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The Mechanical Axis of the First Ray: A Radiographic Assessment in Hallux Abducto Valgus Evaluation

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ABSTRACT

The present report describes a new method of hallux abducto valgus deformity correction planning using the mechanical axis of the medial column (mechanical axis planning). This method of radiographic evaluation identifies an ideal position for the first metatarsal after correction and is useful regardless of the surgical procedure chosen. We retrospectively reviewed 200 radiographs to identify a “normal” value for the mechanical axis angle. We reviewed 100 radiographs of patients with hallux abducto valgus deformity (deformity group) and 100 radiographs of patients without hallux abducto valgus deformity (control group). The deformity group revealed an M1-M2 anatomic axis angle of 13.5° ± 2.83° and an M1-M2 mechanical axis angle of 11.58° ± 1°. The control group revealed an M1-M2 anatomic axis angle of 7.5° ± 1.76° and an M1-M2 mechanical axis angle of 11.19° ± 0.9°. The differences in the M1-M2 anatomic axis angle and M1-M2 mechanical axis angle were statistically significant between the control and deformity groups. We sought to provide a reliable method for planning hallux abducto valgus deformity correction by aligning the mechanical axis of the medial column and the mechanical axis of the first ray to the “normal” value of 11° to reduce the deformity.

Hallux abducto valgus (HAV) deformity is an acquired, progressive disorder involving the first metatarsal phalangeal joint and metatarsal-sesamoid complex. This often painful deformity is a common complaint of patients presenting to the foot and ankle specialist. A longstanding deformity can produce varying degrees of functional adaptation, leading to pain and difficulty with ambulation. Reduction of the intermetatarsal angle (M1-M2 anatomic axis angle) has long been identified as essential for successful correction of HAV (1–5). The extensive published data on HAV have concentrated on surgical procedures, fixation techniques, and longitudinal studies of various periods. Despite the extensive amount of data published, no consensus has been reached on the ideal position of the first metatarsal after deformity reduction.

A significant focus of the HAV deformity evaluation has been placed on radiographic interpretation. In addition to the multiple radiographic angles described to evaluate HAV, other areas commonly assessed on the HAV radiograph are the joint space, sesamoid position, axial rotation of the hallux, metatarsal head shape, bone stock, and degenerative joint disease (3,6). The M1-M2 anatomic axis angle, formed by bisecting the first and second metatarsal shafts (intermetatarsal angle) is commonly used to choose the correct surgical procedure. The final position of the first metatarsal varies among foot and ankle surgeons. The postoperative position has ranged from 12° to 0° and brings into question how consistent results can be achieved (1–6). The present report describes the concept of the mechanical axis of the medial column and first ray and provides instructions on how to determine this mechanical axis. The HAV deformity planning we describe is a reliable method of determining the amount of translation and angulation necessary for deformity correction.

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Anatomic and Mechanical Axis Description

All long bones have both a mechanical and an anatomic axis (7,8). The mechanical axis of a bone is a straight line connecting the joint centers of the proximal and distal joints. The anatomic axis of a bone is defined as the mid-diaphyseal line (Fig. 1) (7,8).

Hallux Valgus Mechanical Axis Planning Technique

Mechanical axis planning for HAV deformity is an accurate method to determine the amount of correction necessary to reduce the deformity. The following examples describe a method (mechanical axis planning) to determine the amount of angular and translational correction necessary with any osteotomy or fusion procedure. Adherence to this method will result in realignment of the axes of deformity (colinear). This technique requires weightbearing radiographs, preferably in angle and base of gait.

Mechanical axis deformity planning has been described in the lower extremity; however, it has not been applied to the HAV deformity (7,8). We applied the concepts described by Paley (7) for lower extremity deformity planning to the medial column and the first ray in an effort to standardize HAV deformity planning. Similar to the use of the center of the femoral head as the joint center in creating the mechanical axis of the femur, we used the center of the talar head as the joint center in creating the mechanical axis of the medial column. In the following paragraphs we outline our method to determine the mechanical axis of the first ray and medial column and apply this method to HAV deformity planning.

