METATARSAL OSTEOTOMY FOR THE CORRECTION OF METATARSUS ADDUCTUS

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INTRODUCTION

Any discussion of metatarsal osteotomies for the correction of metatarsus adductus must address a number of points. What follows is an attempt to focus on several of these including basic philosophy in clinical examination, radiographic evaluation, and treatment techniques employed.

Treatment Philosophy

The diagnosis of metatarsus adductus has been fully reviewed elsewhere. For the sake of our discussion we will define metatarsus adductus as a transverse plane deformity at the level of the tarsometatarsal joint. Further definition and classification of the deformity will be discussed in terms of our surgical approach.

The pediatric/adolescent patient with the deformity metatarsus adductus, represents an entirely different set of circumstances from a surgical standpoint than does the adult patient. In dealing with a pediatric deformity there exists many more surgical variables. An individual with metatarsus adductus as a primary deformity will have greater expectations from treatment than will the patient that presents with residual metatarsus adductus from a previously treated club foot. Both the presence of open epiphyses and extrinsic forces that exist can significantly alter the structure of the foot over time. Finally, of great importance to the treatment is the parents' expectations and depending on the age of the patient, the patient's expectations.

Timing of surgical procedures is of great importance in treating this deformity. The physician must develop a time frame for this overall treatment. Younger patients should receive a course of casting prior to any surgical repair.

As with most pediatric deformities the patient does not experience the same symptoms that are characteristic of adult deformities. If the pediatric patient is experiencing pain the seriousness of the condition is signaled. Generally, in the metatarsus adductus patient, the parent will describe the symptoms as a set of clinically related conditions. These may include excessive and abnormal shoe wear, marked in-toe walking, constant tripping, and inability to maintain the same activity level as children the same age.

Considerations for surgery include the age of the patient, symptomatology, severity of deformity, degree of compensation, and the degree of control which may be present.

Indications for surgery will be twofold: in the asymptomatic patient there should be severe structural deformity with uncontrolled compensation or rapid progression of deformity. In the symptomatic patient whether it is compensated or uncompensated, controllable or uncontrollable surgery is advisable.

Contraindications to surgery are the asymptomatic deformity with only mild structural deformity that is controllable and with only minimal progression whether it be uncompensated or compensated.

CLINICAL EVALUATION

A thorough clinical evaluation includes:

- Inspection of the entire lower extremity for gross orthopedic deformities and the presence of any existing deformities proximally
- Determination of the primary plane of the deformity
- Biomechanical examination
- Gait examination.

It is helpful for the patient to be in shorts for the examination to allow the physician to inspect the entire lower extremity. The thigh should reveal development consistent with age. The presence of genu valgum or genu varum may contribute to the deformity and should be noted. Further inspection of the leg should be made to determine the existence of tibial torsion or tibial varum.

Generally speaking metatarsus adductus exists as a purely transverse plane deformity at the level of the tarsometatarsal joint, as evidenced by the disparity in the medial and lateral foot borders (Fig. 1). The presentation of a convex lateral border and a concave medial border will be evident but depends on the degree of compensation. In the uncompensated foot the convexity of the lateral border will be most marked with the styloid process of the fifth metatarsal very prominent. The medial arch may exhibit more height than expected for a child in his/her particular age group. In contrast the totally compensated deformity may reveal only a mild amount of convexity to the lateral border, a rather low or even flattened medial arch and even some abduction of the digits. Many authors have observed the separation of the hallux and the second digit and have suggested that this seems more prevalent in the uncompensated and partially compensated foot types.

During a thorough biomechanical evaluation, determination of the presence of sagittal and frontal plane abnormalities must be made. This will affect the surgical strategy. The presence of a gastrocnemius or gastrocnemius-soleus equinus must be addressed to insure the success of a metatarsus adductus repair. Evaluation of subtalar joint motion is also of great importance. Finally, the presence of an uncompensated rearfoot varus if present must also be addressed.

The forefoot should be examined in the standard fashion, the subtalar joint should be in its neutral position, the midtarsal joint should be locked. This will permit an accurate appraisal of the metatarsal alignment in all three planes. If a true transverse plane deformity exists, the metatarsal heads will all be aligned on the same transverse plane. Any difference in elevation between metatarsals can be compensated at the time of surgery. Careful preoperative planning will help to ensure a successful outcome. A gross frontal plane deformity may exist in the form of a rigid forefoot varus. Actual determination of inversion of the metatarsals is not clinically possible.

A common radiographic finding that is difficult to quantify clinically is the degree of adduction of each metatarsal. There may be an actual increase in the degree of adduction of each metatarsal from lateral to medial with the greatest amount being present in the first metatarsal. This can be considered as the domino effect.

