle third of the first metatarsal. Exposure of the thick cortical bone along this area is important when compression screw fixation is used. The thick cortical bone in this area is an excellent area for screw head contact to aid in compression across the arthrodesis site. Additionally, screw and wire placement becomes technically easier when one begins from a more distal site. When a dorsal or medial plate is used, then dissection needs to be extended to expose most of the metatarsal shaft distally and to identify the naviculocuneiform joint proximally. If more proximal dissection is done, care must be taken to avoid inadvertent damage to the saphenous nerve.

The joint may be resected using the technique preferred by the surgeon. When power saws are employed, the first metatarsal may be manually reduced to the desired position. Care should be taken to align the first metatarsal in both sagittal and transverse planes. This alignment often places the osseous structures in such a position that any wedging will tend to occur by default, as opposed to any freehand wedge resection that may be required otherwise. Osseous resection should proceed with care to avoid penetration of the second metatarsal. This occurs most often when the lateral aspect of the joint is not well visualized. If difficulty is encountered during transposition of the first metatarsal, the lateral proximal condyle at the base of the first metatarsal may also require resection.

Hand instruments may also be used to resect the joint surfaces. An osteotome and mallet is generally employed to begin the process, with curettes useful in some instances. A power bur may be helpful in reducing any remaining portions of cartilage or subchondral bone. With this technique, the surgeon is better able to preserve the normal contours of the joint and to achieve a good fit, generally with less bone resection. Therefore, when hand instruments are used, the correction of deformity is based on the ability to realign the joint about its normal articular shape.

Transverse plane correction may be achieved using a combination of wedge resections and simple repositioning, which is readily facilitated once the joint has been freed of the surrounding soft tissue. By using a power saw, the technique of reciprocal planing may be employed to remove areas of incongruity gradually until a good fit is achieved. However, in patients with more significant deformity, intentional wedge resections will likely be required. A laterally based wedge is preferably resected from the medial cuneiform because the distal articular surface of this bone typically exhibits some degree of deviation from the long axis of the first ray. Therefore, one is simply using the normal alignment to best advantage in reducing the intermetatarsal angle. In addition, wedge resection of the medial cuneiform preserves a large cancellous portion of bone for apposition.

Sagittal plane alignment of the first ray may be influenced by displacement of the first metatarsal dorsally or plantarly. This maneuver requires less bone resection, is technically simple, and avoids any additional shortening (5,25). If the metatarsal is shifted plantarly, a small ledge of bone at the dorsal joint level may be present that will require remodeling once the fixation has been applied. However, wedge removal, either dorsally or plantarly based, is an effective means of achieving greater degrees of correction. In some patients, a combination of both elements may be employed to achieve the desired position (Figs. 21 through 23).

Once the preferred alignment is achieved, and before the joint surfaces are approximated, a small drill or Kirschner wire may be used to fenestrate the medial cuneiform and first metatarsal base in an effort to facilitate arthrodesis. The first metatarsal and medial cuneiform are then repositioned, and provisional fixation is applied.

Bone Grafting

Supplemental bone grafts may also be employed with arthrodesis of the first metatarsocuneiform joint in several situ-

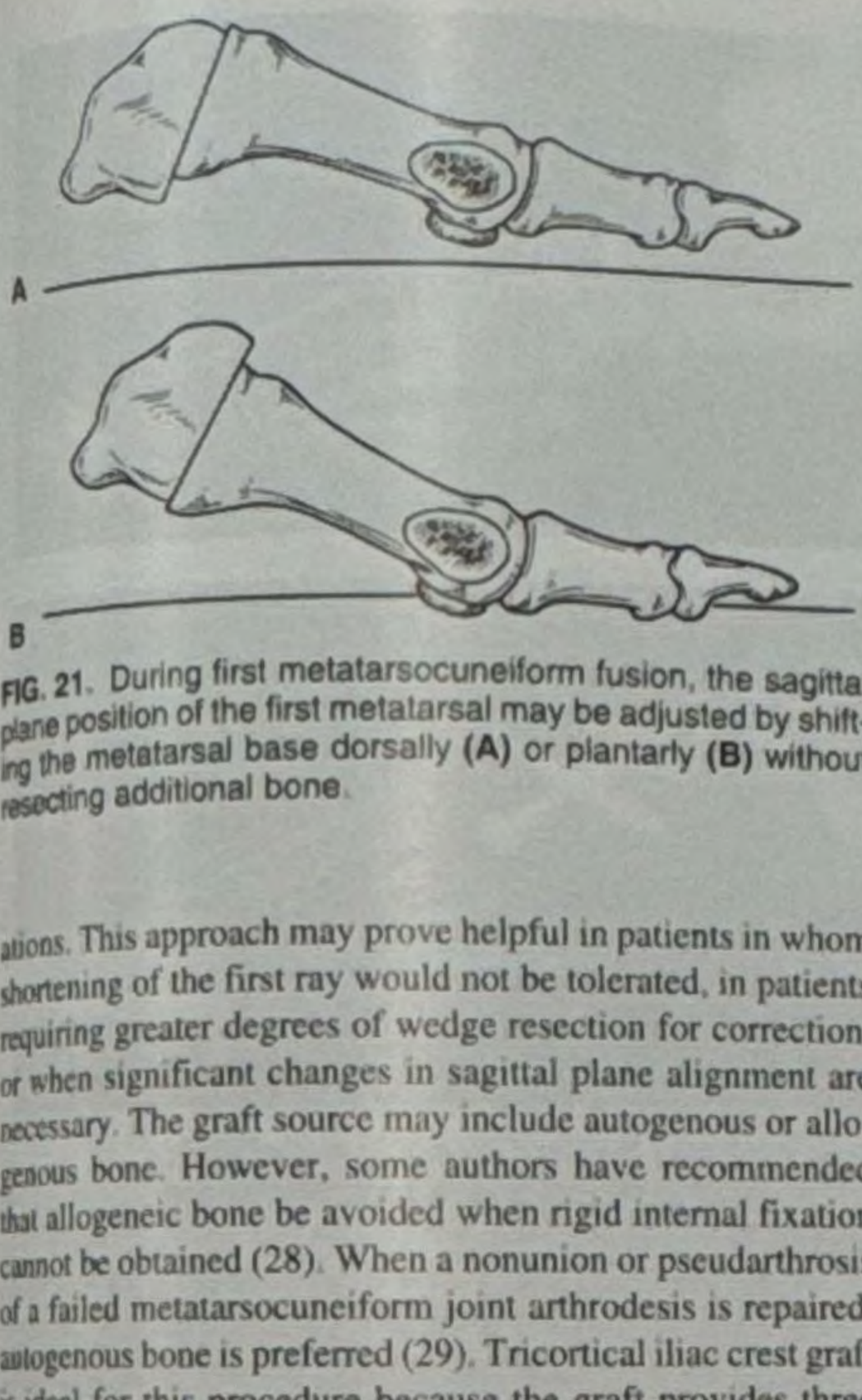


FIG. 21. During first metatarsocuneiform fusion, the sagittal plane position of the first metatarsal may be adjusted by shifting the metatarsal base dorsally (A) or plantarly (B) without resecting additional bone.

ations. This approach may prove helpful in patients in whom shortening of the first ray would not be tolerated, in patients requiring greater degrees of wedge resection for correction, or when significant changes in sagittal plane alignment are necessary. The graft source may include autogenous or allogenous bone. However, some authors have recommended that allogeneic bone be avoided when rigid internal fixation cannot be obtained (28). When a nonunion or pseudarthrosis of a failed metatarsocuneiform joint arthrodesis is repaired, autogenous bone is preferred (29). Tricortical iliac crest graft is ideal for this procedure because the graft provides three cortical surfaces for excellent stability dorsally, plantarly, and medially. The cortical bone provides and maintains positional correction and allows the use of rigid internal compression across the arthrodesis site. The cancellous bone provides a lattice network for osteoconduction throughout the healing process.

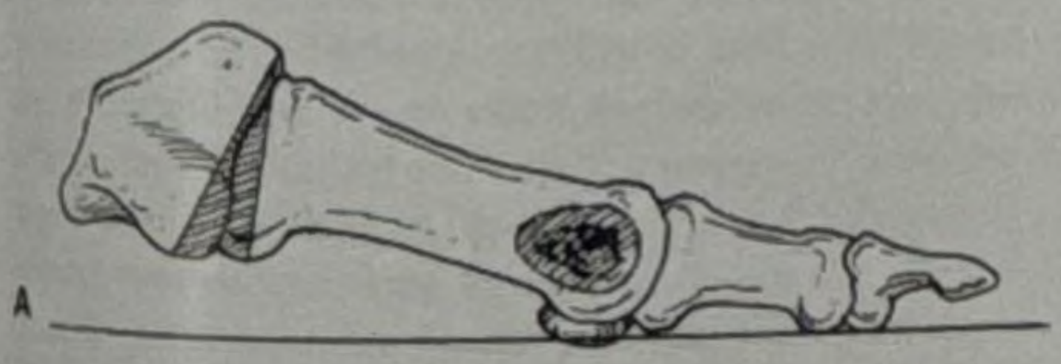


FIG. 22. A,B: A greater degree of plantarflexion of the first metatarsal may be achieved by resecting a plantar wedge from the joint area.

Modifications

Several authors have proposed several modifications to the basic technique described. The exostosis removed from the medial first metatarsal head has been used as a graft in the arthrodesis site to limit first metatarsal shortening (30). However, in most patients, the amount of bone resected is too small to have any meaningful effect on first metatarsal length. Other investigators have suggested that less aggressive resection of the joint may be adequate to provide suitable fusion. In some instances, cartilage has been removed to expose only the subchondral bone (22). When the joint is wedged for correction of the metatarsus primus adductus, several authors have resected bone from the lateral aspect of the joint, to leave the cartilage intact medially (22,24). Mauldin and associates released the joint, adjusted the position of the metatarsal, then applied the fixation. A medial trough was created in the medial first metatarsocuneiform joint, and an onlay graft was applied (23).

Fixation

Because of the relatively transverse orientation of the first metatarsocuneiform joint, numerous options are suitable for stabilizing the area. Kirschner wires or Steinmann pins provide good fixation and are quick and easy to use. Generally, two wires are preferred, to reduce any potential for rotation and to create additional stability. Pins may prove advantageous in patients with osteopenia and in pediatric patients with an open growth plate. Another advantage of using wires is that dissection may be more limited than when screws or plates are employed.

Compression screw fixation provides excellent stability and was first employed by Rutherford (20). Devices used to date most commonly consist of 3.5- or 4.0-mm fully or partially threaded cortical or cancellous screws inserted in lag fashion. These screws may be introduced in several orientations. Exposure along the proximal one-third of the metatarsal base is important, to ensure that the appropriate-length screw is used and that adequate compression is obtained by the screw head making contact with the thick cortical bone in this area. A common error is to begin screw placement too close to the arthrodesis site. The bone content here is more cancellous, and compression may be less effective. A key step with osteosynthesis in this area is adequate countersinking. This facilitates appropriate screw orientation into the plantar portion of the cuneiform, enhances optimal compression, prevents stress risers along the dorsal cortex of the metatarsal, and reduces the prominence of the screw head. Screws that cross the intercuneiform joints have not been noted to create any functional or symptomatic problem (22). Certainly, a combination of screws and wires may be used as well.

