Iatrogenic Metatarsus Primus Elevatus

Etiology, Evaluation, and Surgical Management

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Iatrogenic metatarsus primus elevatus is an infrequent but devastating complication of first ray surgery. The authors address their clinical and radiographic evaluation of metatarsus primus elevatus, and describe a surgical treatment with emphasis on the sagittal plane Z-osteotomy. This osteotomy provides predictable and versatile correction for the treatment of iatrogenic deformities of the first metatarsal. It allows for plantarflexion and lengthening of the first metatarsal while avoiding an interpositional bone graft. The technical aspects of the procedure are thoroughly discussed.

Complications of first ray surgery commonly reduce the weightbearing capability of the medial column of the foot. The direct etiology is usually a combination of elevation and shortening of the first metatarsal. The clinical syndrome of iatrogenic metatarsus primus elevatus is often secondary to malunion of a proximal or distal osteotomy originally intended for reduction of metatarsus primus varus. Inaccurate preoperative or intraoperative planning or poor execution of the osteotomy may be contributing factors. Excessive shortening of the first metatarsal creates the same effect as excessive elevation.

Various complications routinely result from an iatrogenic metatarsus primus elevatus. These include hallux limitus and rigidus, subsecond metatarsal pathology, generalized lesser metatarsalgia, and increased pronation of the foot. Residual or recurrent hallux valgus may further complicate the forefoot derangement. Long-term sequelae include abnormal compensatory gait patterns with lateral weight transfer, and when recalcitrant to accommodative management, require surgical treatment.

Many such patients have also experienced significant wound-healing complications following their previous surgeries. There is often a history of delayed union, nonunion, or malunion of a first metatarsal osteotomy, wound dehiscence or infection, and a prolonged period of cast immobilization. Not surprisingly, these patients also frequently have postsurgical neuritic pain, either from direct nerve entrapment, or causalgia related to prolonged immobility.

Such patients have usually been managed with conservative measures following the original surgery, in an attempt to accommodate the elevated medial column. The typical postoperative course following wound healing and scar maturation demonstrates a clinical plateau of improvement at 1 year. This is when most patients either seek another opinion, or are referred for further evaluation or surgical management.

Evaluation of Metatarsus Primus Elevatus

Accurate clinical and radiographic assessment of metatarsus primus elevatus are essential components of successful conservative or surgical management. The clinical examination is the primary means of determining the severity of the deformity. Radiographic assessment serves to confirm the findings of
the clinical examination. Manual evaluation of the “loaded” distal weightbearing plane of the first metatarsal, as compared with the second metatarsal, will determine the degree of dorsal elevation of the first metatarsal (Fig. 1). It is important to manually assess and visually imprint the position of the first metatarsal in the mind of the surgeon, as the clinical assessment will be the determinant of the corrected position in surgery. Although a subjective means of assessment, this technique is the authors’ measure of both the preoperative condition and the intraoperative corrected position of the first metatarsal relative to the lesser metatarsals.5

Sagittal plane deviation of the first metatarsal is classically rigid and fixed in the iatrogenic deformity. Clinically, the distal first metatarsal exhibits a dorsally displaced attitude in relation to the second metatarsal. Plantar tylomas beneath the lesser metatarsals, and restricted mobility of the first metatarsophalangeal joint (structural hallux limitus) caused by previous surgery, are common presenting chief complaints. Not infrequently, the presence of hallux equinus introduces an added negative effect.1 During gait, the hallux may plantarflex or “grip” the ground in an attempt to stabilize the medial column. The resultant retrograde dorsiflexory force on the metatarsal head further aggravates the existing hallux limitus and metatarsus primus elevatus.

Radiographic Assessment

Radiographic evaluation is imperative and serves essentially as the baseline for comparison between the preoperative state and the postoperative result. It is clearly evident that radiographic variables, such as tube-head angle, can easily alter the apparent first-to-second metatarsal relationship on a lateral projection of the foot. However, an angular relationship between the first and second metatarsals exists on a weightbearing lateral projection that remains relatively constant and independent of radiographic technique.2

Anatomically, the dorsal diaphyseal portion of a metatarsal is consistently flat from the proximal to distal metaphyseal flares. Furthermore, the articular base of the metatarsal forms a $90^\circ$ relationship to the dorsal diaphyseal portion of the bone (Fig. 2). This is consistently and clearly demonstrable on a lateral projection radiograph of the foot, regardless of the position of the foot or underlying deformity. There are, however, a few conditions in which this relationship is violated. In the event of a previously malunited osteotomy of the first metatarsal, or following trauma to the first metatarsal, a deviation from this right-angle relationship may exist.