Another parameter to consider is the degree of flexibility present in the deformity. A rigid metatarsus adductus deformity will require more aggressive treatment than a flexible deformity. Postoperative casting and splinting will be of assistance in reducing the adductus in the flexible deformity.

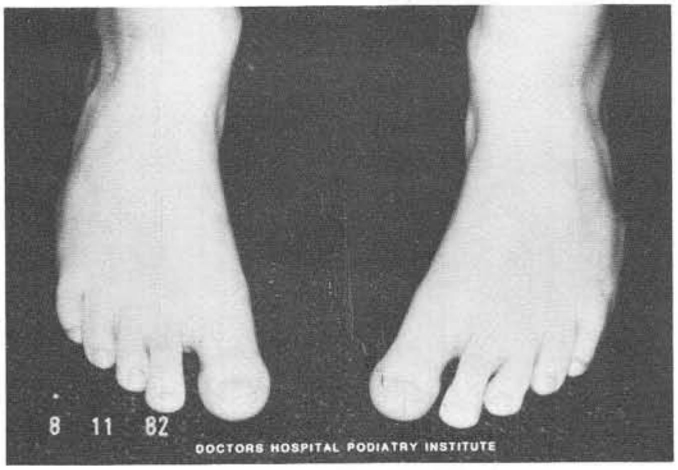

Fig. 1. Clinical representation of resistant metatarsus adductus.

Consideration of the presence of functional hallux limitus must be made. Functional hallux limitus is the inability of the great toe to extend over the first metatarsal when the heel is lifting off the ground. This creates a sagittal plane motion blockade at the first metatarsophalangeal joint which must be compensated for at the level of the midtarsal joint or ankle joint. The end result is an accentuation of the deformity through an adductory twist at heeloff. This can be corrected at the time of surgery by plantarflexing the first metatarsal and increasing the declination and stability of the first ray.

RADIOGRAPHIC EVALUATIONS

The diagnosis of metatarsus adductus is generally made by clinical evaluation. Radiographic studies do contribute to determining the extent of the deformity as well as providing greater insight to the osseous relationships. Full weight-bearing dorsoplantar and lateral views are performed and used not only for determination of angular relationships but to evaluate the osseous maturity of the foot (Fig. 2).

The dorsoplantar view is of primary importance for determination of the metatarsus adductus angle. There are two methods currently used. The first depends on defining the longitudinal axis of the lesser tarsus. This is accomplished by plotting a series of points beginning with the medial most aspect of the first metatarsal cuneiform joint followed by the medial most aspect of the talonavicular joint, the lateral most aspect of the fifth metatarsal cuboid joint, lastly the lateral most aspect of the calcaneocuboid joint. Two lines are then drawn, one connecting the medial points and one connecting the lateral points. Each of these lines is then bisected and a third line is drawn connecting the bisect points across the midfoot. A fourth line is then constructed perpen-

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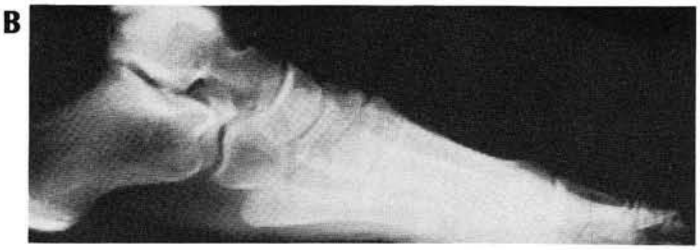

Fig. 2. Preoperative radiographs, A & B, of symptomatic metatarsus adductus.

dicular to the third line and represents the longitudinal axis of the midfoot.

The bisection of the second metatarsal will serve as the longitudinal axis of the metatarsals. The angular relationship between the longitudinal axis of the lesser tarsus and the longitudinal axis of the second metatarsal will represent the metatarsus adductus angle (Fig. 3).

A second method of defining the metatarsus adductus angle has been proposed. In this method the longitudinal axis of the metatarsals remains the longitudinal bisector of the second metatarsal. The angle is defined utilizing the longitudinal bisector of the second cuneiform (Fig. 4). The authors found that their method resulted in an increase of three degrees over an accepted normal measurement of twenty-one degrees.

There is much controversy over a strict definition of metatarsus adductus. Some authors define pathological metatarsus adductus as being greater than twenty-one degrees. Others have liberally defined normal as ten to twenty degrees. The faculty and staff at the Podiatry Institute use the following guidelines for defining metatarsus adductus.

