The Journal of Foot & Ankle Surgery 53 (2014) 548–556

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Accurate Determination of Relative Metatarsal Protrusion with a Small Intermetatarsal Angle: A Novel Simplified Method

Lawrence Osher, DPM [1], Marie Mantini Blazer, DPM [2], Stacie Buck, DPM, AACFAS [3], Tomasz Biernacki, DPM [4]

[1] Professor, Kent State University College of Podiatric Medicine, Independence, OH
[2] Assistant Professor, Kent State University College of Podiatric Medicine, Independence, OH
[3] Private Practice, Fredericksburg Foot and Ankle Center, Fredericksburg, VA
[4] First Year Podiatric Medical Resident, St. Mary Mercy Hospital, Livonia, MI

A R T I C L E I N F O

Level of Clinical Evidence: 4

Keywords:
hallux valgus
hallux limitus
intermetatarsal angle
metatarsal length
metatarsus primus adductus angle
metatarsal protrusion distance
relative metatarsal protrusion

A B S T R A C T

Several published studies have explained in detail how to measure relative metatarsal protrusion on the plain film anteroposterior pedal radiograph. These studies have demonstrated the utility of relative metatarsal protrusion measurement in that it correlates with distal forefoot deformity or pathologic features. The method currently preferred by practitioners in podiatric medicine and surgery often presents one with the daunting challenge of obtaining an accurate measurement when the intermetatarsal 1-2 angle is small. The present study illustrates a novel mathematical solution to this problem that is simple to master, relatively quick to perform, and yields accurate results. Our method was tested and proven by 4 trained observers with varying degrees of clinical skill who independently measured the same 10 radiographs.

The metatarsal protrusion distance (MPD)—less commonly termed the *metatarsal protrusion index* (MPI)—is routinely used in the radiographic evaluation of hallux valgus and hallux rigidus (1–5). The MPD has generally been defined as the difference in the length in millimeters of the first metatarsal compared with the second metatarsal, taken from their common point of axis convergence (4–9) (i.e., the vertex of the first intermetatarsal angle [IM 1-2 or the metatarsal primus adductus angle]; Fig. 1). Although this difference has frequently been represented by the radial distance between drawn arcs of corresponding concentric circles, its value can be directly determined by simply taking the difference of the 2 radii (Fig. 1). The normal range for MPD is +2 mm to −2 mm (8). When the first metatarsal is longer than the second, the MPI value will be positive, and vice versa.

The phrase *metatarsal protrusion index* first appeared in the 1930 hallux rigidus study by Nilsonne (1), although Nilsonne's method of determining metatarsal protrusion was quite different from the currently used methods. A similar method was alluded to by Morton (10) in his 1930 study on the structural factors in static disorders of the foot. Nilsonne's technique relies on the construction of a perpendicular line to the longitudinal axis of the second metatarsal at the most distal projection of the second metatarsal head (1) (Fig. 2). This perpendicular line was then compared with a parallel line constructed at the distal-most protrusion of the first metatarsal head. A plus index implied that the first metatarsal was longer than the second, and vice versa. A plus–minus index signified that the first and second metatarsals shared the same length. However, the accuracy of his method can be affected by the presence of metatarsus primus varus and metatarsus adductovarus (2). Over time, other methods—by Harris and Beath in 1947 (11) and 1949 (12), Hardy and Clapham (6) in 1951, Laporta et al (13) in 1974, and Lundberg and Sulja (14) in 1972—have been proposed and/or developed. In their 1947 Canadian Army Foot survey, Harris and Beath (11) created arcs tangential to the first and second metatarsal heads, corresponding to a common concentric mid-posterior point of the calcaneus. However, in most instances, the posterior calcaneal point cannot be visualized on standard anteroposterior pedal radiographs; thus, this method cannot recommended.

One method that has been occasionally used relies on the construction of an angle that correlates the distal aspects of the most medial and lateral metatarsal bones with that of the second metatarsal. This has generally been known as the metatarsal break angle or metatarsal parabolic angle (15–18). Not to be confused with the break angle of Inman, it has also been referred to as Meschan's angle (19) and is constructed from the distal-most points of the first, second, and fifth metatarsals (Fig. 3). The angle generally increases with a long first metatarsal and vice versa, with values less than 135°

Address correspondence to: Lawrence Osher, DPM, Kent State University College of Podiatric Medicine, 6000 Rockside Woods Boulevard, Independence, OH 44131.
E-mail address: losher@aol.com (L. Osher).