Using these two parameters (angular deviation between first and second metatarsals, and the right-angle relationship of the metatarsal shaft to base), radiographic metatarsus primus elevatus can be differentiated and classified. Although elevation of the

Figure 1. Clinical assessment of postsurgical metatarsus primus elevatus, through manual loading of the first metatarsal.

Figure 2. Normal right-angle architectural relationship of the first metatarsal articular base to the dorsal diaphysis.
first metatarsal in iatrogenic deformities is predominantly structural and rigid, extrinsic or positional elevatus is an equally important entity.

Positional or extrinsic metatarsus primus elevatus is present when there is clinical and radiographic divergence between the first and second metatarsals with a normal structural architecture of the first metatarsal bone. The assessment of metatarsal architecture is first determined by evaluation of the right-angle relationship of the first metatarsal base to dorsal diaphysis. When the normal right-angle relationship is preserved, then the bone itself is structurally normal. The deformity is extrinsic to the metatarsal. The second measurement is the amount of angular divergence between the first and second metatarsals. This is accomplished by tracing the dorsal diaphyseal surfaces of the first and second metatarsals and measuring the amount of angular change with a goniometer.

The lateral weightbearing radiograph of the patient in Figure 3A shows an angular dorsal deviation of the first metatarsal over the second metatarsal, suggesting a true metatarsus primus elevatus deformity. In Figure 3B, the right-angle relationship of the first metatarsal base to the dorsal diaphysis is outlined, and it is apparent that a normal relationship exists. This suggests that the elevatus deformity is extrinsic to the metatarsal, and thus positional in nature. Figure 3C highlights the outline of the first and second metatarsals, which aids in defining the dorsal diaphysis of each bone. Two straight lines are then drawn to define the dorsal diaphysis of the first and second metatarsals, and a goniometer is used to quantify the amount of metatarsus primus elevatus (9.5°).

Figure 3A. Lateral weightbearing radiograph of a foot with an elevated first metatarsal. Note the angular deviation between the first and second metatarsals.

Figure 3B. A normal first metatarsal right-angle relationship between the articular base and dorsal diaphysis is shown. This indicates that the etiology of the metatarsus primus elevatus is extrinsic to the metatarsal, and positional in nature.

Figure 3C. Outline of the first and second metatarsals, defining the dorsal cortex of each bone.

Figure 3D. Lines have been drawn to represent the dorsal cortex of the first and second metatarsals. Measuring the angle created between these two lines, it is apparent that there is 9.5° of extrinsic metatarsus primus elevatus.
of extrinsic elevatus) (Fig. 3D).

Metatarsus primus elevatus occurring secondary to changes within the metatarsal bone itself may be appropriately termed intrinsic or structural elevatus. The most dramatic and frequently encountered example of this is postsurgical elevatus resulting from malunion of a metatarsal osteotomy. This can be seen following both proximal and distal metatarsal osteotomies (Fig. 4). Early ambulation with a fractured base-wedge hinge, failure or the inadequate use of internal fixation, or displacement of a distal metatarsal osteotomy can all lead to iatrogenic elevatus of the first metatarsal. Less frequently, traumatic fracture with malunion of the first metatarsal can lead to an intrinsic metatarsus primus elevatus (Fig. 5).

The patient in figure 6 had a transverse base wedge for correction of a hallux abducto valgus deformity. Figure 6A shows severe angular elevation of the first metatarsal over the second metatarsal (the first metatarsal is outlined to define its shape). In figure 6B, the predicted normal right-angle relationship of the first metatarsal base to diaphysis is outlined. It is clear that this relationship is violated, as the distal metatarsal protrudes far above the predicted normal right-angle position of the metatarsal. The locus of the elevatus deformity is within the structural architecture of the metatarsal bone, or intrinsic. By outlining the first and second metatarsals, the reference lines that represent the dorsal diaphysis of the first and second metatarsals may be drawn (Fig. 6C). A measurement of this angular relationship shows 19° of intrinsic metatarsus primus elevatus (Fig. 6D).

The radiographic identification and appreciation of the intrinsic metatarsus primus elevatus greatly facilitate the surgical treatment of iatrogenic first ray deformities. Likewise, these radiographic parameters will be the benchmark by which the surgical outcomes are assessed.