Classification of Metatarsus Adductus

Normal	< 15 degrees
Mild	16-25 degrees
Moderate	26-35 degrees
Severe	> 35 degrees

These numbers are guidelines and are to be used in quantifying the deformity. Keep in mind the importance of angle and base of gait radiographs. The patient must be positioned carefully because supination of the subtalar joint can result in an apparent increase in the amount of metatarsus adductus.

As the child matures the appearance of the bases of the metatarsals will also change. Recall that the epiphysis of the first metatarsal is at its base and final ossification does not take place until 16 to 20 years of age and can vary substantially. The epiphyses of the lesser metatarsals are at the neck. They close at approximately the same age. In early childhood the bases are rather round in appearance. As the child reaches adolescence the base and neck will square themselves off and resemble adult metatarsals. The majority of procedures will be performed at the proximal one-third to one-fourth of the metatarsal.

OSSEOUS SURGERY

Metatarsal osteotomy has been advocated for the correction of metatarsus adductus alone or in combination with other procedures. Berman and Gartland introduced osteotomies of all five metatarsals for the correction of metatarsus adductus in 1971. Since that time the procedure has undergone several refinements. It serves as the foundation for the correction of resistant metatarsus adductus in children age six to eight or older.

The original Berman and Gartland procedure used dome-shaped osteotomies of the base of the metatarsals. In severe cases the removal of laterally based wedges of bone from the metatarsal base facilitated the correction. Initially the metatarsal osteotomies were not fixated, but eventually unthreaded Steinmann pins were used for fixation of the first and fifth metatarsals.

