CHAPTER **24**

# Radiographic Evaluation And Classification of Metatarsus Primus Elevatus

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## INTRODUCTION

Metatarsus primus elevatus is a clinical diagnosis in which the first metatarsal is dorsally deviated in the sagittal plane in relation to the lesser metatarsals. The most common sequela of a metatarsus primus elevatus is hallux limitus or rigidus, which has been described as either structural or functional in nature. The most accurate method of assessing the sagittal plane relationship of the first metatarsal is through manual range of motion examination. However, the radiographic appearance of an elevated first metatarsal (lateral projection) provides insight to the static, stance position of the forefoot. A clear understanding of the radiographic appearance of this relationship can facilitate both conservative and surgical management of this condition.

## ETIOLOGY

A variety of structural and positional conditions of the forefoot and rearfoot predispose the patient to the development of metatarsus primus elevatus. In addition, the structural predisposing condition may be either developmental or acquired in nature. One must also realize that early in the progression of elevation of the first metatarsal, the deformity may appear flexible and reducible. However, as time ensues, the positional relationship of the first metatarsal to the lesser metatarsals may become rigid and fixed.

Commonly identified structural conditions predisposing to metatarsus primus elevatus include an excessively long or short first metatarsal, or a short proximal phalanx of the hallux. A hypermobile medial column or first metatarsal can also lead to sagittal plane elevatus. An uncompensated or partially compensated forefoot varus or supinatus, rearfoot, or ankle varus, can prevent the first metatarsal from purchasing the weight-bearing surface. Degenerative arthritis or neuropathic arthropathy, with a loss of integrity of the load-bearing medial column of the foot, can lead to an acquired elevatus. Finally, iatrogenic elevatus is a not uncommon, yet debilitating sequela of first ray surgery.

## CLINICAL ASSESSMENT

The sagittal plane relationship of the adjacent distal metatarsals is appreciated on physical examination through manual loading of the weight-bearing forefoot. With metatarsus primus elevatus, the distal first metatarsal appears to have a dorsally displaced end range of motion, when compared to the position of the second metatarsal. The clinical significance of such a condition is variable, based on the severity of elevatus in relation to the amount of compensation.

For instance, an excessively long first metatarsal will require a certain amount of elevatus in order to maintain an even plane of contact between the metatarsal heads and the ground. In relation to the position of the first metatarsal, the lesser metatarsals must assume a more plantarflexed position in order to make contact with the ground.

In extreme contrast, a short first metatarsal can also lead to an apparent elevation of the first metatarsal. A developmental arrest of growth of the first metatarsal will preclude weight-bearing of the distal metatarsal head, and in an attempt to gain stability of the medial column, the hallux will often plantarflex or "grip" the ground. The resultant retrograde effect on the first metatarsal will be elevation of the metatarsal. This is best appreciated through stance and gait analysis.

The least discussed and most commonly overlooked component of the first metatarsophalangeal joint complex is the sesamoid apparatus. Its contribution to first metatarsal position and load-bearing of the medial column must be evaluated both clinically and radiographically. Degenerative arthritis

of the metatarsal-sesamoid articulation often leads to longitudinal enlargement of the sesamoids and ankylosis of the sesamoids to the plantar aspect of the metatarsal head. "Locking" of the normal gliding motion of this joint prevents dorsal excursion of the proximal phalanx on the metatarsal head, which in effect renders the entire metatarsal-sesamoid-phalangeal joint immobile. The required amount of metatarsophalangeal joint dorsiflexion for propulsion is thus transferred to the next most proximal and/or distal joint(s) (metatarsal-cuneiform or hallux interphalangeal joint). The initial effect on the first metatarsal is propulsive elevatus, which can later progress to a fixed position of stance-phase elevatus.

## CORRELATING CLINICAL AND RADIOGRAPHIC FINDINGS

Few sources have attempted to classify or quantify the various types of metatarsus primus elevatus based on radiographic examination. Meyer et. al described a method of measuring the distance between the first and second metatarsals at the flare of the surgical neck. Their study concluded that a normal amount of elevation (6.91 mm) was present between the first and second metatarsals, and that no correlation existed between radiographic and clinical findings in hallux valgus, hallux limitus, and control patients. However, one would expect that the first metatarsal lies dorsal to the second metatarsal by virtue or fact that the first metatarsal has a larger girth than the second. In addition, the head of the first metatarsal rests upon the sesamoid apparatus, which displaces the bone in a dorsal direction. Thus, the normal radiographic observance of a separation of the first and second metatarsals is assumed, both anatomically and functionally.