**Surgical Considerations and the Sagittal Plane Z-Osteotomy**

Intrinsic or structural elevation exists within the bone itself, most often as a result of previous surgical intervention. Therefore, surgical correction should

![Figure 4A. Metatarsus primus elevatus secondary to a proximal metaphyseal osteotomy malunion.](image)

![Figure 4B. Metatarsus primus elevatus secondary to a diaphyseal osteotomy malunion.](image)

![Figure 4C. Metatarsus primus elevatus secondary to a distal metaphyseal osteotomy displacement.](image)

![Figure 5. Traumatic fracture with malunion of the first metatarsal resulting in an intrinsic metatarsus primus elevatus deformity.](image)
be directed at the first metatarsal. An attempt at correction of this deformity should be resisted by addressing a more proximal or distal site (first metatarsophalangeal or first metatarsocuneiform joint), as the site of correction should correlate to the actual location of the deformity.

Structural, sagittal plane elevation of the first metatarsal produces a distinct syndrome of symptoms and related deformities. Therefore, surgical correction should aim to recreate an even weightbearing plane to the forefoot, and restore motion to the first metatarsophalangeal joint. As the architecture of the first metatarsal bone has been violated, surgical correction through the use of an osteotomy most appropriately achieves the desired correction. Surgical manipulation of the bone should aim to avoid large interposition bone grafts, and provide optimal stability through the use of rigid internal fixation.

The primary goals for correction of an iatrogenic metatarsus primus elevatus deformity are to plantarflex the metatarsal segment and lengthen if necessary. Mild intermetatarsal angle reduction is also possible for addressing recurrent or residual metatarsus primus varus. These goals are adequately achieved through the use of a sagittal plane $Z$-osteotomy. Furthermore, this technique eliminates the need for a bone graft that must eventually accept weightbearing forces while maintaining the achieved correction, as is the case with opening plantarflexory wedge osteotomies. The ultimate aim is to reestablish weightbearing to the metatarsal head and restore function to the medial column.

Certain physiologic and functional factors of the deformity must be recognized prior to performing this procedure. Adaptive soft tissue contracture commonly surrounds the shortened and elevated metatarsal. This is addressed by thorough delamination of tissue planes, using the techniques of anatomic, lay-

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**Figure 6A.** Lateral weightbearing radiograph with a postsurgical metatarsus primus elevatus following a transverse base wedge osteotomy.

**Figure 6B.** The predicted right-angle relationship of the first metatarsal dorsal cortex to the articular base is shown. Note the elevated position of the distal metatarsal in relation to the predicted outline. This indicates that the locus of the elevatus deformity is within the structural architecture of the metatarsal bone itself, and thus an intrinsic metatarsus primus elevatus.

**Figure 6C.** Outline of the first and second metatarsals, defining the dorsal cortex of each bone.

**Figure 6D.** Lines have been drawn to represent the dorsal cortex of the first and second metatarsals. By measuring this angular relationship, it is apparent that there is $19^\circ$ of intrinsic metatarsus primus elevatus.
ered dissection. If this is not adequately accomplished, the restrictive soft tissue envelope will impede lengthening of the metatarsal. The potential for poor bone strength and decreased mineral content of the metatarsal secondary to disuse osteopenia is also a consideration. Iatrogenic shortening and dorsiflexion of a metatarsal may reduce the normal physiologic stresses of weightbearing required for optimal osseous strength. An analogous situation is encountered with an atrophic lesser metatarsal (brachymetatarsia) that has not been stress-loaded, and has a resultant cortical bone diameter that is narrower than the surrounding metatarsals.

Regarding function, hallux limitus or rigidus is an almost universal feature of these cases. Lengthening of the first ray in the presence of restricted metatarsophalangeal joint mobility and soft tissue contractures may exacerbate the limitus. Cheilectomy, distal osteotomy, implant arthroplasty, or resection arthroplasty are all viable options to improve the range of motion of the metatarsophalangeal joint. The authors typically favor resection arthroplasty of the base of the proximal phalanx, and use the base of the proximal phalanx as an autogenous bone graft. Although this bone does not possess impressive structural strength, it is suitable for filling any defects created by lengthening of the metatarsal.

**Technical Considerations of the Sagittal Z-Osteotomy**

The Z-configuration osteotomy is performed in the sagittal plane on the first metatarsal. The shape of the cut is similar to the “step-down osteotomy” described by Giannestras for lesser metatarsals. Axis guide Kirschner wires are used proximally and distally to ensure accurate bone cuts. The metatarsal is cut longitudinally between the axis guides. The proximal cut exits medially to avoid the entrance point of the nutrient artery laterally, and the distal cut exits laterally. The proximal axis guide may be placed slightly medial to midline of the metatarsal to maximize bone strength at the base. The distal axis guide is then placed slightly lateral to midline (Fig. 7).