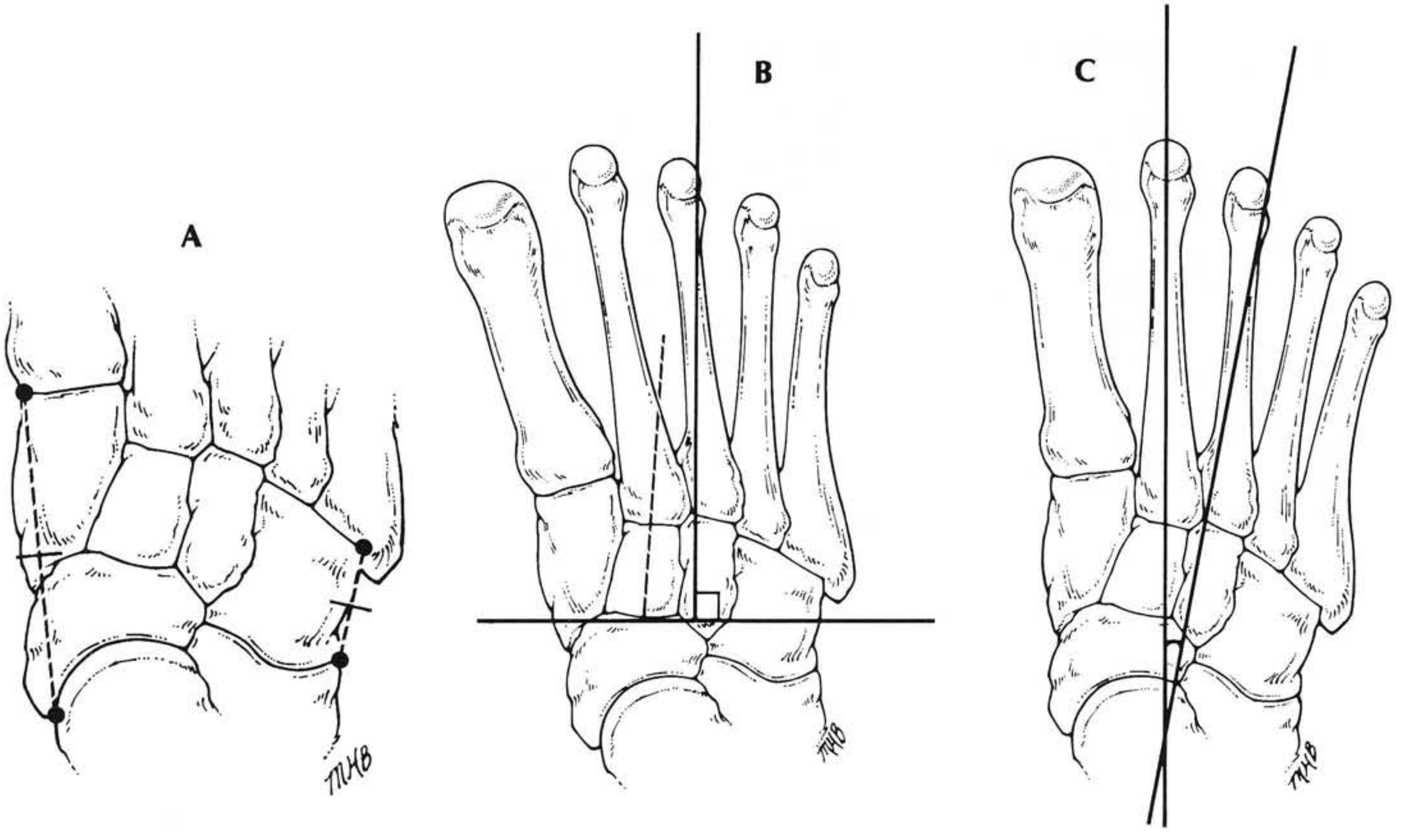

Fig. 3. Diagrammatic representation of determination of metatarsus adductus angle by Whitney. A. Plotting of critical points and determination of longitudinal bisector of lesser tarsus. B. Lesser tarsus axis is represented by the bisection of the longitudinal bisector of the lesser tarsus. C. Diagrammatic representation of the metatarsus adductus angle (see text for complete details).

Fig. 4. Alternative method of determining metatarsus adductus angle according to Engel.

In the following section the various modifications of the Berman and Gartland procedure will be examined, the different types of fixation will be discussed as well as the complications and postoperative management. The soft tissue dissection has been discussed elsewhere and will not be addressed.

Over the past fifteen years the staff of the Podiatry Institute has used a combination of procedures for the correction of metatarsus adductus in the child age six and older with moderate to severe metatarsus adductus unresponsive to conservative therapy. In addition these procedures are used for the correction of symptomatic residual metatarsus adductus in the patient with previously corrected talipes equinovarus.

Modified Berman-Gartland Procedure

The modified Berman-Gartland procedure uses either transverse base wedge osteotomies or oblique base wedge osteotomies of the metatarsals with internal fixation of stainless steel wire, Kirschner wire (K-wire), small bone staples or small bone screws (Fig. 5).

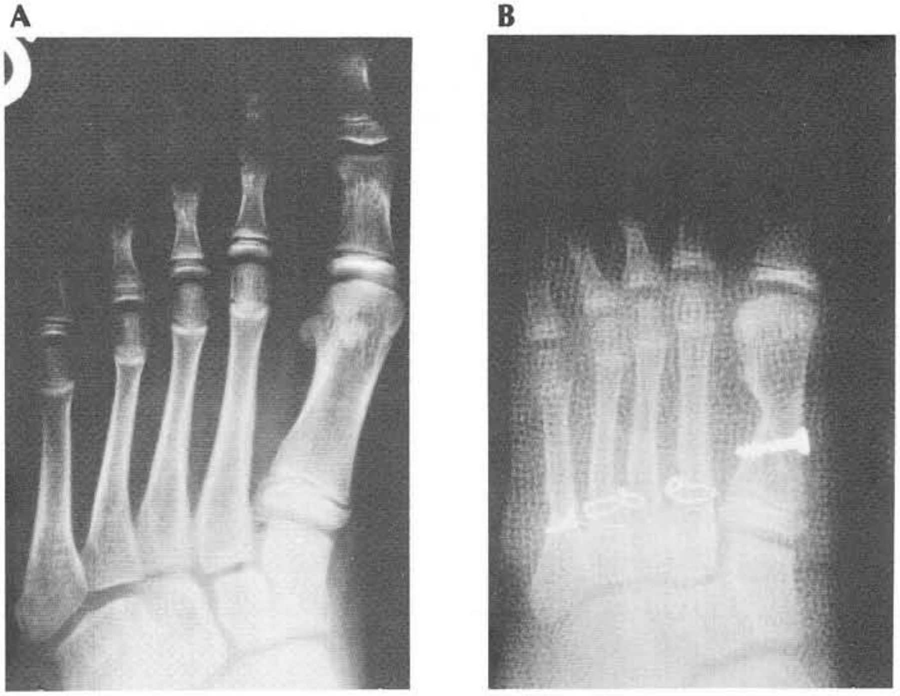

Fig. 5. Preoperative and postoperative radiographs of metatarsus adductus repair using modified Berman and Gartland procedure.

The Modified Berman-Gartland usually employs three dorsal longitudinal skin incisions and the principles of anatomic dissection. The periosteum of each metatarsal must be preserved with great care when exposing the proximal metaphyseal region. Nowhere is this more important than in exposing the base of the first metatarsal. Identification of the epiphyseal growth plate is critical to avoid damaging it during the osteotomy, and one should avoid excessive reflection of the periosteum surrounding the growth plate (Fig. 6).