The distance between the first and second metatarsal on a lateral-projection radiograph, although, can be greatly increased in instances where a patient has an uncompensated or partially compensated forefoot or rearfoot varus deformity which prevents the first metatarsal from contacting the ground. In this setting, a patient may have a clinically apparent hallux limitus deformity secondary to an underlying extrinsic condition. One may view this "separation" of the first and second metatarsals as a metatarsus primus elevatus, however, the angular relationship between the first and second metatarsals remains parallel to one another. This phenomenon may appropriately be termed a "pseudo-metatarsus primus elevatus."

Conversely, a patient may present with hallux limitus in conjunction with a collapsing pes valgo planus deformity. One may be led to believe that a metatarsus primus elevatus deformity exists, since the first metatarsal assumes an elevated position relative to the midfoot or rearfoot. However, if the deformity is fully compensated in the forefoot, the distal metatarsals will all contact the ground on the same plane. Although the first metatarsal may radiographically and clinically be horizontal in the sagittal plane (parallel to the ground), the relative relationship between the first and second metatarsals is radiographically normal (no angular deviation between the first and second metatarsals). Thus, one can see that an angular deviation between the first and second metatarsals is required for the diagnosis of metatarsus primus elevatus.

One must be aware that there are radiographic technique-dependent variables which can alter the first-to-second metatarsal relationship on a lateral projection of the foot. It is generally assumed that a lateral projection radiograph is taken with the foot in the angle and base of gait, and that the tube head of the x-ray machine is perpendicular to the foot and parallel to the ground. If one alters the angle of the tube head, then the amount of "separation" (super-imposition) of the first and second metatarsals is also altered. The effect of angulating the tube head can be seen in Figures 1A-C. In Figure 1A, a lateral projection radiograph of the author's foot was taken with the tube head parallel to the weight-bearing surface (control). In Figure 1B, the tube head was directed 10° dorsally (upward), and in Figure 1-C, the tube head was directed 10° plantarly (downward). By directing the tube head plantarly, there is an apparent decrease in the "separation" of the metatarsals, as the bones become superimposed. Conversely, directing the tube head dorsally creates an increased "separation" of the two bones. With this demonstration, it is apparent that a proper and consistent radiographic technique is required to prevent distortion of an image of the weight-bearing foot.

A review of patients with concomitant hallux limitus and metatarsus primus elevatus, however,

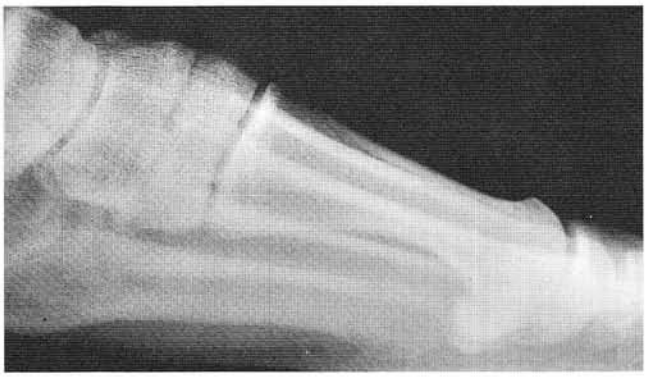

**Figure 1A.** Lateral weight-bearing radiograph taken with the tube head parallel to the ground, and perpendicular to the foot.


**Figure 1B.** Lateral weight-bearing radiograph with the tube head directed upward 10° (dorsally). Note the amount of separation of the first and second metatarsals, while the angular relationship between these two bones remains constant.