1067-2516/$ - see front matter
http://dx.doi.org/10.1053/j.jfas.2014.04.021

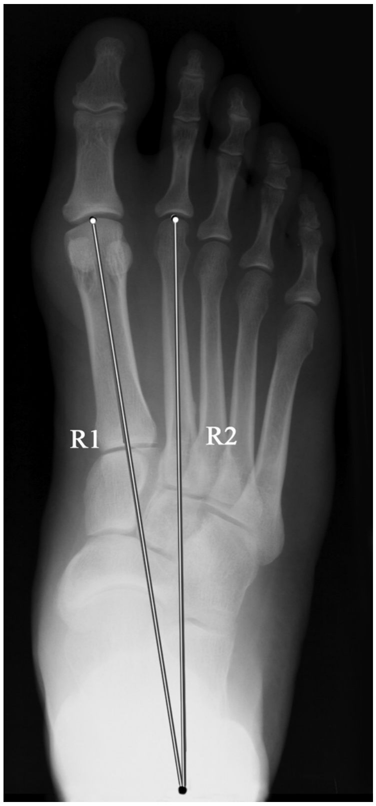

Fig. 1. Metatarsal protrusion/metatarsal protrusion index (MPI). Protrusion is related to the point of convergence created by the intersection of the longitudinal axes of the first and second metatarsals. These axes can be likened to 2 differing radii, R1 and R2, of a circle with its center at the vertex of the intermetatarsal angle. The MPI is thus the difference in length in millimeters from this point (in common) of axis convergence to the distal-most aspects of the first and second metatarsals.

Fig. 2. At the most distal extent of the second metatarsal bone, perpendicular to the longitudinal axis is created. This line reflects the distal-most protrusion of the second metatarsal. A line parallel to this is now constructed coursing through the distal-most point of the first metatarsal. The difference between these 2 parallel lines is the protrusion index.

strongly indicative of a short first metatarsal. In contrast, Inman's break angle is formed by the intersection of the longitudinal axis of the rearfoot with a line joining the distal aspects of the second and fifth metatarsal heads (19). With an average angle of 62°, this second to fifth line is oblique to the long axis of the foot. Inman (19) noted that if the subtalar joint did not exist, to distribute the weight simultaneously through the heads of the metatarsals, the foot would have to deviate laterally and be supinated slightly at heel lift. This was a primary consideration in the UC-BL dual-axis ankle brace design.

Although the construction of Meschan's metatarsal break angle is undeniably fast and simple, its value has been debated. In a recent study of 31 patients whose feet had undergone surgery using long oblique second metatarsal osteotomies (for concurrent plantar callosities) associated with hallux valgus deformities, Rajan et al (16) noted that the metatarsal break angle generally increased by a median of 8°. However, there has been debate regarding its functional correlation in gait (20). Moreover, no direct correlation can be drawn regarding the actual lengths of the first and second metatarsals. Just as with the methods of Morton (10) and Nilsonne (1), the presence of metatarsus primus adductus will predictably decrease Meschan's angle, although the actual length of the first metatarsal will remain unchanged. Therefore, in current practice, the metatarsal break angle seems to serve a more adjunct role in metatarsal length analysis, although the bulk of the published data concerning the influence of the metatarsal length in hallux valgus and hallux limitus or rigidus have advocated methods that determine the relative metatarsal protrusion of the first 2 metatarsal bones.

Currently, 2 methods based on metatarsal protrusion are widely used and will be referred to separately as the *metatarsal protrusion distance* (MPD) and the *metatarsal protrusion index* (MPI). The method of the MPD, as devised by Hardy and Clapham (6) in 1951 (Fig. 4) is most notable in that it has become the preferred method of Mann, Coughlin et al (2) and also the Research Committee of the American Orthopaedic Foot and Ankle Society (AOFAS) (21). Considered a compromise between the methods of Morton (10) and those of Harris and Beath (11), this technique bases protrusion on a point of convergence defined by the intersection of the second metatarsal longitudinal bisection with a transverse tarsal line. This transverse tarsal line is constructed by bridging points on the posterolateral articular surface of the cuboid and posteromedial navicular or navicular tuberosity (Fig. 4). From the point of the second metatarsal axis intersection, concentric circular arcs are then constructed, and the distance in millimeters along the radius between both the first and the second metatarsal heads is then determined (6).

In a somewhat similar fashion, the method of Laporta et al (13) constructs a transverse tarsal line but differs in that arcs of 2 nonconcentric circles are constructed with centers that correspond to the intersections of the first and second metatarsal longitudinal axes and the transverse tarsal line. From a mathematical perspective, their method is questionable in that in constructing arcs that correspond to different, nonconcentric circles, their difference cannot be directly taken or determined. Moreover, the presumptive use of normal values that have been established with other methods requires additional study for verification.

In 1972, Lundberg and Sulja (14) defined relative metatarsal protrusion as the difference between the distal articular joint