Prior to performing the osteotomies the surgeon must decide upon the sequence of execution of multiple metatarsal procedures. This will vary with the preference and experience of the surgeon. Common patterns for performing the osteotomies are 5-1-2-3-4 and 1-2-3-4-5. In severe deformities, it may be difficult to reduce the adduction of the first metatarsal after osteotomy without first completing osteotomies on the adjacent metatarsals. In some cases it may not be necessary to to perform an osteotomy on the fifth metatarsal to achieve correction.

The staff at the Podiatry Institute has further modified the technique of Berman and Gartland to use closing abductory base wedge osteotomies of the first and fifth metatarsal as opposed to transverse base wedge osteotomies. The oblique base wedge osteotomies facilitate the use of AO/ASIF internal fixation techniques with small cortical or cancellous screws.

The fifth metatarsal is identified through the lateral incision, the periosteum is incised in a linear manner over the base and proximal portion of the shaft. The

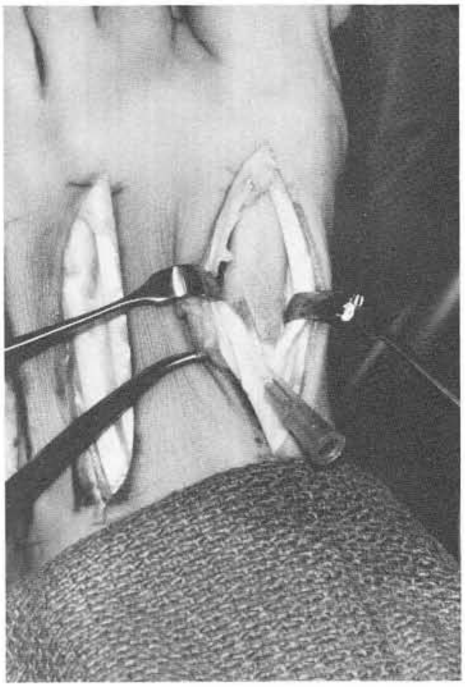

Fig. 6. Clinical photo of epiphysis of first metatarsal. Note identification of first metatarsal cuneiform articulation.

insertion of the peroneus brevis tendon should not be disturbed. If a peroneus tertius is present then the periosteal incision should be placed laterally. An oblique osteotomy is performed from distal-lateral to proximal-medial preserving a medial cortical hinge. The osteotomy is placed such that it is oriented approximately sixty degrees to the long axis of the metatarsal and lies in the sagittal plane. To insure that the osteotomy is in the sagittal plane the medial cortical hinge should be perpendicular to the weightbearing surface or the plantar surface of the foot.

If sagittal plane correction is also desired (dorsiflexion or plantarflexion) then the cortical hinge is appropriately angled to the transverse plane. A second converging osteotomy is then performed and an appropriate wedge of bone removed (Fig. 7). The exact size of the wedge is determined by the extent of the deformity. The cortical hinge is weakened, the osteotomy is reduced and stabilized temporarily.

The first metatarsal is identified through the medial incision, following deep fascial dissection, the first metatarsal cuneiform articulation is located. This will assist in identifying the epiphyseal growth plate. The periosteum is incised in an oblique fashion from proximal-medial to distal-lateral along the course of the proposed osteotomy. The epiphyseal growth plate is identified, and minimal stripping of the periosteum is performed at this level. The osteotomy is then performed in an oblique fashion from distal-lateral to proximal-medial, preserving a medial cortical hinge in the sagittal plane. The osteotomy should be approximately 45 degrees to the long axis of the first metatarsal (Fig. 8). A second converging osteotomy is performed and an appropriate wedge section of bone removed, the hinge is weakened and the osteotomy is reduced and temporarily stabilized.

Generally, osteotomies are performed on the central three metatarsals in a similar fashion. The decision to perform transverse or oblique base wedge osteotomies is a matter of surgeon's preference. An influencing factor in that decision is the type of fixation to be used. If the surgeon elects to use stainless steel wire in a vertical mattress fashion or a horizontal mattress fashion the oblique base wedge osteotomy will facilitate its use. The transverse base wedge is easily fixated with K-wires. Fixation techniques will be discussed in more detail later.

Both transverse and oblique base wedge osteotomies are performed in the proximal metaphysis and require an intact medial cortical hinge that lies primarily in the sagittal plane. Proper orientation of the osteotomy is critical to maintaining the metatarsal head level in both the sagittal and transverse planes. This also requires accurate wedge resections of bone from each affected metatarsal. The severity of the deformity will dictate the amount of bone that is removed. Usually a greater amount of bone removal is required from the medial metatarsals (one and two) than from the lateral three metatarsals. Maintenance of the medial cortical hinge becomes increasingly more difficult as the size of the wedge resection increases. Intraoperative radiographs are helpful to insure adequate wedge resection and corrective alignment of the metatarsals.