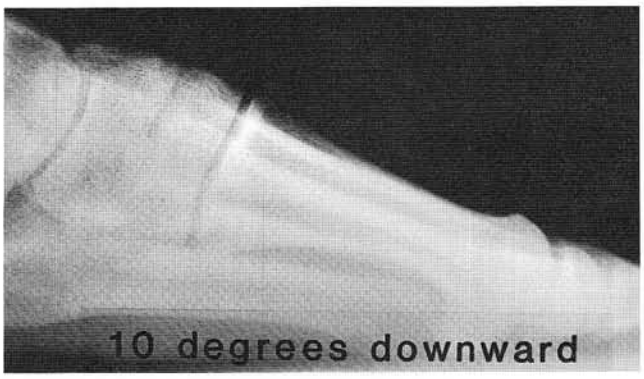


**Figure 1C.** Lateral weight bearing radiograph with the tube head directed downward 10° (plantarly). Note the increased superimposition of the first and second metatarsals. The angular relationship between these two bones remains constant.

clearly demonstrates that an angular relationship often exists between the first and second metatarsals, as viewed from a weight-bearing lateral-projection radiograph. This relationship of the first metatarsal to the second metatarsal compares similarly to the method of clinical examination of this condition. Thus, an assessment of this angular relationship appears to be a more reliable method of analysis of metatarsus primus elevatus.

The aforementioned demonstration of radiographic technique-dependent alteration of metatarsal superimposition also brings to light another observation. Although the sagittal relationship ("separation") of the first-to-second metatarsal is altered by angulation of the tube head, the angular relationship of these two bones (dorsal diaphysis of first and second metatarsals) remained the same in all three techniques. From this observation, one can conclude that the angular relationship between the first and second metatarsals remains relatively constant (independent of radiographic technique), and that angular divergence of the first and second metatarsals is required for the radiographic diagnosis of metatarsus primus elevatus.

A review of the anatomy of a metatarsal bone reveals that the dorsal diaphyseal portion of the bone is consistently flat from metaphyseal flare to flare (proximal to distal). Of more interest, however, is the observation that the articular base of the metatarsal forms a 90° relationship to the dorsal diaphyseal portion of the bone. This is consistently and clearly demonstrable on lateral-projection radiograph of the foot as well, regardless of the position of the foot or underlying deformity (acquired or congenital). There are, however, a few conditions in which this relationship is violated. In the event of trauma to, or surgery on the first metatarsal, one may see a deviation from this right-angle relationship.

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

## EXTRINSIC (POSITIONAL) METATARSUS PRIMUS ELEVATUS

In evaluating metatarsus primus elevatus, it is apparent that the level of deformity is either within

the metatarsal bone (structural) or extrinsic to it (positional). Positional or extrinsic metatarsus primus elevatus is present when there is a divergence between the first and second metatarsals (clinical and radiographic), 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 one can conclude that the bone itself is structurally normal (extrinsic deformity). The next step is to measure 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, in degrees with a goniometer, the amount of angular change.

The lateral weight-bearing radiograph of the patient in Figure 2 demonstrates an angular dorsal deviation of the first metatarsal over the second metatarsal, suggesting a true metatarsus primus elevatus deformity (Fig. 2A). In Figure 2B, the right-angle relationship of the first metatarsal base to the dorsal diaphysis is outlined, and one can see that a normal relationship exists. This suggests that the elevatus deformity is extrinsic to the metatarsal, and thus positional in nature. Figure 2C 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 (Fig. 2D), and a goniometer is used to quantify, in degrees, the amount of metatarsus primus elevatus (9.5° of Extrinsic Elevatus).

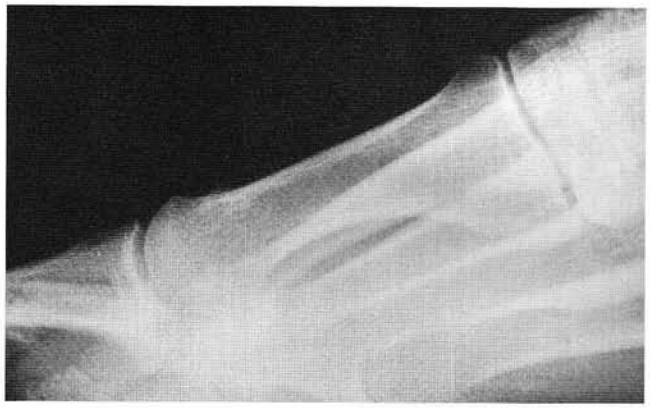

**Figure 2A.** Lateral weight-bearing radiograph of a foot with an elevated first metatarsal. Note the angular deviation between the first and second metatarsals.

**Figure 2B.** A normal first metatarsal right-angle relationship between the articular base and dorsal diaphysis is demonstrated. This indicates that the etiology of the metatarsus primus elevatus is extrinsic to the metatarsal, and positional in nature.