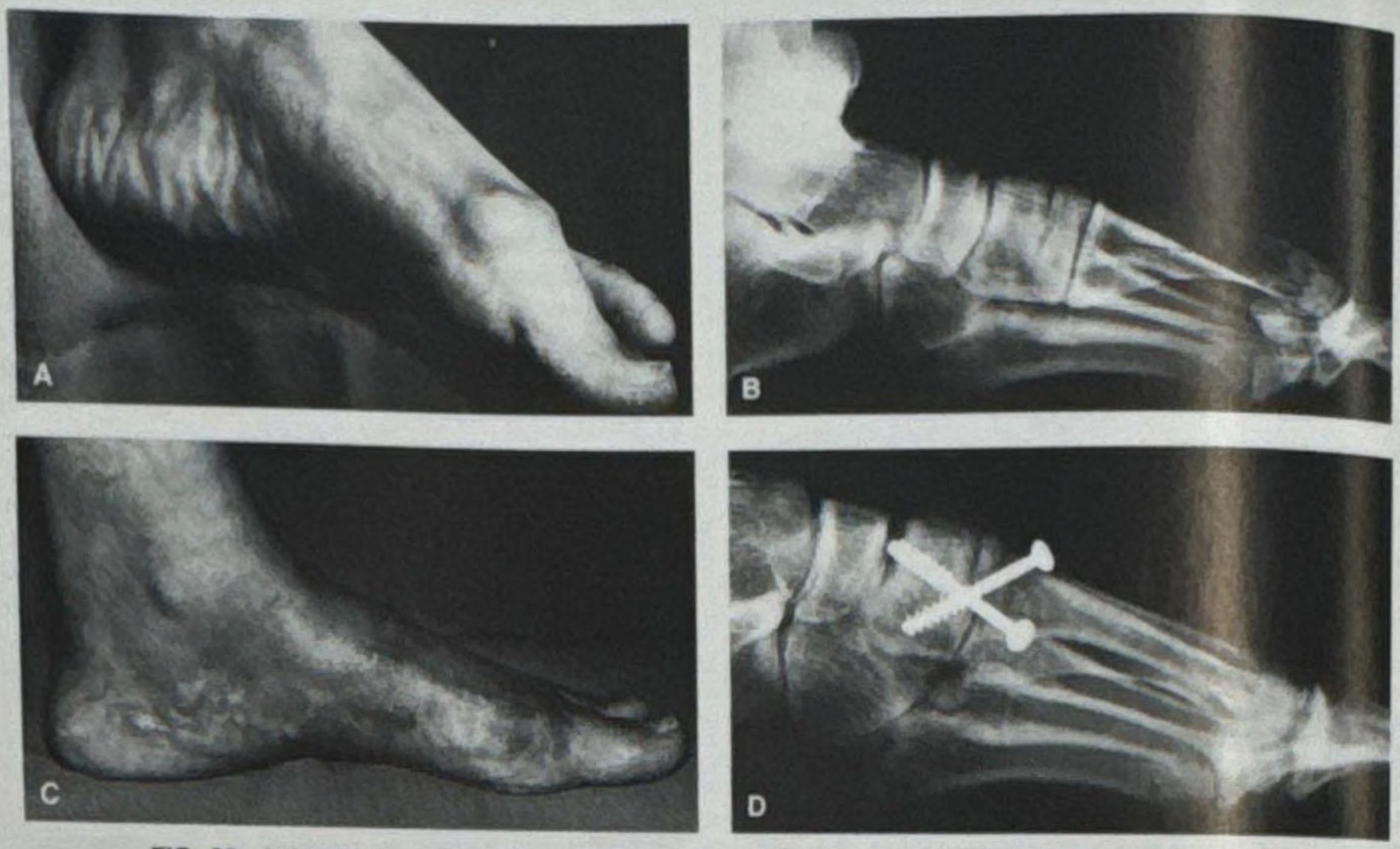


FIG. 23. Arthrodesis of the first metatarsocuneiform joint may also be used to alleviate metatarsus primus elevatus associated with a dorsal bunion. **A,B:** Preoperative clinical and radiographic appearance. **C,D:** Postoperative clinical and radiographic appearance.

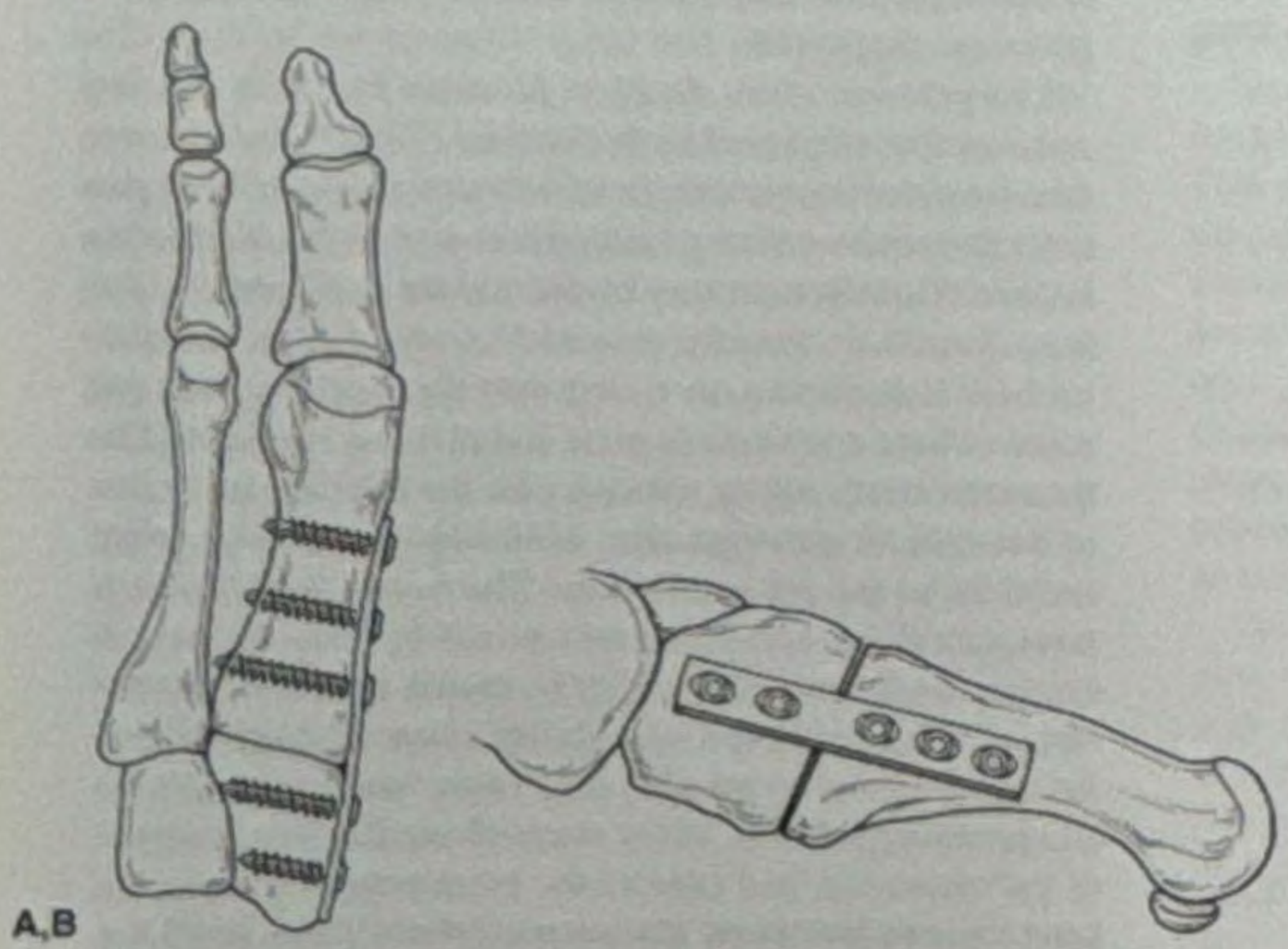


FIG. 24. A,B: Plate fixation may also be employed with or without the addition of an interfragmental screw. In many patients, the additional bulk of the plate proves problematic and requires subsequent removal.



FIG. 25. A medial plate works well when a large graft is incorporated into the arthrodesis site.

Cannulated screws have also proved useful for osteosynthesis. However, with some products, the screw head is large, and often this feature limits the ability to insert two screws in the area. The screws are placed in the same fashion as previously mentioned. The first step is to countersink. If desired, a rotary bur may be used for this purpose. Initial countersinking allows appropriate placement of the guide pin. The guide pin is then visualized through the metatarsal segment. At that point, the metatarsal is placed in the appropriate alignment, and the guide pin is then driven into the cuneiform segment.

Plate fixation is also an option for the modified Lapidus arthrodesis and is particularly useful when bone graft is used (Figs. 24 and 25). The technique may be employed in other situations when additional stability is preferred. However, the plate and screws are often prominent postoperatively after complete healing and create a source of irritation for many patients. Therefore, they often require subsequent removal, thus necessitating an additional surgery. Plate fixation has been described for the procedure in both dorsal and medial positions (25,31). Eccentric drilling can be used to afford compression across the arthrodesis site as the screws are inserted into the plate. The addition of a plantar interfragmentary screw was also noted to enhance stability further (31) (Fig. 26). However, when osteopenia is present and compression fixation is difficult to achieve, large-diameter Steinmann pins may be adequate. Burying the pins may prove helpful in eliminating pin tract irritation and loosening of the wires within the cast.

Chang and Ruch undertook a study to determine the effectiveness of different fixation methods for the first metatarsocuneiform fusion. A medial five-hole plate with a plantar screw was noted to resist disruptive forces to the greatest degree. Other forms of fixation that were tested are listed in order of decreasing strength: crossed 4.0-mm screws, medial five-hole plate, and crossed Kirschner wires (31). However, this finding does not imply that any of these methods of fixation are inferior; it simply provides the surgeon with a means of assessing the available options. Each form of fixation has its own advantages and disadvantages, and any of these methods may be adequate for stabilizing the fusion site, provided patient compliance is good.

Postoperative Management

The patient is maintained non–weight bearing for 6 to 10 weeks or until radiographic evidence of an osseous union is noted. If bone grafting is performed, this non–weight-bearing period will be extended, typically for a minimum 12 weeks. Postoperative radiographs may be obtained at regular intervals to evaluate joint consolidation.

Ancillary procedures may be required for complete reduction of the hallux abducto valgus deformity. The release of deformity at the first metatarsophalangeal joint should be considered an integral part of surgical treatment. When the effective articular surface of the first metatarsal head is laterally deviated, a distal metaphyseal osteotomy may be necessary for cartilaginous realignment.

Results

Overall, the results obtained with first metatarsocuneiform fusion for the repair of hallux abducto valgus have been good (Fig. 27). Rutherford reported good results in more than 120 feet. Minor keratoses were said to develop beneath the second and third metatarsal heads in some patients, presumably from shortening of the first metatarsal. Otherwise, no specific problems were noted (20). Using the medial eminence of the first metatarsal head as a graft, Butson reported excellent or good results in 110 of 119 feet (92%) in patients evaluated between 2 and 16 years postoperatively. No cases of nonunion were reported. Fixation consisted of two Kirschner wires inserted between the shafts of the first and second metatarsals (30).

Clark and colleagues reported on 20 adolescent patients representing a total of 32 procedures. Good correction of deformity was noted, in addition to alleviation of the medial column hypermobility, which was noted in 93% of the feet preoperatively. Two patients sustained problems related to lesser metatarsalgia (21).

A thorough report was provided by Saffo et al., who evaluated patients undergoing 54 procedures between 1 and 5 years earlier. Of these patients, 82% reported good or excellent results. However, several problems were identified. Transfer lesions were found in 14% of the patients, although symptoms were experienced by only 4%. An asymptomatic pseudarthrosis was found in 12% of their patients. The first metatarsal was 6 mm shorter compared with the second metatarsal, but the authors believed that this was readily over-













FIG. 26. **A,B:** Preoperative clinical and radiographic appearance of a patient with hallux abducto valgus deformity, metatarsus adductus, and joint space narrowing at the medial first metatarsocuneiform joint. **C,D:** Immediate postoperative results. **E:** Radiographic appearance 10 weeks postoperatively. **F:** Clinical appearance 6 months postoperatively.



FIG. 27. A,B: Preoperative and postoperative radiographs 1 year after repair of hallux abducto valgus deformity with first metatarsocuneiform fusion.

come by the plantarflexion introduced in the medial column at the time of surgery (5).

A 10% nonunion rate was also present in the series of patients reviewed by Sangeorzan and Hansen, although all the patients with nonunion in their series were symptomatic. In patients in whom bone grafting was not used, an average shortening of 5 mm was reported. Overall, only 75% of patients achieved a successful result (22).

Using an inlay graft technique, Mauldin and colleagues found satisfactory or very satisfactory results in 90% of 51 feet in patients undergoing surgical procedures. However, trabecular bridging at the fusion site was noted in only 25% of the cases. Despite this finding, no correlation was found between the radiographic evidence of fusion and patient satisfaction. The intermetatarsal angle was reduced from an average preoperative value of 14.6 degrees to a postoperative value of only 8.7 degrees (23). This finding leads one to question whether better correction of the metatarsus primus adductus deformity could have been achieved with a more traditional joint resection.

Myerson et al. reported on 67 cases; 77% of their patients were judged to have achieved total resolution of their preoperative symptoms, and 15% achieved partial relief. Five dorsal bunions were noted at follow-up. Seven nonunions occurred, only one of which was symptomatic. Three neuromas of the deep peroneal nerve were noted (24). Moreover, patients were allowed to bear weight fully during the recovery period. This could be one possible explanation for the demonstration of dorsal prominence of the metatarsal head.

Complications

Fortunately, major complications associated with the first metatarsocuneiform arthrodesis are not common. Because part of the motion of the first ray is eliminated, deviations in the sagittal plane may not be as well tolerated. Although some degree of plantarflexion of the metatarsal is desirable, excessive plantarflexion may result in sesamoiditis. Accommodative padding or orthoses may frequently resolve symptoms related to the plantar pressure. When conservative treatment fails, surgical treatment may include tibial or fibular sesamoid planning, tibial or fibular sesamoidectomy, or dorsiflexory wedge osteotomy of the first metatarsal in severe cases. A metatarsal resting in a more dorsal position could lead to additional pronation within the foot and is typically more difficult to accommodate.