Lengthening, plantarflexion, or a combination of both lengthening and plantarflexion of the metatarsal is achieved by sliding the free distal or medial fragment distally on the proximal fragment (Fig. 8). The principles of such slide lengthening demand preoperative evaluation of the amount of lengthening desired, and assessment of the available fixation area.

Rigid internal fixation of the osteotomy is routinely accomplished with two 2.7-mm cortical screws. Typi-

![Figure 7. Diagrammatic representation of the sagittal Z-osteotomy of the first metatarsal, from the dorso-plantar (A) and medial views (B).](image1)

![Figure 8. Three forms of osteotomy manipulation are possible with the sagittal Z-osteotomy, including lengthening (top), plantar rotation (middle), or a combination of lengthening and plantar rotation (bottom).](image2)
cally, 1.5 to 2.0 cm of osseous overlap or fixation area between the transposed bone segments is required to achieve rigid fixation and minimize the risk of a stress riser between the screw heads. The amount of metatarsal lengthening desired is then added to the fixation area. The result is the minimal allowable length of the required osteotomy. For example, if 1 cm of length is desired, and approximately 2 cm of fixation area is required, the osteotomy must be at least 3 cm long.

The preoperative determination of these parameters is critical. Quite frequently in iatrogenic metatarsus primus elevatus deformities, some form of internal fixation is still present in the metatarsal. Although the presence of cerclage wire does not generally pose a problem, the presence of previously inserted screws requires special attention (Fig. 9).

Plantarflexion of the metatarsal segment is an expected result of lengthening. As a declinated structure lengthens, it relatively plantarflexes as well. However, additional plantarflexion is achievable by rotating the distal fragment downward. This is particularly advantageous when adequate lengthening of the metatarsal is not possible or perhaps undesirable. Pure translational shift of the medial metatarsal half plantarward is avoided to prevent a troughing effect. Rather, the swivel movement ensures solid cortical abutment where the dorsal and plantar cortices overlap, providing medial to lateral stability (Fig. 10).

If plantarflexion of the metatarsal head is obtained solely through rotation, a small wedge of bone is removed at the proximal-planter corner of the medial metatarsal half to facilitate movement. This is not required when lengthening is performed simultaneously, as no impingement exists in this instance.

Residual or recurrent hallux valgus is frequently a component of an iatrogenic metatarsus primus elevatus deformity. Minor intermetatarsal angle reduction is possible with the sagittal plane Z-osteotomy in three ways. First, the intermetatarsal angle will be diminished slightly by the width of the saw blade when the proximal cut exits medially and the distal cut laterally. Second, if the longitudinal osteotomy is made obliquely, from proximal-medial to distal-lateral, as the metatarsal is lengthened it will likewise reduce the intermetatarsal angle. Last, if the axis guides of the longitudinal cut are inserted from dorsomedial to planar-lateral, as the capital fragment is rotated plantarly, it will move closer to the second metatarsal (Fig. 11).

Aggressive intermetatarsal angle reduction is not attempted or advised with this procedure. It is the authors’ experience that internal fixation is more difficult and tenuous if correcting residual metatarsus primus varus is the chief goal of the procedure. Numerous other first metatarsal osteotomies are better
Figure 11. A, A minor degree of intermetatarsal angle correction can be obtained by altering the longitudinal osteotomy in an oblique fashion, thereby reducing metatarsus primus varus through lengthening. B, Preoperative radiograph of a failed hallux valgus surgery. C, Surgical correction is achieved. D, 4-year follow-up examination. E, The clinical result at 4 years.
suited toward this aim than the sagittal plane Z-osteotomy.

A distinct benefit of the sagittal plane Z-osteotomy is predictable and adjustable manipulation of the metatarsal head. Rigid interfragmentary compression is generally accomplished with 2.7-mm cortical screws applied from medial to lateral, using the lag technique. The free distal fragment is first temporarily stabilized with a proximal pin. The distal fragment is then swiveled or slide-lengthened into the desired position. A bone clamp is next applied distal to the initial pin, and the chosen correction verified. If any adjustment is required, the bone clamp is simply removed, the adjustment is made, and the bone clamp reapplied. The distal screw is then inserted using standard technique, followed by insertion of the proximal screw. Alternatively, threaded pin fixation may be used in case specific situations (Fig. 12).

Any osseous gaps created by lengthening of the segment may be filled with bone graft. The authors frequently use a portion of the resected base of the proximal phalanx as incidental graft, and stabilize it with additional pins or 2.0-mm screws. However, autogenous calcaneal graft or allogenic cadaveric bone are also suitable. The role of this graft is simply a space filler and it is not a factor in maintenance of correction (Fig. 13). Where incidental bone grafting is not deemed necessary because of minimal lengthening, the Regnauld procedure may be used to increase range of motion at the metatarsal phalangeal joint.