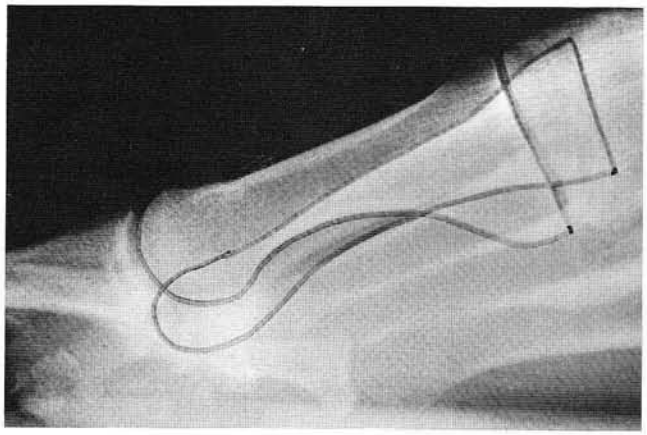

**Figure 2C.** Outline of the first and second metatarsals, defining the dorsal cortex of each bone.

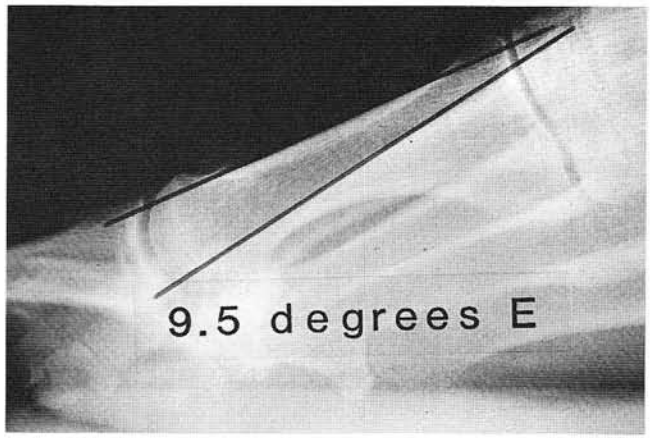


**Figure 2D.** Lines have been drawn to represent the dorsal cortex of the first and second metatarsals. Measuring the angle created between these two lines, it is apparent that there is 9.5 degrees of Extrinsic metatarsus primus elevatus.

## INTRINSIC (STRUCTURAL) METATARSUS PRIMUS ELEVATUS

Metatarsus primus elevatus can also occur secondary to changes within the metatarsal bone itself. The most dramatic and frequently encountered example of this is post-surgical elevatus resulting from malunion of a metatarsal osteotomy. This can be seen following both proximal and distal metatarsal osteotomies. Early ambulation with a fractured base-wedge hinge, failure 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 also lead to an intrinsic metatarsus primus elevatus.

The patient in Figure 3 had a transverse base-wedge osteotomy for correction of a hallux abducto valgus deformity. Figure 3A demonstrates severe angular elevation of the first metatarsal over the second metatarsal (the first metatarsal has been outlined to define its shape). In Figure 3B, the predicted normal right-angle relationship of the first metatarsal base-to-diaphysis has been outlined. One can clearly see that this relationship has been violated, as the distal metatarsal protrudes far above the predicted normal right-angle position of the metatarsal. From this exercise, one can conclude that the locus of the elevatus deformity is within the structural architecture of the metatarsal bone (Intrinsic). By outlining the first and second metatarsals (Fig. 3C), one can then draw reference lines which represent the dorsal diaphysis of the first and second metatarsals. A measurement of this angular relationship demonstrates 19° of Intrinsic metatarsus primus elevatus (Fig. 3D).

**Figure 3A.** Lateral weight-bearing radiograph with a post-surgical metatarsus primus elevatus following a transverse base wedge osteotomy.