Previous authors noted significant amounts of shortening of the first metatarsal in some instances (5,22). Excessive shortening of the first metatarsal has the potential to cause complications including transfer lesions, less effective hallux purchase, and metatarsalgia. Although one may compensate for shortening to some extent with plantarflexion of the first metatarsal, the amount of shortening that may be overcome is limited. Furthermore, significant plantarflexion

alters the loading of the plantar joint structures and encourages less effective purchase of the hallux, a problem that is compounded by shortening of the metatarsal. Such difficulties are more likely to occur in patients who require significant wedge resections to achieve the desired correction. The use of a bone graft may reduce the risks of this type of complication, but it also adds another level of complexity to the procedure and a more prolonged recovery process.

Neuritic symptoms have also been described in some patients (21,24). The medial dorsal cutaneous nerve will almost certainly be encountered during the dissection process, and if more proximal dissection is done, the saphenous nerve will often be visualized. The deep peroneal nerve may also be susceptible to disruption in the first interspace area. Proper tissue handling minimizes the risk of nerve entrapment. However, the normal scarring process that is part of healing may create nerve entrapment even in the best circumstances.

Hallux limitus is not a common complication, but it may be encountered as a consequence of any first metatarsophalangeal joint repair. Hallux limitus is more likely when the first metatarsal is lengthened with a graft as part of the fusion or when the arthrodesis heals with the first metatarsal in an elevated position.

Failure to achieve radiographic union of the arthrodesis site has been seen in about 10% of cases in several studies (5,22,24). Although this complication has generally been noted to be asymptomatic, painful nonunions have developed that have required subsequent surgical treatment (22) (Fig. 28).

Arthrodesis of the first metatarsocuneiform joint is a versatile procedure that may be employed in a variety of situations. Overall results have been suitable. Numerous forms of fixation are applicable and work well. Patients are best maintained non–weight bearing until healing of the osteotomy is achieved.

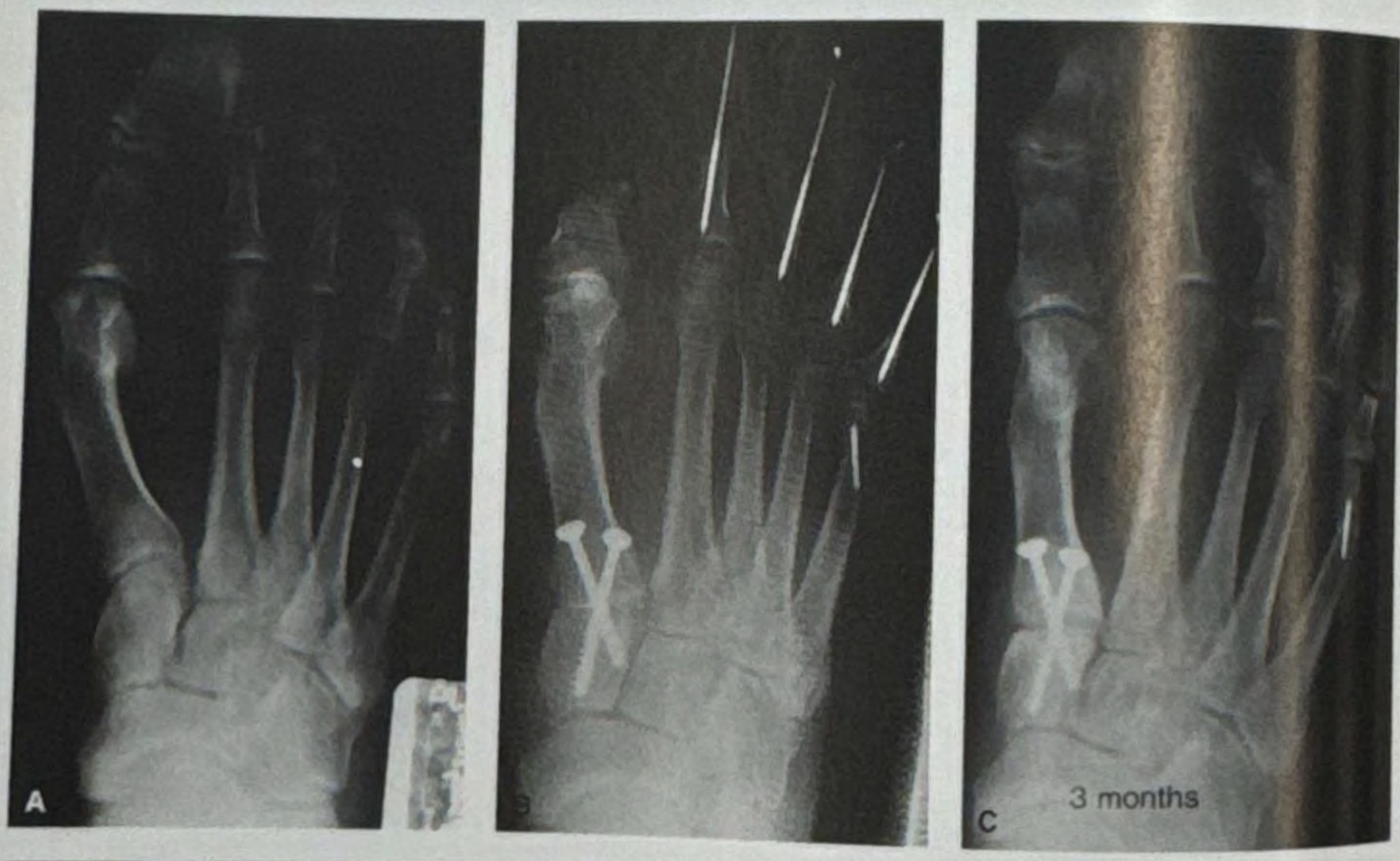


FIG. 28. A,B: Preoperative and immediate postoperative radiographs of a patient with recurrent hallux abducto valgus deformity with an associated hypermobile first ray. **C,D:** Radiographic appearance 3 months postoperatively demonstrating a delayed union that is asymptomatic. *(continued)*

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A,B: Preoperative and immediate postoperative radio- f a patient with recurrent hallux abducto valgus defor- an associated hypermobile first ray. C,D: Radiographic nce 3 months postoperatively demonstrating a delayed at is asymptomatic. *(continued)*



FIG. 28. *Continued.* E,F: Despite continued immobilization and an external bone stimulator, the patient developed an asymptomatic nonunion at the first metatarsocuneiform fusion site. This has been noted in several studies.

CUNEIFORM OSTEOTOMIES

Several authors have discussed cuneiform osteotomies for the correction of certain foot deformities. Cotton recommended an opening wedge osteotomy of the medial cuneiform with allogeneic femoral graft to correct sagittal plane deformity in collapsed pes valgus (32). Other investigators have used an opening wedge cuneiform osteotomy for correction of residual forefoot adductus in the treatment of clubfoot deformity (33,34). Joplin performed an opening wedge osteotomy for repair of splay foot deformity associated with hallux abducto valgus (35) (Fig. 29). Graver recommended a similar procedure for the correction of metatarsus primus adductus and used a triangular piece of bone from the resected medial eminence of the first metatarsal (36). Hara and associates employed a completely different approach, by resecting a closing abductory wedge from the medial cuneiform to reduce intermetatarsal splay for hallux abducto valgus (37) (Fig. 30).

Indications

Perhaps the primary indication for an opening cuneiform osteotomy is in conjunction with a repair of metatarsus adductus with and without hallux abducto valgus. In this case, the opening wedge cuneiform osteotomy is generally combined with a closing wedge osteotomy of the cuboid. The wedge of bone removed from the cuboid may then be used to augment the material inserted into the medial cuneiform (38). Other investigators have noted that cuneiform osteotomies may be employed in patients with hallux abducto valgus who have increased obliquity of the first metatarsocuneiform joint (37,39). However, questions have been raised

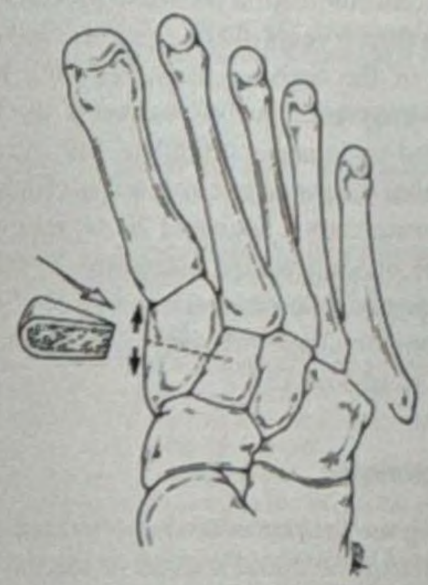


FIG. 29. The opening cuneiform osteotomy with graft for reduction of the intermetatarsal angle associated with hallux abducto valgus deformity.

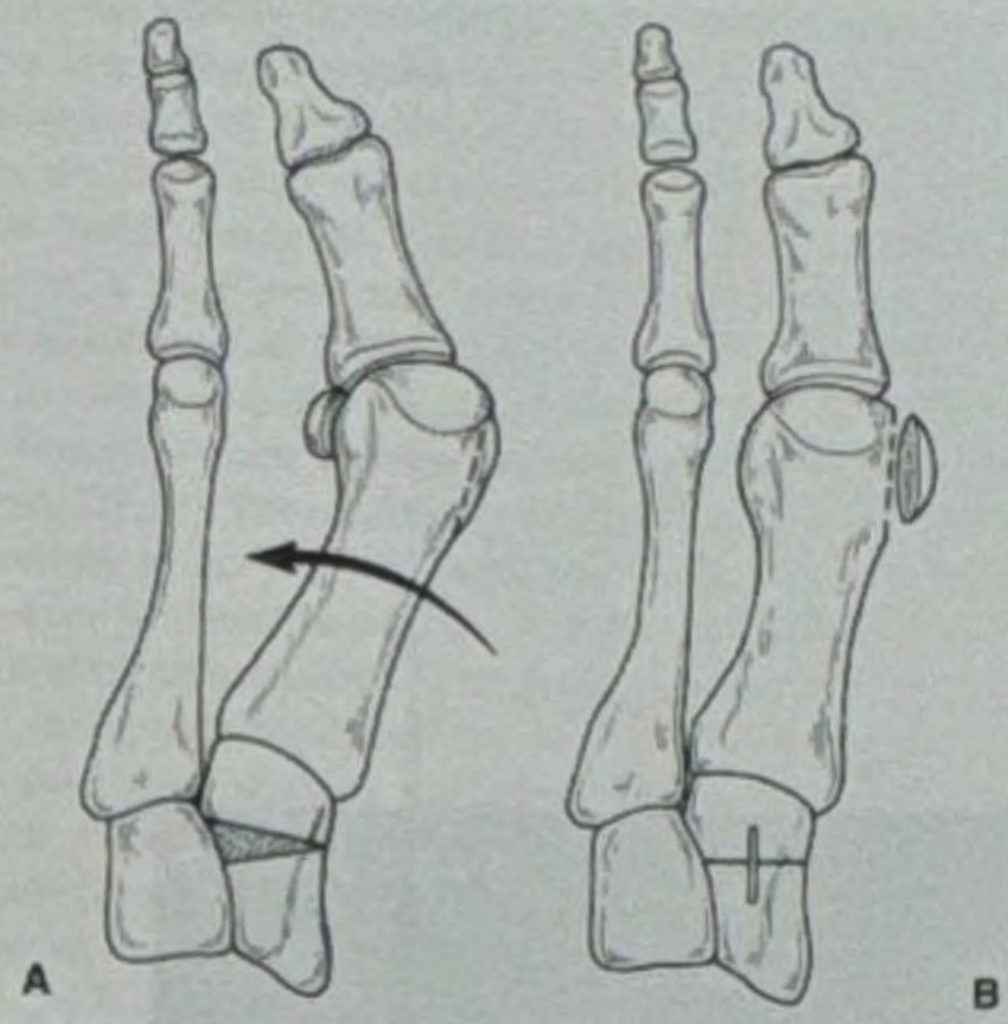


FIG. 30. A,B: The closing cuneiform osteotomy for repair of intermetatarsal splay associated with hallux abducto valgus deformity.

regarding the reliability of this measurement on standard radiographs (17,27).

Bacardi and Frankel employed a biplane opening cuneiform osteotomy for surgical repair of juvenile hallux abducto valgus (40). Lynch noted that juvenile hallux valgus was often associated with metatarsus adductus deformity, so this procedure is a logical choice in these patients or in patients with forefoot adductus. In addition to making an oblique osteotomy, wedging of the graft may be helpful in plantarflexing the medial column to address sagittal plane deformity or hypermobility (39). Ganley and Ganley noted that the procedure would be useful in correcting metatarsus primus adductus in patients after a failed closed base wedge osteotomy with residual dorsiflexion (38).

A general contraindication for these procedures has been in patients less than 6 years old because they have inadequate consolidation of the osseous structures (39). Furthermore, the procedure may need to be avoided if the bases of the first and second metatarsals articulate with each other (38). Graver noted that the procedure was not as effective in reducing larger intermetatarsal angles of 20 degrees or more (36). Relative to the closing wedge osteotomy of the cuneiform, Hara et al. reported that general contraindications were osteoporosis, bone blockage between the first and second metatarsals, or a rigid foot (37).