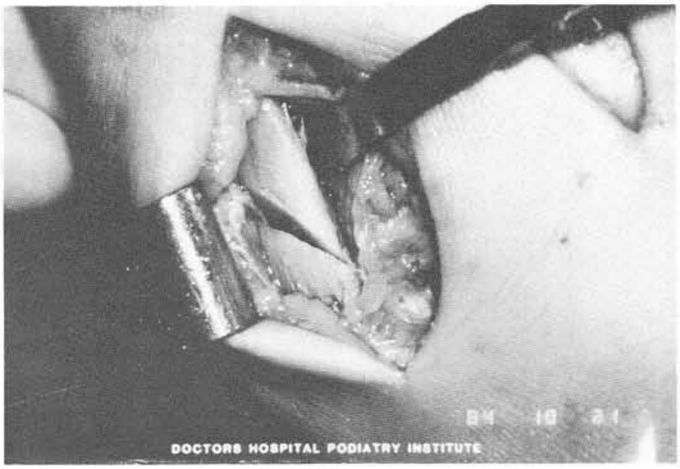

Fig. 7. Oblique base wedge osteotomy of fifth metatarsal.

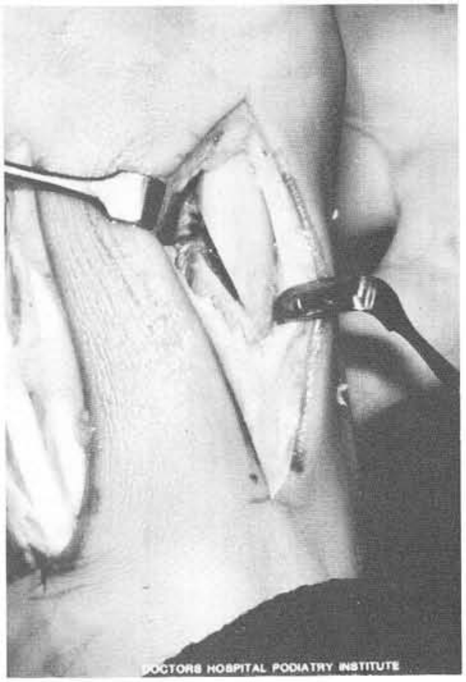

Fig. 8. Oblique base wedge osteotomy of first metatarsal.

Lepird Procedure

Richard Lepird (1981) introduced a new osseous procedure for the correction of metatarsus adductus in the child age six to eight years of age. Since its introduction it has been used extensively by the faculty of the Podiatry Institute. The procedure uses rotational osteotomies of the central three metatarsals as opposed to wedge resections (Fig. 9).

The procedure is performed through a standard dorsal three incisional approach similar to that used for the Modified Berman-Gartland procedure. The sequence of execution of the osteotomies will vary with the surgeon. The osteotomies of the first and fifth metatarsals are

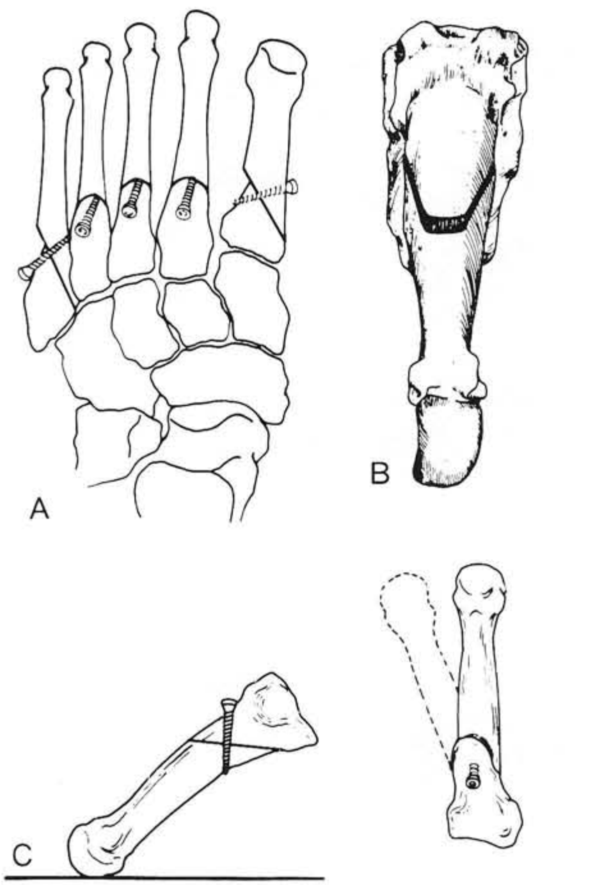

Fig. 9. Diagrammatic representation of the Lepird procedure for correction of resistant metatarsus adductus (see text for details).