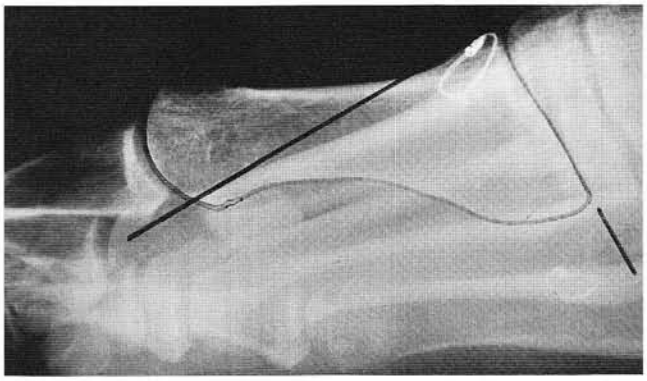

**Figure 3B.** The predicted right-angle relationship of the first metatarsal dorsal cortex to the articular base is demonstrated. Note the elevated position of the distal metatarsal in relation to the predicted outline. This indicates that the locus of the elevatus deformity is within the structural architecture of the metatarsal bone itself, and thus an Intrinsic metatarsus primus elevatus.

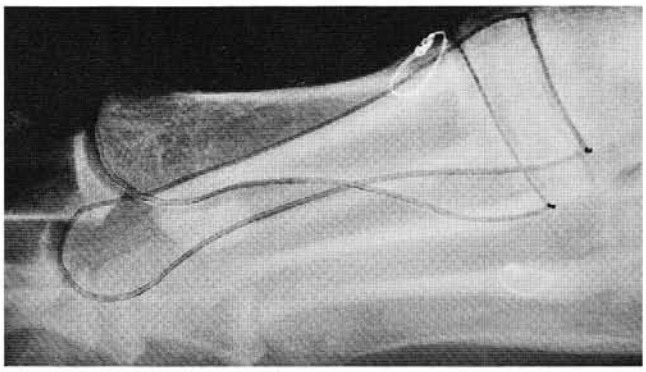

**Figure 3C.** Outline of the first and second metatarsals, defining the dorsal cortex of each bone.

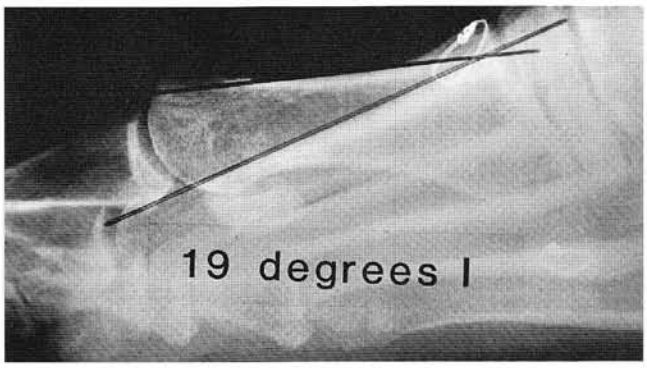


**Figure 3D.** Lines have been drawn to represent the dorsal cortex of the first and second metatarsals. By measuring this angular relationship, it is apparent that this is 19 degrees of Intrinsic metatarsus primus elevatus.

## SUMMARY

Metatarsus primus elevatus, although a clinical diagnosis, can manifest on pedal radiographs as an angular deviation between the first and second metatarsals. Extrinsic or positional elevatus is apparent when the normal architecture of the first metatarsal has been preserved, while Intrinsic or structural elevatus demonstrates a violation of the normal architecture of the first metatarsal bone. The differentiation between an Extrinsic versus an Intrinsic elevatus is made by examination of the normal right-angle relationship of the first metatarsal dorsal diaphysis to proximal articular surface. The most accurate method of quantifying the magnitude of metatarsus primus elevatus is through angular measurement of divergence of the first and second metatarsal bones.

## BIBLIOGRAPHY

Dananberg HJ: Functional Hallux Limitus and Its Relationship To Gait Efficiency. *J Am Pod Med* Assoc 76:11, 648-652, 1986.

Davies GF: Plantarflexory Base Wedge Osteotomy in the Treatment of Functional and Structural Metatarsus Primus Elevatus. *Clin Pod Med* Surg 6:1, 1989.

Mann RA, MJ Coughlin, HL DuVries: Hallux Rigidus. A Review of the Literature and a Method of Treatment. *Clin Orth Rel Res* 142:57-63, 1979.

McMaster MJ: The Pathogenesis of Hallux Rigidus. *J Bone Joint Surg* 60B:1, 82-87, 1978.

Meyer JO, LR Nishon, L Weiss, G Docks: Metatarsus Primus Elevatus and the Etiology of Hallux Rigidus. *J Foot Surg* 26:3, 237- 241, 1987.