Surgical Technique

The opening wedge procedure is performed through a linear incision along the dorsal medial or medial aspect of the midfoot. The primary anatomic structures encountered are the extensor hallucis longus and tibialis anterior tendons and the medial dorsal cutaneous and saphenous nerves. The fascia surrounding the tibialis anterior will need to be released to mobilize the tendon and obtain better access to the cuneiform. A linear periosteal incision is performed in the same orientation as the skin incision, and the tissue is freed. A power saw is used to create an osteotomy approximately 7 to 10 mm proximal to the metatarsocuneiform joint. The lateral cortex is initially maintained intact, but in most cases it fractures as the osteotomy is opened. A lamina spreader may be placed in the osteotomy to separate the two segments and to better determine the appropriate amount of bone graft that is necessary. Intraoperative radiographs may be obtained before insertion of the graft to assess reduction in the intermetatarsal angle.

Tricortical iliac crest allogenic bone graft is well suited for this procedure. Autogenous graft from the calcaneus has also been used with success (39). Fixation is not always necessary, but when it is employed, staples, pins, and wires are all appropriate. Postoperative management includes a 6- to 10-week period of non–weight bearing or longer until radiographs demonstrate consolidation at the host-graft interface.

Results

Graver reported having performed 23 cases of opening wedge cuneiform osteotomy with the medial eminence of the first metatarsal head as the donor graft. No specifics were provided for the group as a whole. Advantages of the procedure were said to be the ease of execution, rapid healing, and the lack of need for no internal fixation. He noted that the procedure could be used in patients with intermetatarsal angles of up to 20 degrees and that the first metatarsal should not be long (36).

Lynch provided the most comprehensive review on the use of the opening wedge osteotomy for the repair of hallux abducto valgus deformity. He described good results in 48 feet of adolescent patients. In addition, he noted that the procedure also provided stabilization of the medial column. Calcaneal allograft was employed, and staple fixation was applied. Capital osteotomies were often required to reduce a deviated proximal articular set angle (39) (Fig. 31).

Hara et al. recommended a different approach consisting of a first cuneiform closing wedge abductory osteotomy for reduction of metatarsus primus adductus in patients with intermetatarsal angles greater than 15 degrees and with pronounced obliquity of the first metatarsocuneiform joint. The procedure was said to be ideal in patients with space at the first intercuneiform joint and the opposing bases of the first and second metatarsals. Steinmann pins were used for fixation, and the patient was maintained non–weight bearing for 6 weeks. In 51 cases, no patients had delayed union or nonunion of the osteotomy. Arthrosis involving the intercuneiform joints did not develop (37).

Complications may include nonunion, graft displacement, and malunion if the graft is not fashioned appropriately. The ability to control precise levels of correction is not as certain

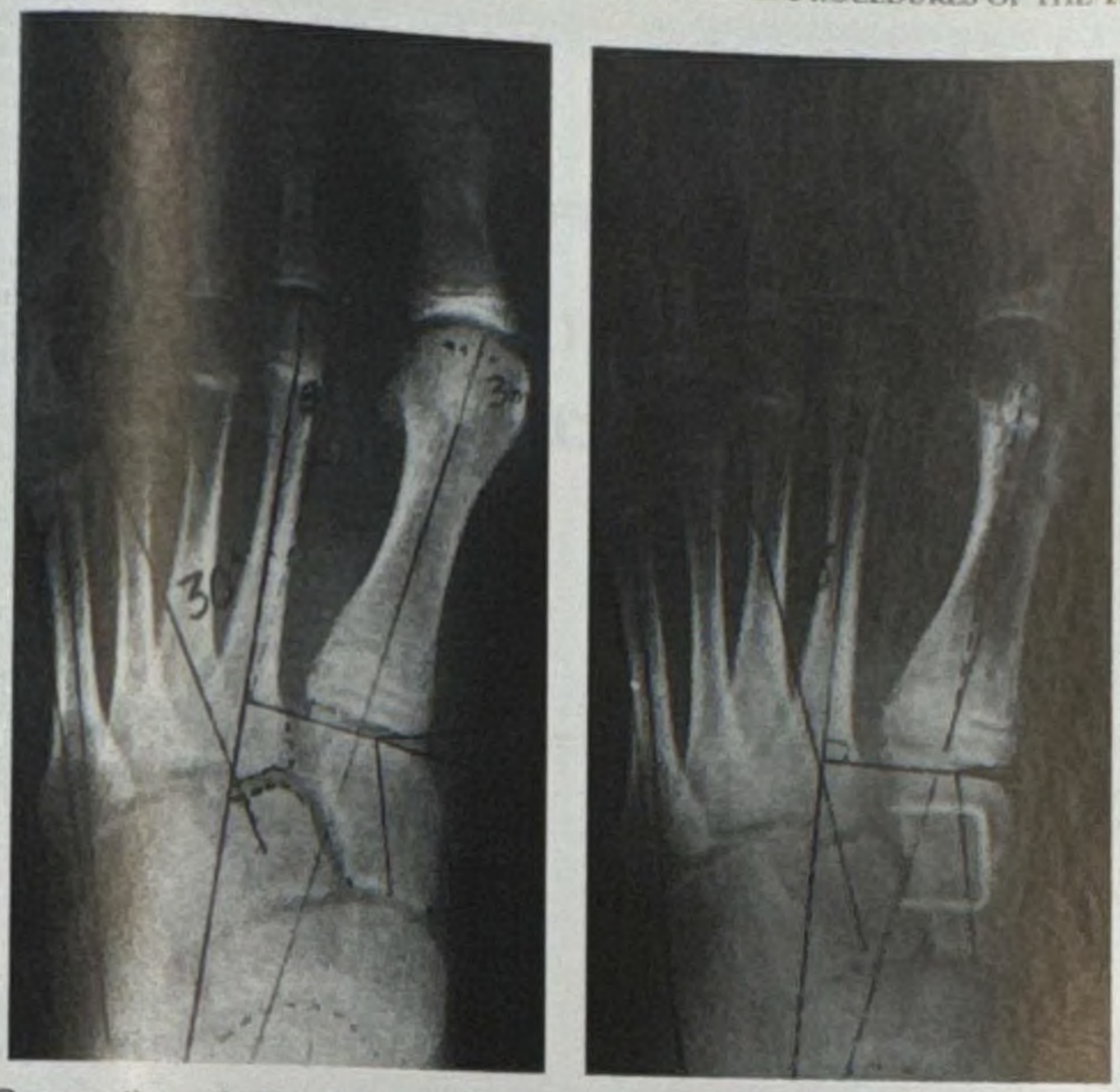


FIG. 31. Preoperative and postoperative radiographs of a patient after opening wedge cuneiform osteotomy with graft for repair of hallux abducto valgus deformity. (From Lynch FR. Applications of the opening wedge cuneiform osteotomy in the surgical repair of juvenile hallux abducto valgus. *J Foot Ankle Surg* 1995;34:103–123, with permission.)

as with other procedures, and in some cases inadequate correction has been noted.

Osteotomies of the cuneiform for the repair of hallux abducto valgus deformity are not commonly employed by most surgeons, but they may have merit. The proposed advantages of this approach include avoiding the growth plate at the base of the first metatarsal in the pediatric patient, the long radius arm that theoretically requires less wedging to gain correction when compared with distal osteotomies, and the ability to provide biplane correction. However, for most patients, other techniques have been better accepted and have proven successful, so determining specific indications for this approach remains difficult.

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Exhibit 1027

Acta Orthop. Belg., 2010, **76**, 1-6

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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Relationship of Frontal Plane Rotation of First Metatarsal to Proximal Articular Set Angle and Hallux Alignment in Patients Undergoing Tarsometatarsal Arthrodesis for Hallux Abducto Valgus: A Case Series and Critical Review of the Literature

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ABSTRACT

Rotation of the first metatarsal, as a component of hallux abducto valgus, is rarely discussed and is not addressed as a component of most hallux valgus corrective procedures. We believe frontal plane rotation of the first metatarsal to be an integral component of hallux abducto valgus deformity (the "third plane of deformity") and believe de-rotation is necessary for complete deformity correction. We observed the change in angular measurements commonly used in the evaluation of hallux valgus deformity in patients who underwent a modified lapidus procedure. We measured the intermetatarsal angle, hallux abductus angle, proximal articular set angle, and tibial sesamoid position on weightbearing radiographs of 25 feet in 24 patients who had undergone tarsal metatarsal corrective arthrodesis and lateral capsular release. Specific attention was given to reduction of the frontal plane rotation of the first metatarsal during correction. Our results showed a change in the angular measurements observed by 4 investigators as follows. The mean change in the intermetatarsal angle was 10.1° ($p < .0001$). The mean change in the hallux abductus angle was 17.8° ($p < .0001$). The mean change in the proximal articular set angle was 18.7° ($p < .0001$). The mean change in the tibial sesamoid position was 3.8 ($p < .0001$). Also, a consistent valgus, or everted position of the first metatarsal, was noted as a component of the hallux abducto valgus deformity in our patient population and was corrected by varus rotation or inversion of the metatarsal. We also reviewed the current literature related to anatomic changes in the first ray in the patient with hallux valgus deformity and reviewed our hypothesis regarding the reduction in the proximal articular set angle, which we believe to be related to frontal plane rotation of the first metatarsal, resulting in a radiographic artifact.

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Measurement of the 2-dimensional radiographic angular relationships has become an integral part of the evaluation and management of hallux abducto valgus (HAV) deformity. The intermetatarsal angle (IMA), hallux abductus angle (HAA), proximal articular set angle (PASA), and tibial sesamoid position are all commonly measured in an attempt to define the continuum of the HAV deformity. Although these measurements are common in practice, we question whether these 2-dimensional parameters accurately describe the HAV deformity. We know from studying anatomic reports that the first ray deformity associated with HAV is actually a triplane deformity with components of the deformity in the transverse, sagittal, and the third, or frontal, plane (1,2). A review of the published data revealed a question regarding the accuracy and reproducibility of these angular measurements, especially the PASA (3,4). Chi et al (4), in 2002, questioned the accuracy and validity of the PASA. They noted in a series of patients who underwent proximal first ray procedures a consistent reduction in the PASA without distal procedures (4). We have noted in our series that this reduction in PASA was consistent and quite dramatic after tarsal–metatarsal corrective arthrodesis. We hypothesized that this reduction resulted from attention to frontal plane rotational correction in addition to transverse plane and sagittal plane correction. From our observations, we believe the PASA might be a radiographic artifact, rather than a fixed deformity of the first metatarsal head. Using this concept of frontal plane rotational correction, we have been able to obtain excellent correction of the HAA, IM, and PASA with no metatarsal head procedures. Additionally, we have questioned the necessity of the commonly used first metatarsophalangeal joint (MTPJ) release

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and soft tissue balancing. A case series is presented, along with a literature review, to support our hypothesis.

Patients and Methods

The radiographic records of patients who had undergone a tarsal metatarsal corrective arthrodesis procedure for HAV from 2009 to 2011 by 2 of us (P.D., M.F.) were retrospectively reviewed. The Des Moines University institutional review board approved the record review. Only patients who had undergone tarsal metatarsal arthrodesis for HAV with limited soft tissue release and no other osseous procedures in the first ray were included in the present review. Limited soft tissue release was defined as lateral capsular release through a medial intracapsular approach. An additional inclusion criterion was the availability of preoperative and postoperative weightbearing anterior posterior radiographs of sufficient quality to make angular measurements. All 4 of us evaluated the IM, HAA, PASA, and tibial sesamoid position measurements independently. The measurement technique was consistent with the recommendations from Gerbert (5). The measurements were recorded, and the mean change in each measurement from preoperatively to postoperatively was calculated. The statistical analysis included calculation of the mean change in the preoperative and postoperative values after the patients were able to ambulate independently and perform full weightbearing for radiographic examination. We then used a paired *t* test to determine whether the pre- and postoperative measurements differed in each of the 4 characteristics that were measured.

The determination of outcomes such as union rate and patient satisfaction were considered to be outside the scope of the present review. We studied only the radiographic changes in position resulting from the procedure.

Surgical Procedure

All patients were evaluated and determined to be satisfactory candidates for the surgical procedure from a medical and anesthetic standpoint. Conservative care and preoperative consent were in accordance with the accepted standards of the American College of Foot and Ankle Surgeons treatment guidelines (6). The procedures were performed using general anesthesia or local anesthesia with sedation, as determined by medical appropriateness and patient preference. All procedures were performed with the patient in the supine position with standard extremity preparation and a single dose of prophylactic antibiotic given within 30 minutes of the initial incision. In general, tourniquet hemostasis was used. The first step involved a lateral sesamoid ligament release through a medial midline incision without subcutaneous separation. The plantar joint pouch was entered, and the sesamoids were retracted plantarly, allowing access to the lateral capsule. The lateral capsule was incised in the transverse plane only. No additional soft tissue release was performed, including no release or dissection of the dorsal capsule, no tendon releases or transfers, and no capsular plication. In most cases, no medial metatarsal head resection was performed.