oblique base wedge osteotomies as described previously. The central three osteotomies are rotational or transpositional through and through cuts that do not require bone resection. The osteotomy is initiated dorsally at the junction of the proximal and middle one thirds of the metatarsal. It is an oblique osteotomy oriented from dorsal-distal to plantar-proximal essentially parallel to the plantar aspect of the foot (approximately 45 degrees to the dorsal surface of the metatarsal). Great care should be taken to insure that the osteotomy exits proximal to the metatarsal cuneiform joint. When the osteotomy is performed a small portion of the cortex is preserved to prevent motion between the proximal and distal segments prior to fixation. The saw blade must parallel the plantar aspect of the foot to produce an osteotomy that results in pure transverse plane motion when the distal segment is abducted on the proximal portion (Fig. 10). If the saw blade is angled medially the resulting osteotomy would produce dorsiflexion as well as abduction to the distal segment. Similarly, if the saw blade were angled laterally the resulting osteotomy would produce simultaneous plantarflexion and abduction. These type results may be warranted depending upon the deformity.

The Lepird procedure was developed to take advantage of the AO/ASIF concept of internal compression fixation.

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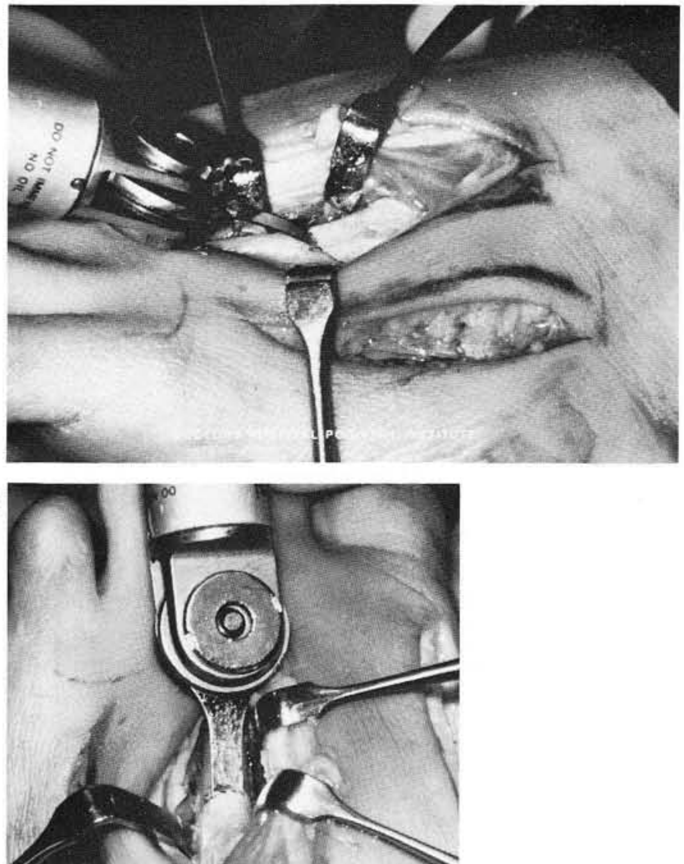

Fig. 10. Rotational osteotomy of lesser metatarsals. Saw blade is essentially parallel to plantar aspect of foot.

Prior to complete transection of the metatarsal, fixation is performed using small cortical bone screws oriented perpendicular to the plane of the osteotomy. Temporary fixation in the form of bone reduction forceps or K-wires is not necessary because a small portion of the cortex had been maintained. When the osteotomy is completed, the screw is placed across the osteotomy. Before the screw is finally secured, the distal shaft portion of the metatarsal is rotated laterally into the desired position (Fig. 11). Radiographs are employed to evaluate the amount of correction. If more or less correction is desired, the screw can be loosened, the appropriate position obtained and the screw secured (Fig. 12).