Fig. 1. Depiction of mechanical and anatomic axes. Right femur: mechanical axis is demonstrated by a line connecting the center of the femoral head and the center of the distal femur. Left femur: anatomic axis is demonstrated by a mid-diaphyseal line. Right tibia: mechanical axis is shown by a line connecting the midpoint between the tibial spines and the midpoint of the tibial plafond. Left tibia: anatomic axis is shown by a mid-diaphyseal line. Note the anatomic and mechanical axes of the tibia are parallel.

First, draw a point at the center of the proximal phalangeal base (point A), the center of the first metatarsal head (point B), the center of the second metatarsal phalangeal joint (point C), and the dorsal lateral proximal corner of the medial cuneiform (point D; Fig. 2*A*). Next, draw any 2 lines tangent to the curvature of the talar head (Fig. 2*B*). Then, draw a line perpendicular to each tangent line (Fig. 2*C*). The intersection of the 2 perpendicular lines represents the center of the talar head (point E).

Next, draw a line from the center of the talar head to the center of the base of the proximal phalanx (line EA). This represents the mechanical axis of the medial column (talus, navicular, medial cuneiform, and first metatarsal; Fig. 3*A*). This line should pass through the dorsal lateral proximal corner of the medial cuneiform (point D), the center of the metatarsal head (point B), and the center of the base of the proximal phalanx (point A). In the normal foot, this line will be colinear or parallel to a bisection of the first metatarsal shaft (anatomic axis). A segment of this line (DB) represents the mechanical axis of the first ray (cuneiform and first metatarsal).

Finally, draw a line from the center of the talar head (point E) to the center of the second metatarsal phalangeal joint (point C; Fig. 3*B*). Angle AEC (M1-M2 mechanical axis angle) represents the normal mechanical relationship of the first and second rays. The center of the base of the proximal phalanx will be directly opposite the center of the first metatarsal head (points A and B) in patients without an HAV deformity. The lines EA and DB will be colinear and pass through point D, the dorsal lateral proximal corner of the medial cuneiform. Additionally, the mechanical axis of the medial column and the mechanical axis of the first ray will be colinear or parallel to the bisection of the first metatarsal shaft (anatomic axis of the first metatarsal).

As HAV progresses, angle AEC (M1-M2 mechanical axis angle) will remain unchanged, suggesting that the proximal phalanx and sesamoid apparatus remain in their original position. The splaying of the first ray results in a new angle (ADB), which represents the amount of first ray deformity (Fig. 4). Point D (the dorsal lateral proximal corner of the medial cuneiform), therefore, represents the center of rotation of angulation (CORA) of the first ray. The example shown illustrates a 5° first ray deformity. On a calibrated radiograph, the distance between lines DB and EA at the level of the planned osteotomy or fusion represents the amount of translation necessary to achieve colinear axis lines (Fig. 5).

Metatarsus adductus is a complicating factor in HAV deformity planning. Investigators have described various methods for measuring the metatarsus adductus deformity for incorporation into HAV planning (9). We suggest that our method of mechanical axis planning simplifies deformity planning in the metatarsus adductus foot. We must point out that in the metatarsus adductus foot type, the mechanical axis of the medial column will not pass through the dorsal lateral proximal corner of the medial cuneiform (Fig. 6). Despite this, the goal of correction remains restoration of the M1-M2 mechanical axis angle, and the amount of correction needed can be found by measuring the angle and distance between the mechanical axis of the medial column (line EA) and the mechanical axis of the first ray (line DB).

What Is the "Normal" M1-M2 Mechanical Axis Angle?

Using the method described, we undertook a case-control study to ascertain the "normal" (average) M1-M2 mechanical axis angle in patients with a symptomatic bunion and compared it with the findings from a group of normal controls. In a retrospective review of 200 radiographs, we aimed to determine whether the differences in the M1-M2 mechanical axis angle were statistically significantly associated with any number of demographic variables. We hypothesized that the "normal" M1-M2 mechanical axis angle would be 11° and that