The incision for the tarsal–metatarsal fusion was placed dorsally, directly over the joint. Again, dissection was minimal, avoiding plane separation and preserving the perforating blood supply. Most of the tissue separation was subcapsular and subperiosteal. Initially, we simply observed the frontal plane rotation needed to realign the joint. In later cases, before release of the tarsometatarsal joint (TMTJ) and resection of the articular surfaces, 2 smooth, 2-mm, pins were placed directly in the sagittal plane and parallel, 1 in the base of the metatarsal and 1 in the cuneiform. These pins were used as a reference to more easily visualize the rotation of the metatarsal in the frontal plane. The joint surfaces were next resected, including the cartilage and all subchondral bone. The cuts were oriented to correct the transverse and sagittal components, as needed, with the first metatarsal cut perpendicular to the long axis of the metatarsal. The cuneiform cut was made such that the distal medial portion of the cuneiform was left intact. This allowed reduction of the IMA without sacrificing the length of the first ray. Next, the rotation of the metatarsal was addressed by rotating the bone in a varus, or inverted, direction until congruous alignment of the first MTPJ and sesamoids was observed clinically and on the fluoroscopic examination. We found that using the reference pins allowed us to better note the direction of the rotation (Fig. 1).

The segments were next temporarily stabilized with smooth wires. The final fixation in our cases consisted of multiple methods, including 2 small, flexible, locking plates placed dorsally and medially, single- and double-screw fixation, and anatomic locking plate with compression screw. The fusion site was positioned with the dorsal and medial cortices flush in all cases. No sliding offset was performed in any plane. Thus, all correction in the sagittal and transverse planes was angular.

Results

A total of 24 patients with 25 procedures were identified as having met the inclusion criteria for the present study. All patients reviewed had undergone tarsal–metatarsal arthrodesis, with the only other first

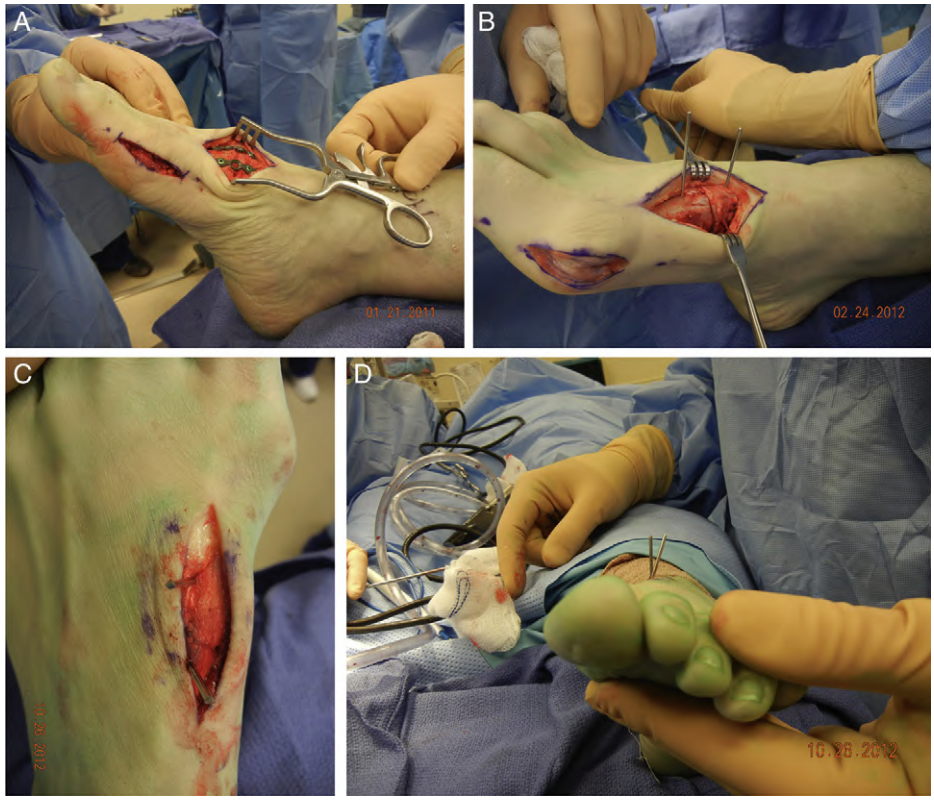


Fig. 1. (*A*) Two-incision approach with medial midline first metatarsal phalangeal incision and 2-plate fixation technique, with (*B*) positioning of reference wires to observe rotation (1 wire in metatarsal base and 1 parallel wire in first cuneiform). (*C*) Varus or inversion rotation of metatarsal indicated by reference wire position after anatomic alignment of first metatarsal and first metatarsal phalangeal joint. (*D*) Second case after correction showing smaller degree but varus or inversion rotation once correction is complete.

ray procedure a limited lateral capsular release through a medial midline incision. Of the 24 patients, 20 were female and 4 were male. The mean age at the procedure was 30.8 (range 14 to 52) years. Four of the patients also underwent lesser metatarsal procedures: 1, an isolated second metatarsal cuneiform arthrodesis; 2, a second and third metatarsal cuneiform arthrodesis; and 1, a fifth metatarsal osteotomy. The preoperative and postoperative IMAs of the 3 patients with the second metatarsal cuneiform arthrodesis procedures were not used in our IMA calculations.

Our first observation was made intraoperatively. In all cases, inversion or varus rotation of the metatarsal was noted when anatomic joint alignment was achieved. Anatomic alignment was determined by congruous reduction of the first MTPJ, anatomic alignment of the HAA, and a normal sesamoid position by both clinical examination and fluoroscopy. Only the direction of the metatarsal or reference pin offset was noted, and no attempt was made to quantify the amount of rotation needed to achieve accurate alignment.

The IMA, HAA, PASA, and tibial sesamoid position were measured on the preoperative and postoperative weightbearing radiographs. The results for each measurement of the 4 investigators were averaged, resulting in a composite mean value. The mean postoperative measurements were significantly lower than the preoperative measurements for each of the 4 traits measured ($p < .0001$, for all tests). The pre- and postoperative measurements for the 4 traits in each patient are shown in Fig. 2.

The mean preoperative IMA was 14.9° (range 10.5° to 23.5°). The mean postoperative IMA was 4.7° (range 1.3° to 7.5°). The mean change in the IMA was 10.1° ($p < .0001$). The mean preoperative HAA was 30.3° (range 18.0° to 48.3°). The mean postoperative HAA was 17.8° (range 4.3° to 21°). The mean change in the HAA was 17.8° ($p < .0001$). The mean preoperative PASA was 25.2° (range 12.8° to 39.3°). The mean postoperative PASA was 6.6° (range 1.3° to 15.0°). The mean change in the PASA was 18.7° ($p < .0001$). The mean preoperative tibial sesamoid position was 5.6 (range 3.3 to 7.0). The mean postoperative tibial sesamoid position was 1.7 (range 1.0 to 4.0). The mean change in the tibial sesamoid position was 3.8 ($p < .0001$).

No complications were noted in the observed postoperative period, including no deep infections, no wound healing issues, and no need for a return to surgery. The healing rates and healing times and postoperative function scoring were not observed and were considered outside the scope of the present review.

Discussion

The surgical approaches for HAV include a myriad of procedures with countless modifications of osteotomies and soft tissue balancing procedures. The procedures are typically classified into metatarsal head, metatarsal shaft, metatarsal base, and distal or proximal arthrodesis. A combination of these procedures is often recommended. The search for consistent and effective procedures has continued for decades, and the attempts to classify the HAV deformity are numerous. Many have attempted to define the HAV by the etiology and progression of the deformity (7–10). Although many descriptions and opinions have been published, disagreement exists regarding the elemental cause and progression of HAV deformity.

According to Kelikian (7), Carl Hueter first introduced the term “hallux valgus” in 1870. Hueter described the great toe moving away from the midline of the body with a first metatarsal that deviates toward the midline of the body (7). This deformity was termed “metatarsus primus varus” by Walter Truslow (8) in 1925. After noting a bone deformity on radiographs at the first metatarsal cuneiform joint and none at the MTPJ, Truslow concluded, “any operative procedure that does not include the correction of the deformity at its proximal focus is unscientific and inadequate.” Although this association of hallux and metatarsal deviation has been widely accepted, which is the primary deformity giving rise to the other has not been.

Munuera et al (9) in 2006 studied the relationship of the HVA to the IMA of metatarsals 1 and 2. They found that a mild HVA deformity

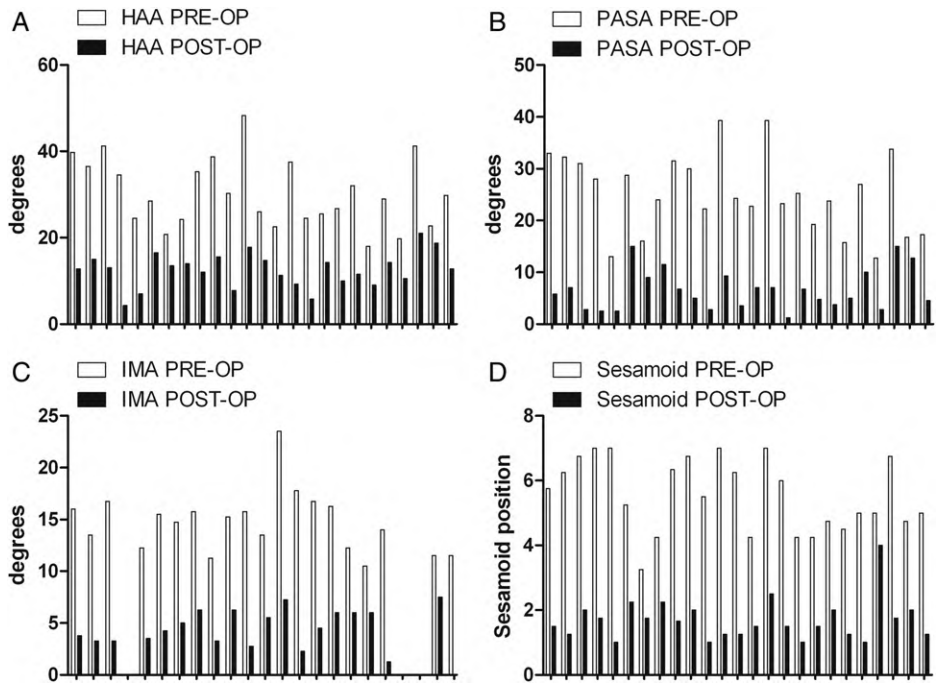


Fig. 2. Results of angular measurements of 25 procedures on preoperative (PRE-OP) and postoperative (POST-OP) weightbearing radiographs, with mean reduction of hallux abductus angle (HAA) of 17.8°, mean reduction of proximal articular set angle (PASA) of 18.7°, mean reduction of intermetatarsal angle (IMA) of 10.1°, and mean reduction of tibial sesamoid position of 3.8.

preceded a clinically meaningful increase in the IMA, leading them to conclude that hallux valgus leads to metatarsus primus varus (9).

Snjeiders et al (10) used a biomechanical study in which they used force vectors to show that walking produced force about a moment arm that deviated the hallux laterally, thereby causing the "spread foot" or medial deviation of the first metatarsal, and recommended that a first MTPJ arthrodesis should be the procedure of choice in addressing HVA deformities (10). Studies have shown that first MTPJ fusions can improve the metatarsus primus varus or IMA without any proximal procedures, possibly because of relief of retrograde buckling of the hallux on the metatarsal (11–13).

Even before Truslow, others had identified the first TMTJ as the apex of the deformity (14,15). Subsequently, other investigators, including Lapidus (16), also suggested that the tarsal metatarsal articulation is the apex and primary deformity in a bunion (17–19).

Although clear etiology and an agreed on progression of HAV deformity eludes us, we must still attempt to define the deformity clinically. Currently, it is taught that the radiographic parameters such as PASA, IMA between the first and second metatarsal, and the HAA must be used to define the deformity and to choose a specific procedure or combination of procedures to correct the HAV deformity. Using these severity-based algorithms, HAV is treated as a continuum of deformities rather than a single deformity. We consider HAV to be a singular deformity, with a consistent level of deformity or center of rotation angulation (CORA), as described by Paley (20). Additionally, we have identified the importance of 3 planar components of the CORA, with the frontal plane rotation ("third plane") playing a central role in the deformity.

Although it might not be intuitive because of generations of teaching and the use of algorithms, the level of the deformity and, therefore, the CORA, as it relates to the evaluation of the HAV deformity, must be considered. All deformities have a position or level at which the deformity originates. As taught by Paley (20), failure to respect this level of deformity prevents accurate alignment of the anatomic and mechanical axes and creates new deformities. Identification of the CORA is vital if we are to correct a deformity without introducing secondary deformities (Fig. 3). If our angulation correction axis, which dictates the level of the osteotomy we make, is located at our CORA, the deformity can be corrected without creating additional or secondary deformities. If we do not address the deformity at the CORA, we will inevitably create secondary deformities in the bone (20). We believe that because most common procedures focus osteotomy or correction at a point in the metatarsal rather than at the metatarsal cuneiform joint, which we believe is the CORA, these procedures will not completely correct the deformity. Many osteotomies create a second deformity while allowing the initial deformity to persist (Fig. 3).