COMPLICATIONS AND FIXATION

Critical to the use of transverse or oblique base wedge osteotomies is the preservation of a medial cortical

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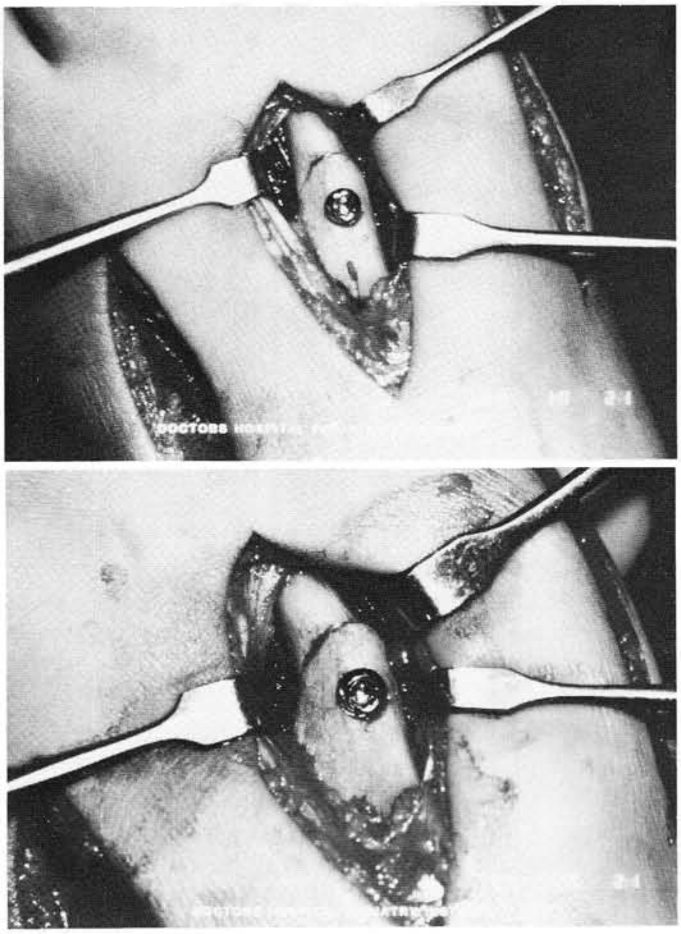

Fig. 11. Fixation of rotational osteotomy using AO technique. Distal metatarsal segment is rotated into desired position.

hinge. If the cortical hinge fractures significant instability can result. It is imperative that adequate stabilization of the segments be accomplished. Significant instability can increase the likelihood of displacement, malalignment, delayed union, nonunion, pseudo-arthrosis, or osseous bridging. Fixation for transverse base wedge osteotomies can be accomplished with the following techniques: K-wires used in a percutaneous or buried fashion, fixating individual metatarsals or a single K-wire to stabilize all the metatarsals. Stainless steel wire can be employed in several ways; in a cerclage fashion, horizontal or vertical mattress, or in combination with K-wires similar to a tension band. Small bone staples may also be employed.

A full discussion of the complications of the oblique base wedge osteotomy and fixation techniques is beyond the scope of this paper. The faculty of the Podiatry Institute has employed screw fixation for oblique base wedge osteotomies for more than ten years with great success. Essential to the use of AO/ASIF techniques of fixation of the first or fifth metatarsal is the preservation of a medial cortical hinge. Strict adherence to the AO principles decreases the incidence of failure. As previously mentioned, in the presence of an open epiphysis in the first metatarsal, the osteotomy is performed a centimeter more distally. This technique has been used both in correction for metatarsus adductus and in juvenile hallux abductovalgus without reported incidence of injury to the physis or shortening of the first metatarsal.

The rotational osteotomy used in the Lepird technique offers a number of advantages over traditional base wedge osteotomies. It precludes the need for an intact medial cortical hinge. Secondly, the use of small cortical or cancellous bone screws provides rigid internal com-

A

Fig. 12. Postoperative radiographs of Lepird procedure.

B

pression fixation resulting in primary bone healing greatly and reducing the likelihood of osseous bridging between adjacent metatarsals. Finally, obtaining desired correction is made easier during surgery simply by loosening the screws and repositioning the metatarsal segments and resecuring the screws.

The technique of rotational osteotomies is not without its disadvantages. If the osteotomy is performed too vertical the screw fixation proves inadequate or may fail, then stabilization of the metatarsal segments will be difficult due to the through and through nature of the osteotomy. In such a situation fixation would best be accomplished with a combination of stainless steel wire and K-wire. If the screw fixation fails during the postoperative period, the screw may function as a distracting force resulting in a delayed union, nonunion, malalignment, or pseudarthrosis. The use of internal fixation may mean removal of hardware in the future and a second surgical procedure.

POSTOPERATIVE MANAGEMENT

Immediately postoperative the patient is placed in a below-knee compression cast for three to five days. This is followed by a below-knee non weight-bearing cast for six to eight weeks. Radiographs are performed periodically to access the healing process. In selected cases, the patients may have the cast bivalved permitting early active range of motion exercise and faster return to normal function.

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