Postoperative management consists of strict non-weightbearing for 6 to 8 weeks in a below the knee cast or brace, followed by gradual return to full activity. The osteotomy and fixation are not stable against the normal cantilever load of ground reactive forces on the metatarsal head. However, as any bone graft is incidental in nature, it need not incorporate fully prior to weightbearing. Premature attempts at weight-bearing will likely jeopardize the result and lead to further complications (Fig. 14).

Discussion

The surgical reconstruction of many iatrogenic metatarsus primus elevatus deformities necessarily addresses elevation and shortening of the metatarsal. The preoperative goals are to improve functional loading and weight transfer to the medial column, and relieve compensatory symptomatology caused by the original deformity. The surgical options that will accomplish these goals are few.

A plantarflexory base osteotomy is a historically popular method of regaining weightbearing to an elevated metatarsal. However, certain limitations are apparent with this approach. A plantarflexory closing base wedge osteotomy adds further undesirable shortening to the first metatarsal. The opening plantarflexory wedge osteotomy can achieve plantarflexion and some lengthening simultaneously with the use of an interpositional bone graft. Unfortunately, the final degree of correction depends on precise siz-
Figure 13. Autogenous bone from the base of the proximal phalanx is used as an incidental graft to fill the medial and lateral voids that were created through lengthening. A, Diagrammatic representation. B, Intraoperative appearance following lengthening and screw placement. C, Following bone grafting.

Nevertheless, this is probably unnecessary and excessively cumbersome for treating lesser degrees of deformities, and seems less controllable in respect to sagittal plane correction. Modifications of Juvara-type osteotomies such as the Juvara “C” are also viable options in treating iatrogenic hallux limitus and rigidus. They may be preferable where more intermetatarsal angle correction is desired rather than regaining metatarsal length. These osteotomies do allow for sagittal plane manipulations nicely.

The final option for stabilizing and returning function to a deficient medial column is first metatarsophalangeal joint fusion. Arthrodesis is an effective way to rectify the sequelae of an iatrogenically shortened metatarsal, but could require the use of an
Figure 14. The osteotomy is not stable against the forces of unprotected weightbearing. A, Preoperative anteroposterior radiograph. B and C, Postoperative anteroposterior and lateral radiographs. D and E, Disruption of the osteotomy and failure of fixation caused by premature weightbearing in the surgical cast.
interpositional bone graft to regain the needed length. Additionally, sagittal plane deviation of the first ray may not be salvageable by metatarsophalangeal fusion alone. Any intrinsic metatarsal elevatus present must be resolved prior to stabilization of the ray on the weightbearing plane.

The sagittal plane Z-osteotomy, as described, combines the advantages of these procedures while minimizing their shortcomings in a surgical solution to iatrogenic metatarsus primus deformities. Reliable plantarflexion and lengthening of the metatarsal segment, without the need for an interpositional bone graft, are its main highlights (Fig. 15).

Summary

Iatrogenic metatarsus primus elevatus is a debilitating result of a failed first metatarsal osteotomy. A painful clinical syndrome secondary to inefficient medial column loading is characterized by lesser metatarsalgia, plantar transfer tylomas, and hallux limitus and rigidus. The clinical and radiographic findings have been detailed, with an emphasis on delineating intrinsic structural elevatus within the architecture of the first metatarsal from extrinsic causes.

The sagittal plane Z-osteotomy possesses unique advantages versus other salvage procedures of the first ray. This technique effectively deals with the components of intrinsic metatarsus primus elevatus and shortening that are encountered in many iatrogenic foot deformities. Intraoperative correction is both versatile and adjustable, and rigid interfragmentary compression fixation is readily attained. No major bone grafting is required, which simplifies the postoperative course and adds predictability to the procedural technique and final outcome. Adjunctive procedures addressing residual or recurrent hallux valgus, as well as first metatarsophalangeal joint contracture and limitation of motion (hallux limitus and rigidus), are also frequently required to restore function to this joint.

Figure 15. Three different patients with follow-up weight-bearing radiographs following sagittal Z-osteotomy correction of iatrogenic metatarsus primus elevatus, A, At 1 year, B, At 3 years, and C, At 3 1/2 years. Note the parallel sagittal relationship between the first and second metatarsals, and the recreated 90° orientation of the first metatarsal’s articular base to dorsal cortex.

References

Additional References