Despite the universality of radiographic analysis of the HAV deformity, disagreement exists regarding the significance and reliability of even our most common measurements. Vanore et al (6), in their clinical guide, defined the PASA as the lateral adaptation of the distal first metatarsal articular surface that occurs with long-standing HAV. PASA is typically assessed on the radiograph but can also be observed qualitatively by direct intraoperative inspection. This angle has also been described as the distal metatarsal articular angle (DMAA). The normal values are 0° to 8°; however, interobserver variability exists, and the value might not correlate with the intraoperative observations (3,4,21–23).

Piggott (24) in 1960 conducted a radiographic study of adolescents and proposed that 4 types of changes occurred at the head of the metatarsal and that those changes determine the severity of the HAV deformity. He determined that these changes at the DMAA were the pre-existing condition that caused the deviation of the metatarsal and the bony prominence of the medial aspect of the foot (24). He also stated that when the DMAA is shifted laterally, it decreases the amount of correction that can be achieved (24). Piggott (24) believed the deformity would be likely to revert back to its preoperative state unless correction has been made at the DMAA.

Coughlin (25), in 1997, took the information that Piggott (24) presented in 1960 and applied it to surgical correction. Coughlin (25) agreed with Piggott (24) and concluded that the reason behind undercorrection of hallux valgus deformities, or the high rate of recurrence seen, resulted from the lack of correction of the DMAA. McInnes and Bouché (26) in 2001 agreed with that tenent and stated that the PASA is responsible for undercorrection of the hallux valgus angle, even if the IMA was completely reduced. They also advised that when performing a modified Lapidus procedure, we should consider a head procedure to correct for the PASA (26).

In 2001, Coughlin and Freund (3) concluded, "The interobserver reliability in the assessment of the DMAA is questioned." Physicians participating in the study did not consistently measure the DMAA with the precision with which they measured the IMA and HAA. Coughlin and Freund (3) further stated that the decreased reliability of this measurement between the different observers resulted from the "difficulty in consistently determining the medial and lateral

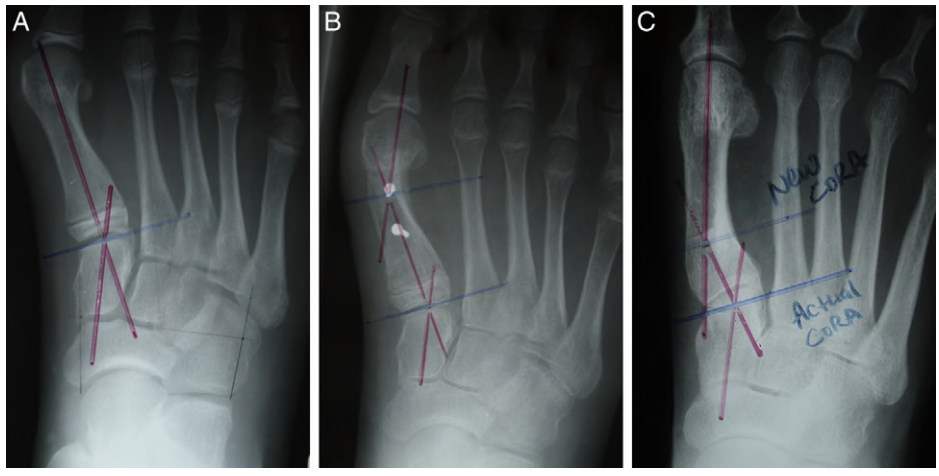


Fig. 3. Evaluation of hallux abducto valgus (HAV) using center of rotation angulation (CORA) principle. Deformity level was at metatarsal cuneiform joint, with no deformity noted in the metatarsal. (*A*) Alignment after midshaft sliding osteotomy showing persistence of original intermetatarsal angle (IMA), nonanatomic alignment of first metatarsophalangeal joint (MTPJ) and sesamoids and new deformity CORA in the metatarsal. (*B*) Alignment after basilar osteotomy using the CORA principle and showing residual CORA at original deformity, a new deformity in the metatarsal, and nonanatomic alignment of the first MTPJ.

extent of the distal metatarsal articular surface." Vittetoe et al (21) and Robinson et al (22) also confirmed that the PASA measurement was unreliable between observers. In both studies, they radiographically measured a cadaveric first metatarsal and found that with frontal plane rotation of the metatarsal, the PASA measurements changed.

Martin (23), in 1993, presented a different perspective on the changes at the head of the metatarsal in his critical analysis of the PASA. Martin (23) found that the preoperative PASA is rarely visualized intraoperatively and was often decreased postoperatively without any procedure to address the PASA or the head of the metatarsal. The study by Chi et al (4) in 2002 also showed a decreased PASA with proximal bunion repair procedures using pre- and postoperative radiographic measurements.

The results from our series agree with the observations of first metatarsal phalangeal realignment and a decreased PASA (18.7° in our series) after tarsal metatarsal corrective arthrodesis. We believe that it is the frontal plane rotation of the metatarsal ("third plane of deformity") that changes the appearance of the articular surface of the metatarsal head on radiographs. Furthermore, we have noted that rotation also allows accurate realignment of the joint and a substantial decrease in the HAA (17.8° in our series). Because the metatarsal head is an imperfect sphere, any change in rotation will have a corresponding change in the direction and profile of the articular surface, both clinically and radiographically. This could be the basis for the changes seen on the pre- and postoperative radiographs (Fig. 4).

We recognize that in some instances the distal metatarsal articular surface might appear deviated on direct inspection. Thordarson and Krewer (27) discussed the idea that the medial cartilage loss resulting from abnormal forces of the deviated hallux might be responsible for the apparent enlargement of the medial eminence. They noted that although the head was more exposed medially, it was not necessarily enlarged (27). Perera et al (28), in 2011, discussed the PASA and noted changes in the angle over time, indicating it might be a developmental, not a fixed or intrinsic, deformity. We believe that this loss of medial cartilage could also change the intraoperative appearance of the articular surface enough to give the appearance of a deviated PASA. This, however, does not, in reality, change the alignment and congruency of the first MTPJ, which is determined by the intrinsic bone shape and position of the first metatarsal in the transverse, sagittal, and frontal planes.

Because of these same observations, we question whether routine resection of the so-called medial eminence is necessary or prudent. We believe the often-described medial eminence enlargement might be accentuated on anteroposterior radiographic examination owing to the abnormal profile caused by eversion, or valgus positioning, of the metatarsal. We rarely find it necessary to resect any significant portion of the metatarsal head once the frontal plane rotation has been corrected. We believe it is prudent to wait until the abnormal frontal plane position is addressed before excising any metatarsal head. We have noted a persistent medial bump in some cases and have found this to be largely due to thickening of the medial capsule. We have found it necessary to thin the capsule to decrease the clinical appearance of medial prominence if noted on clinical inspection after deformity correction.

Reviewing again the common radiographic relationships used to assess the HAV deformity, the measurements are taken in 2 dimensions, with an emphasis on the transverse plane components of the deformity. A lower priority is typically placed on the sagittal plane component of the deformity. The least consideration is given to the frontal plane rotation in both the radiographic evaluation and the procedure choice. Although rotation of the first metatarsal as a component of the HAV deformity has been described, the definitions have been inconsistent. Some investigators have been in favor of inversion of the first ray on dorsiflexion. Hicks (29), in 1953, used 5 normal amputated feet and, after attaching pulleys and springs, isolated the motion of extension and supination in the first ray (i.e., dorsiflexion and inversion). Ebisui (30), in 1968, found that as he applied internal and external rotary forces to 15 freshly amputated legs, dorsiflexion of the first ray occurred with internal rotation of the leg. This happened about the axis Hicks had determined and carried with it concomitant inversion of the first ray. In 1982, Kelso et al (31) manually moved the first ray on an immobile hindfoot into

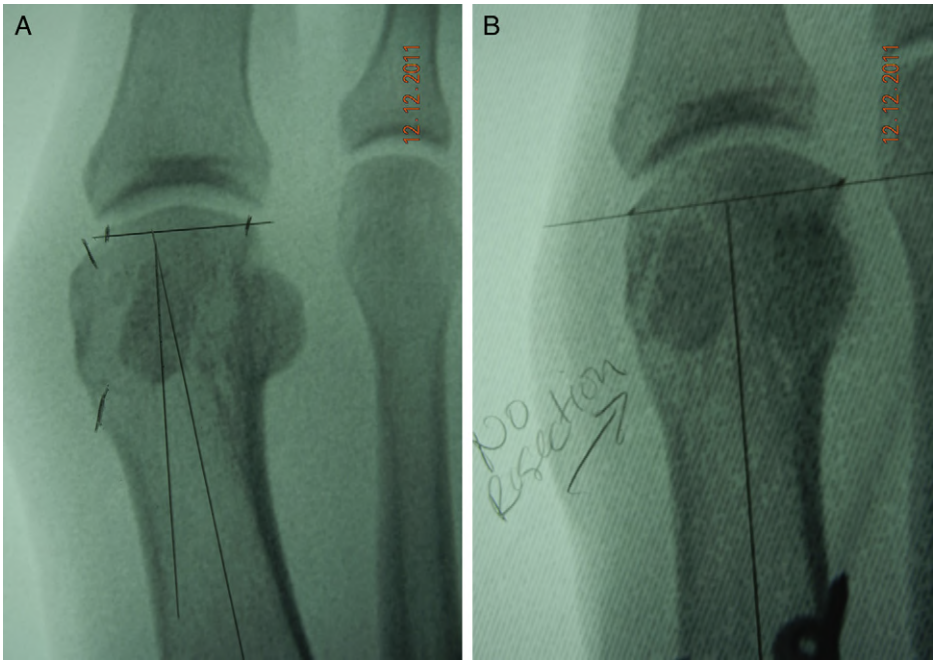


Fig. 4. (*A*) Preoperative first metatarsophalangeal joint alignment and apparent prominence of medial eminence. (*B*) Postoperative first metatarsophalangeal joint alignment showing reduction in proximal articular set angle after rotation and reduction in apparent prominence of medial eminence without bone resection.

dorsiflexion and plantarflexion. Using pins as reference points, they found that inversion occurred as the first ray was dorsiflexed (31).

These findings of dorsiflexion and inversion have been opposed in a number of studies starting in 1974 with Inman (32). Inman (32) used a pin in the hallux to show that as the leg was internally rotated, the foot pronated and the hallux everted into a valgus rotated position. He interpreted this to mean that the entire first ray everted as it dorsiflexed (32). In 1979, D'Amico and Schuster (33) used pins to visually show that as they manually moved 5 cadaver feet from a neutral to a pronated position the dorsal surface of the first metatarsal moved medially and inferiorly. Therefore, it everted as it was dorsiflexed (33). Also, in 1979, Oldenbrook and Smith (34) used accelerometers to measure first ray motion in 5 cadaveric feet. All the specimens showed dorsiflexion and eversion occurring in tandem as they internally rotated the leg (34).

Other interesting studies by Scranton and Rutkowski (1) and by Grode and McCarthy (2) investigated feet with bunion deformities. Scranton and Rutkowski (1) used 35 cadaveric and fresh feet. On anatomic inspection, they found that the hallux was in a valgus position and that pronation of the metatarsal head had occurred (1). They hypothesized that this pronation of the metatarsal was the cause of the plantar migration of the abductor hallucis muscle. Grode and McCarthy (2) took 3 cadaveric specimens and subjected them to a cryomicrotomic study. They found that the crista and orientation of the head of the metatarsal in feet with bunion deformities showed clear eversion.

Thus, it is clear that there is no final recommendation on the topic of first ray motion. In our recent experience, we have found consistent valgus rotation, or eversion, of the first metatarsal in association with HAV deformity. In our series, we directly observed varus rotation, or inversion, of the metatarsal to have occurred when the joint was corrected into congruous alignment using TMTJ corrective arthrodesis (Fig. 1). We believe this supports the hypothesis of valgus rotation or eversion of the metatarsal associated with the metatarsus primus adductus seen in hallux valgus. This has led us to our recommendation that rotational correction be considered when correcting the HAV deformity. Unlike most head, shaft, and base osteotomy procedures, TMTJ arthrodesis allows triplane correction at the deformity's CORA. Although measurement and calculation of the absolute amount of rotation were outside the scope of the present review, the direction of rotation we observed was consistent in all patients. Additional prospective studies could be designed to measure the mean amount of rotation and would help to clarify the rotational component of the deformity.

If we can accept that HAV deformity is triplane, it follows that each of these planes should be addressed in the corrective operation. Nearly all head, shaft, and basilar procedures provide measurable correction only in the transverse plane. Many others have attempted correction in the sagittal plane; however, when simple geometry is used, very little sagittal plane correction can be obtained with most angular and sliding metatarsal osteotomies. Also, the location of popular osteotomies is placed within the metatarsal. When considering the deformity correction rules, we question whether sound osteocorrective principles are being used with these procedures if the correction is attempted at a point other than at the CORA. In addition, the fact is evident from intrinsic geometry that most procedures, especially sliding procedures, cannot address frontal plane rotation.

However, tarsal metatarsal corrective arthrodesis can address all 3 planes of the HAV deformity. In our series, joint alignment, including a decrease in the PASA and HAA, was seen concurrently with minimal or no soft tissue balancing and no distal osteotomy. Our preferred lateral capsule/sesamoid ligament release was done from a medial midline incision through the plantar joint pouch. The entire dorsal joint pouch was maintained, and no additional tendon release, tendon balancing, capsulorrhaphy, or other soft tissue procedure was performed to attempt additional correction at the first MTPJ. We believe this further supports the idea of the HAV deformity as a triplane

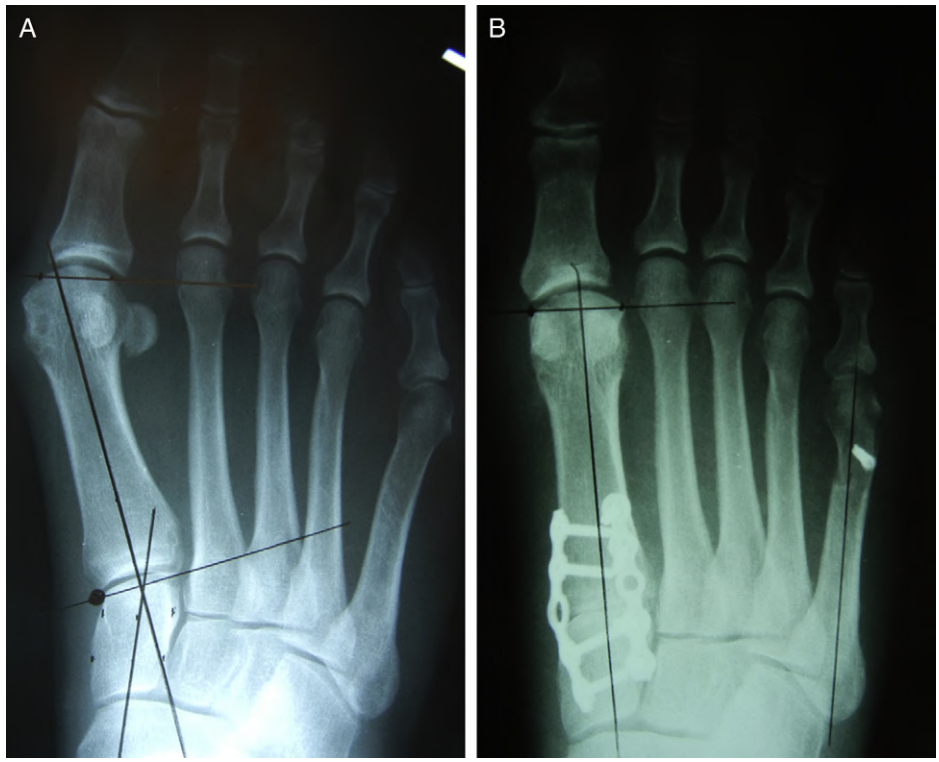


Fig. 5. Alignment of first ray and first metatarsophalangeal joint before (*A*) and after (*B*) tarsal metatarsal corrective arthrodesis. Triplane correction resulted in anatomic alignment of first metatarsophalangeal joint without distal procedures or medial eminence resection.

deformity and indicates that "third plane" or rotational correction is necessary to obtain anatomic alignment at the first metatarsal phalangeal joint and of the sesamoids (Fig. 5). We hypothesized that some de-rotation of the first ray might occur with other procedures and could be based on relieving the retrograde buckling forces that the deformed hallux and first metatarsal phalangeal joint have on the proximal first ray. This example is clear in the case of reduction of the IMA, which is seen after first MTPJ fusion.

Our series has shown a dramatic and consistent reduction in the PASA by simply inverting, or rotating, the metatarsal in a varus direction, with transverse plane and sagittal plane correction during tarsal metatarsal corrective arthrodesis. We consider this the "third" plane of deformity in HAV. As we have noted, most procedures have focused primary attention on the transverse plane of the deformity and have attempted to correct a metatarsal deformity that does not exist. We believe that 2-dimensional radiographic analysis does not accurately define the HAV deformity, because it does not address the third plane. We believe that the frontal plane component is a key component of first MTPJ misalignment in HAV deformity and must be addressed during correction to provide anatomic alignment of the first MTPJ.

Acknowledgment

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Attachment 2E

MARC record

LC control no.:	sh 85130766
LCCN Permalink:	https://lccn.loc.gov/sh85130766 (link opens in a new tab)
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001	sh 85130766
005	20250804133638.2
003	DLC
008	860211i| anannbabn |a ana
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

page delivered in 0.162s

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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 3A

MARC Bibliographic Record

LEADER		02619cas a22006257a 4500
001		9911025916302121
005		20251106213014.0
006		m o d
007		cr |||||||||||
008		050921c19869999pauqr p o 0 a0eng
010		$a 2005213182
016	7_	$a016630078$2Uk
022		$a1558-2302
023	0_	$a0891-8422$21
029	1_	$aAU@$b000044979773
029	1_	$aNZ1$b15412792
029	1_	$aNZ1$b15904880
029	1_	$aOCLCS$bOP-7696
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035		$a(CONSER) 2005213182
035		$a(CKB)954927698005
035		$a(EXLCZ)99954927698005
037		$bElsevier Health Sciences Division, 170 S Independence Mall W 300

040		$aNSD$beng$cNSD$dNSD$dOCLCQ$dLGG$dDLC$dOCLCQ$dOPELS$dOCLCF$dFFQ$dC
042		$ansdp$apcc
050	14	$aRD563$b.C63
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)
245	10	$aClinics in podiatric medicine and surgery.
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.
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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
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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
999 f f	$i 66d14e6e-6ee7-4ef9-bd37-9f15fa7fc79e $s 74f9c8f8-c52d-4a0d-876b-2cfdd9c1ceb2

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

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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

040 CLU **$b** eng **$c** CLU **$d** NLM **$d** DLC **$d** NST **$d** DLC **$d** NST **$d** NSD **$d** NST **$d** NSD **$d** OCLCQ **$d** NSD **$d** DLC **$d** NLM **$d** NSD **$d** DLC **$d** OCLCQ **$d** CUX **$d** OCLCF **$d** OCL CO **$d** DLC **$d** OCLCQ **$d** AU@ **$d** OCLCO **$d** OCLCQ

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

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022 0 0891-8422 **$y** 0742-0668 **$z** 1559-6486 **$2** 1

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 **$0** (OCoLC)fst00931326
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776 1 **$t** Clinics in podiatric medicine and surgery (Online) **$x** 1558-2302 **$w** (DLC) 2005213182 **$w** (OCoLC)61680715
776 0 8 **$i** Online version: **$t** Clinics in podiatric medicine and surgery **$w** (OCoLC)732993715
780 0 0 **$t** Clinics in podiatry **$x** 0742-0668 **$w** (DLC) 84646078 **$w** (OCoLC)10255369
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856 4 1 **$u** http://www.podiatric.theclinics.com/
029 1 AU@ **$b** 000004684678
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Attachment 4A

MARC Bibliographic Record

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337		$acomputer$bc$2rdamedia
338		$aonline resource$bcr$2rdacarrier
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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588		$aDescription based on print version record.
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650	_2	$aBone and Bones$vPeriodicals.
650	_2	$aOrthopedics$vPeriodicals.
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650	_7	$aOrthopedics.$2fast$0(OCoLC)fst01048565
655	_2	$aPeriodical.
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776	08	$x0095-8654
785	00	$tCLINICAL ORTHOPAEDICS AND RELATED RESEARCH$w(CKB)954925391294$w(
906		$aJOURNAL

MMS IDs

Document ID:

9911121818302121

Network Electronic IDs:

9911121818302121

Network Physical IDs:

999482902802121

mms_mad_ids:

991021974301802122

mms_lc_ids:

99992913402125

Attachment 4B

MARC record

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005	20250804140332.9
003	DLC
008	100324|| anannbabn |n ana
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040	$a DLC $b eng $c DLC
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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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003	DLC
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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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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 **$0** (OCoLC)fst01048565
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029 1 UKMGB **$b** 012396419

Attachment 5A

MARC Bibliographic Record

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500		$aOfficial scientific journal of the American College of Surgeons.
510	1_	$aExcerpta medica
510	2_	$aBiological abstracts$x0006-3169
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510	2_	$aEnergy research abstracts$x0160-3604
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510	0_	$aNuclear science abstracts$x0029-5612
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650	_0	$aSurgery$vPeriodicals.
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Attachment 5B

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Attachment 5C

MARC record

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Attachment 5D

MARC record

LC control no.:	sh2008108563
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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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Bethesda, MD 20894

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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

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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 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
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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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655 7 Periodicals. **$2** rbgenr
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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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Attachment 9A

Bibliographic Record - OCLC Number: 27182191

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001	27182191		
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	Date2/Ending Date of Publication	'9999'	
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	Government Publication	' ' - Not a government publication	
	Conference Publication	'0' - Not a conference publication	
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037 **$b** Williams & Wilkins, 428 E. Preston St., Baltimore, MD 21202

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210 0 J. foot ankle surg.
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-
300 volumes : **$b** illustrations ; **$c** 28 cm
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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
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Attachment 22A

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362 0#$aVol. 1, no. 1 (1996)-
510 1#$91 $aMEDLINE $bv3n1, 1998-
510 0#$91 $aPubMed $bv3n1, 1998-
510 1#$aIndex medicus
530 ##$aAlso issued online.
583 ##$3Vol. 2, no. 1 (JAN 1997) $c19981002 $fNotice not published $lPrinted on acid-free paper
650 #2$aOrthopedics
655 #2$aPeriodical
710 2#$aNihon Seikei Geka Gakkai.
856 4#$uhttps://link.springer.com/journal/776
856 4#$uhttp://www.sciencedirect.com/science/journal/09492658
911 ##$aElectronic and print, print canceled 2018
914 ##$aPortico $bCurrent to 2025 as of 20250227 $cISSN_09492658_8
935 ##$a(DNLM)807585-nlmdb
995 ##$aAUTH $b19960516 $cREV $d20250227
996 ##$aNOTCNSR $b20000101
998 ##$aERMSFP 118128 $b20161003
998 ##$aERMSLC 108649 $b20160829
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035 ##$a(OCoLC)34753655

Attachment 22B

Bibliographic Record - OCLC Number: 34753655

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	Bibliographic Level	's' - Serial
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	Encoding Level	' ' - Full level
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	Date1/Beginning Date of Publication	'1996'
	Date2/Ending Date of Publication	'9999'
	Place of Publication, Production, or Execution Code	'ja ' - Japan
	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	' ' - No alphabet or script given/no key title
	Entry Convention	'0' - Successive entry
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	Modified Record	' ' - Record is not modified
	Cataloging Source Code	' ' - National bibliographic agency
007	Category of Resource	'c' - Electronic Resource
	Specific Material Designation (c)	'r' - Remote
	Color (c)	'c' - Multicolored
	Dimensions (c)	'n' - Not applicable

Sound (c)	'u' - Unknown
Image Bit Depth (c)	'|||'
File Formats (c)	'|' - No attempt to code
Quality Assurance Target(s) (c)	'|' - No attempt to code
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030 JOSCFS

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050 1 4 RD701 **$b** .J68

060 0 0 W1 **$b** JO804SGD

210 1 0 J Orthop Sci

245 0 0 Journal of orthopaedic science : **$b** official journal of the Japanese Orthopaedic Association.

260 Tokyo : **$b** Springer-Verlag Tokyo, **$c** ©1996-

264 3 1 **$3** 2016- : **$a** Tokyo : **$b** Elsevier

300 volumes : **$b** illustrations

310 Bimonthly

336 text **$b** txt **$2** rdacontent

337 unmediated **$b** n **$2** rdamedia

338 volume **$b** nc **$2** rdacarrier

362 0 Vol. 1, no. 1 (1996)-

530 Also issued by subscription via the World Wide Web.
650 0 Orthopedics **$v** Periodicals.
650 2 Orthopedics
650 6 Orthopédie **$v** Périodiques.
650 7 Orthopedics. **$2** fast **$0** (OCoLC)fst01048565
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650 7 Zeitschrift **$2** gnd
650 7 Bewegungsapparat **$2** gnd
650 7 Krankheit **$2** gnd
650 1 7 Orthopedie. **$2** gtt
655 2 Periodical
655 7 Periodicals. **$2** fast **$0** (OCoLC)fst01411641
710 2 Nihon Seikei Geka Gakkai. **$1** https://id.oclc.org/worldcat/entity/E39QH7JmtgTYkfJvF7VK6hP9PF
776 1 **$t** Journal of orthopaedic science (Online) **$x** 1436-2023
850 DNLM
856 4 1 **$u** http://link.springer.de/link/service/journals/00776/index.htm
856 4 **$u** http://www.sciencedirect.com/science/journal/09492658
891 3 3 **$9** 853 **$8** 1 **$a** v. **$b** no. **$u** 06 **$v** r **$i** (year) **$w** b
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029 1 UKMGB **$b** 010491303

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041 0#$aeng
042 ##$apcc
044 ##$9United States
060 00$aWE 880 $bM478 2001
245 00$aMcGlamry's comprehensive textbook of foot and ankle surgery / $ceditors, Alan S. Banks ... [et al.] ; author's editor, Nancy Sinnott Vickers.
246 30$aComprehensive textbook of foot and ankle surgery
250 ##$a3rd ed.
260 ##$aPhiladelphia : $bLippincott Williams & Wilkins, $cc2001.
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337 ##$aunmediated $bn $2rdamedia
338 ##$avolume $bnc $2rdacarrier
504 ##$aIncludes bibliographical references and index.
650 12$aFoot $xsurgery
650 22$aAnkle $xsurgery
650 22$aFoot Deformities $xsurgery
650 22$aFoot Injuries $xsurgery
700 1#$aMcGlamry, E. Dalton.
700 1#$aBanks, Alan S.
730 0#$aComprehensive textbook of foot surgery.
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Attachment 25B

Bibliographic Record - OCLC Number: 44167920

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005	20250807183939.6	
008	Date Entered on File	'000522'
	Type of Date/Publication Status	's' - Single date
	Date1/Beginning Date of Publication	'2001'
	Date2/Ending Date of Publication	' '
	Place of Publication, Production, or Execution Code	'pau' - Pennsylvania
	Illustrations	'a '
	Target Audience	' ' - Unknown or unspecified
	Form of Item	' ' - None of the following
	Nature of Contents Code	'b '
	Government Publication	' ' - Not a government publication
	Conference Publication	'0' - Not a conference publication
	Festschrift	'0' - Not a festschrift
	Index	'1' - Index present
	Literary Form	'0' - Not fiction
	Biography	' ' - No biographical material
	Language Code	'eng' - English
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	Cataloging Source Code	' ' - National bibliographic agency

010 00042036

040 DNLM/DLC **$b** eng **$c** DLC **$d** NLM **$d** C#P **$d** BAKER **$d** BTCTA **$d** YDXCP **$d** U3Q **$d** TULIB **$d** MMU **$d** BDX **$d** OCLCF **$d** OCLCO **$d** OCLCQ **$d** OCLCO **$d** OCLCA **$d** OCLCO **$d** IG# **$d** OCLCL

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050 1 0 RD563 **$b** .C657 2001
060 0 0 2001 I-561
060 1 0 WE 880 **$b** M478 2001
082 0 0 617.5/85059 **$2** 21 **$1** https://id.oclc.org/worldcat/ddc/E3wxPfTgh4KbhWyym3r4kCCHcC
245 0 0 McGlamry's comprehensive textbook of foot and ankle surgery / **$c** editors, Alan S. Banks [and others].
246 3 0 Comprehensive textbook of foot and ankle surgery
246 3 0 Foot and ankle surgery
250 3rd ed.
260 Philadelphia : **$b** Lippincott Williams & Wilkins, **$c** ©2001.
300 2 volumes (xxiv, 2117, 66 pages) : **$b** illustrations ; **$c** 29 cm
336 text **$b** txt **$2** rdacontent
337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
500 Revised edition of: Comprehensive textbook of foot surgery / editors, E. Dalton McGlamry, Alan S. Banks, Michael S. Downey. 2nd ed. c1 992.
504 Includes bibliographical references and indexes.
505 0 V. 1. Technical principles -- Perioperative management -- Fundamental conditions and procedures -- First ray, hallux abducto valgus, and rel ated deformities -- Compound deformities -- v. 2. Major arthrodesis procedures -- Special surgery -- Trauma of the foot and leg -- Postopera tive complications and considerations.
650 0 Foot **$x** Surgery.
650 0 Ankle **$x** Surgery.
650 0 Foot **$x** Wounds and injuries **$x** Surgery.
650 0 Ankle **$x** Wounds and injuries **$x** Surgery.
650 1 2 Foot **$x** surgery
650 2 2 Ankle **$x** surgery
650 2 2 Foot Deformities **$x** surgery
650 2 2 Foot Injuries **$x** surgery
650 6 Pied **$x** Chirurgie.
650 6 Cheville **$x** Chirurgie.
650 6 Pied **$x** Lésions et blessures **$x** Chirurgie.
650 6 Cheville **$x** Lésions et blessures **$x** Chirurgie.

650 7 Ankle **$x** Surgery. **$2** fast **$0** (OCoLC)fst00809686
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650 7 Foot **$x** Wounds and injuries **$x** Surgery. **$2** fast **$0** (OCoLC)fst00931341
700 1 McGlamry, E. Dalton.
700 1 Banks, Alan S.
730 0 Comprehensive textbook of foot surgery.
776 0 8 **$i** Online version: **$t** McGlamry's comprehensive textbook of foot and ankle surgery. **$b** 3rd ed. **$d** Philadelphia : Lippincott Williams & Wilkins, ©2001 **$w** (OCoLC)741712400
856 4 2 **$3** Publisher description **$u** http://catdir.loc.gov/catdir/enhancements/fy0711/00042036-d.html
938 Ingram Library Services **$b** INGR **$n** in009412750
938 Baker & Taylor **$b** BKTY **$c** 399.00 **$d** .00 **$i** 0683304712 **$n** 0003613248 **$s** active
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938 Baker and Taylor **$b** BTCP **$n** 00042036
938 YBP Library Services **$b** YANK **$n** 1613118
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029 1 NLGGC **$b** 203287703
029 1 NLM **$b** 100955968
029 1 NZ1 **$b** 5857527
029 1 YDXCP **$b** 1613118

Attachment 25C

Detailed Record View

Registration record TX0005457146

Copyright Catalog
Displaying 3 of 3 entries

Previous Next

McGlamry's Comprehensive textbook of foot and ankle surgery /Alan S. Banks, Michael S. Downey, Dennis E. Martin, Stephen J. Miller.

Share Actions

Registration Number / Date	TX0005457146 / 2001-10-05
Previous Registration	Prev. reg. 1992.
Type of Work	Text
Title	McGlamry's Comprehensive textbook of foot and ankle surgery /Alan S. Banks, Michael S. Downey, Dennis E. Martin, Stephen J. Miller.

Other Title	Comprehensive textbook of foot and ankle surgery
Date of Creation	2001
Date of Publication	2001-06-06
Copyright Claimant	Lippincott Williams & Wilkins
Authorship on Application	on editing, original text & some ill.: Alan S. Banks & 30 others;on original text & some ill.: Patrick S. Agnew & 102 others;on editing: Nancy Sinnott Vickers.
Basis of Claim	New Matter: additions, revisions, updating.
Description	2 v.
Imprint	Philadelphia : Lippincott Williams & Wilkins, c2001.
Edition	3rd ed.
Names	Banks, Alan S. Downey, Michael S. Martin, Dennis E. Miller, Stephen J. Agnew, Patrick S. Vickers, Nancy Sinnott Lippincott Williams & Wilkins

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For information on searching copyright records, see How to Investigate the Copyright Status of a Work (Circular 22). You can also request that the Copyright Office perform a search of its records. To request a Search Report, please contact the Records Research and Certification Division. For information on removing personal information from Copyright Office public records, refer to Privacy: Public Copyright Registration Records (Circular 18).

Attachment 23A

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510 1#$91 $aMEDLINE $bv.31n3,May-Jun. 1965-
510 1#$91 $aPubMed $bv.31n3,May-Jun. 1965-
510 0#$aOLDMEDLINE
510 1#$aIndex medicus
525 ##$aSupplements accompany some issues.
530 ##$aAlso issued online.
533 ##$aMicrofilm. $mv. 12 (1946)-16 (1950). $b[Bethesda, Md.] : $cNational Library of Medicine, $d2003. $e2 microfilm reels : negative ; 35 mm.
546 ##$aText in French; some summaries in Esperanto, German, English, Italian, Dutch, and Spanish.
550 ##$aOfficial organ of the Société belge d'orthopédie, de traumatologie et de chirurgie de l'appareil moteur.
583 ##$3Vol. 46, no. 1 (1980) $c19921022 $fNotice not published $lPrinted on acid-free paper
650 12$aOrthopedics
655 #2$aPeriodical
710 2#$aSociété belge d'orthopédie, de traumatologie et de chirurgie de l'appareil moteur.
780 00$tBulletin of the Société belge d'orthopédie et de chirurgie de l'appareil moteur
856 4#$uhttp://www.actaorthopaedica.be
935 ##$a(DNLM)303829-nlmdb
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Attachment 23B

Bibliographic Record - OCLC Number: 1779082

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	Type of Control	' ' - No specified type of control
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001	1779082	
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008	Date Entered on File	'751101'
	Type of Date/Publication Status	'c' - Continuing resource currently published
	Date1/Beginning Date of Publication	'1946'
	Date2/Ending Date of Publication	'9999'
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	Frequency	'b' - Bimonthly
	Regularity	'r' - Regular
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	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	'b' - Roman, extended
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010 sn 86012729

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222 0 Acta orthopaedica belgica
245 0 0 Acta orthopaedica belgica.
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336 text **$b** txt **$2** rdacontent
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338 volume **$b** nc **$2** rdacarrier
362 0 t. 12- 1946-
500 "Organe officiel de la Société belge de Chirurgie orthopédique et de Traumatologie."
525 Supplements accompany some issues.
546 Text in French; some summaries in Dutch, English, Esperanta, German, Italian or Spanish.
550 Official organ of the Société Belge d'Orthopédie et de Chirurgie de l'Appareil moteur, 1946-58; of the Société belge de d'Orthopédie, de Traumatologie, et de Chirurgie de l'Appareil moteur, 1959- Juill/Août 1973; of the Société belge de Chirurgie orthopédique et de Traumatologie, Sept./Oct. 1973-
650 0 Orthopedics **$v** Periodicals.
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650 6 Orthopédie **$v** Périodiques.
650 7 44.83 rheumatology, orthopedics. **$0** (NL-LeOCL)077596757 **$2** bcl
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650 1 7 Orthopedie. **$2** gtt
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655 7 Periodicals. **$2** fast **$0** (OCoLC)fst01411641
710 2 Société belge de chirurgie orthopédique et de traumatologie.
710 2 Société belge d'orthopédie et de chirurgie de l'appareil moteur.
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770 0 **$t** Acta orthopaedica belgica. Supplementum **$x** 0772-7623
776 0 8 **$i** Online version: **$t** Acta orthopaedica belgica **$w** (OCoLC)590240860
776 0 8 **$i** Online version: **$t** Acta orthopaedica belgica **$w** (OCoLC)610150219
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029 1 NLGGC **$b** 840978359
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029 1 ZWZ **$b** 038657465
029 1 UKMGB **$b** 009185378

Attachment 1A

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	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
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	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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019 221526201 **$a** 995484954 **$a** 1053978593 **$a** 1063456326 **$a** 1089787521

022 0 1067-2516 **$2** j

023 0 1067-2516 **$2** j

030 JFSUEI

032 922540 **$b** USPS

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

042 nsdp **$a** pcc
050 4 RD560
060 0 0 W1 **$b** JO652S
082 1 0 617 **$2** 12 **$1** https://id.oclc.org/worldcat/ddc/E3YM8MMTVgYPgDmxF4cHh8XGcP
210 0 J. foot ankle surg.
222 4 The Journal of foot and ankle surgery
245 0 4 The Journal of foot and ankle surgery.
260 Baltimore, MD : **$b** Williams & Wilkins, **$c** ©1993-
300 volumes : **$b** illustrations ; **$c** 28 cm
310 Bimonthly
336 text **$b** txt **$2** rdacontent
337 unmediated **$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 **$v** Periodicals.
650 0 Foot **$x** Surgery **$v** Periodicals.
650 2 Ankle **$x** surgery.
650 2 Foot **$x** surgery.
650 7 Ankle **$x** Surgery. **$2** fast **$0** (OCoLC)fst00809686
650 7 Foot **$x** Surgery. **$2** fast **$0** (OCoLC)fst00931326
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
891 4 0 **$9** 863 **$8** 1 **$a** <33> **$i** <1994> **$x** provisional
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029 1 UKMGB **$b** 012116839

Attachment 1B

MARC record

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003	DLC
008	860211i| anannbabn |n ana
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035	$a (DLC)5096
040	$a DLC $c DLC $d DLC
150	$a Ankle $x Surgery
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Attachment 1C

MARC record

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010	$a sh 85099890
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053 0	$a AP $c General periodicals
053 0	$a PN4700 $b PN5650 $c History
150	$a Periodicals
360	$i subdivision $a Periodicals $i under specific subjects, e.g. $a Engineering--Periodicals; United States--History--Periodicals
450	$a Journals (Periodicals)
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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040	$a DLC $c DLC
053 0	$a RD563
150	$a Foot $x Surgery
550	$w g $a Podiatry
681	$i Example under $a Surgery, Operative
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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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