CHAPTER 2

Calculation of the True First Intermetatarsal Angle Based on the Metatarsus Adductus Angle and Engel's Angle

Whitney Ellis-McConnell, DPM
Vanessa Cardenas, DPM
Kieran T. Mahan, DPM
Andrew J. Meyr, DPM

INTRODUCTION

The correction of the hallux abducto valgus (HAV) deformity is a frequently performed elective foot surgical procedure. Although numerous clinical and radiographic factors are utilized with respect to preoperative surgical decision making, identification and measurement of the first intermetatarsal angle represents a near universal tenet of determining HAV deformity severity (1-5). However, the presence of the metatarsus adductus deformity is known to artificially decrease measurement of the first intermetatarsal angle because of the relative adducted position of the second metatarsal. For this reason, it is recommended to calculate a "true" first intermetatarsal angle in cases of metatarsus adductus with the following formula: true first intermetatarsal angle = first intermetatarsal angle + metatarsus adductus angle – 15 degrees (1).

Despite this, it has been our clinical experience that many people choose to define the presence of metatarsus adductus in clinical practice with Engel's angle due to its relatively simple calculation when compared to the metatarsus adductus angle (5). However, we are unaware of any investigation that has specifically compared Engel's angle to the metatarsus adductus angle with respect to the diagnosis of metatarsus adductus and/or with respect to the calculation of the true first intermetatarsal angle. The objective of this investigation was to evaluate calculation of the true first intermetatarsal angle based on both the metatarsus adductus angle and Engel's angle.

METHODS

Following institutional review board approval, preoperative weight-bearing dorsal-plantar radiographs of consecutive patients undergoing elective reconstruction of the first metatarsophalangeal joint for the HAV deformity were evaluated for measurement of the first intermetatarsal angle, metatarsus adductus angle, and Engel's angle (3-5). The first intermetatarsal angle was defined as the resultant angulation between the longitudinal bisection of the first and second metatarsals (Figure 1). Engel's angle was defined as the resultant angulation between the longitudinal axis of the second metatarsal and longitudinal axis of the intermediate cuneiform (Figure 2). The metatarsus adductus angle was defined as the resultant angulation between the longitudinal axis of the lesser tarsus and the longitudinal axis of the second metatarsal (Figure 3).

Measurements were performed by two authors (WE and VC) and verified by the senior study author (AJM) with computerized radiology software measuring to a precision of 0.1 degree (Opal-RAD PACS, Viztek). The presence of metatarsus adductus was defined as either a metatarsus adductus angle ≥15 degrees or an Engel's angle ≥24 degrees (4,5). In their original publication, Engel et al found an

Figure 1. The first intermetatarsal angle was defined as the resultant angulation between the longitudinal axis of the first metatarsal and the longitudinal axis of the second metatarsal.

Figure 2. Engel's angle was defined as the resultant angulation between the longitudinal axis of the second metatarsal and the longitudinal axis of the intermediate cuneiform.

Figure 3. The metatarsus adductus angle was defined as the resultant angulation between the longitudinal axis of the lesser tarsus and the longitudinal axis of the second metatarsal.

average measurement of 21° in their cohort and defined an abnormal measurement as one greater than 24° (5).

In cases of defined metatarsus adductus, a calculation of the true first intermetatarsal angle was performed based on both the metatarsus adductus angle (first intermetatarsal angle + metatarsus adductus angle – 15 degrees) and Engel's angle (first intermetatarsal angle + Engel's angle – 24 degrees).

Data was stored in a password-protected personal computer for subsequent statistical analysis. All statistical analyses were performed using SAS software, version 9.2 (SAS Institute) by an author (AJM). Three analyses were performed. First, descriptive statistics of the angular measurements were performed and included the mean, SD, and range. Second, a comparative statistical analysis of the 2 calculation methods of the true first intermetatarsal angle was performed with a paired student t-test. Third, the measured Engel's angles and the metatarsus adductus angles were graphically depicted on a frequency scatter plot with calculation of a Pearson correlation coefficient.

RESULTS

Radiographs of 140 feet from 125 subjects were analyzed. The mean ± SD subject age was 43.84 ± 14.45 years (range 18-77). Twenty nine (23.2%) of the 125 subjects were male, and 95 (67.9%) of the 140 feet were right-sided. A total of 111 (79.3%) of the 140 feet demonstrated evidence of metatarsus adductus deformity based on either the metatarsus adductus angle or Engel's angle. Metatarsus adductus was defined based on the metatarsus adductus angle alone in 60 (54.1%) of 111 feet, Engel's angle alone in 8 (7.2%) of 111 feet, and by both measurements in 43 (38.7%) of 111 feet.

In the subcohort with metatarsus adductus (Table 1), a mean ± SD age of 44.38 ± 15.12 years (range 18-77 years) was observed. A total of 22 (22.2%) of the 99 subjects were males and 72 (64.9%) of the 111 feet were right-sided. The mean ± SD first intermetatarsal angle was 11.40 ± 3.25 degrees (range 4-22), metatarsus adductus angle was 19.97 ± 5.15 degrees (range 9-41), and Engel's angle was 22.99 ± 4.38 degrees (range 10-37).

The mean ± SD true first intermetatarsal angle calculated based on the metatarsus adductus angle in this subcohort was 16.37 ± 6.33 degrees (range 2-40). The mean ± SD true first intermetatarsal angle calculated based on Engel's angle was 10.39 ± 4.96 degrees (range -3 to 22). The difference between calculation of the true first intermetatarsal angle based on the metatarsus adductus angle or Engel's angle was found to be statistically significant (16.37 degrees versus 10.39 degrees; $P < 0.001$).

Figure 4 demonstrates the frequency scatter plot of measurement of the metatarsus adductus angle aginst Engel's angle. No substantial relationship was observed with a nonsignificant Pearson's correlation coefficient (-0.29; $P = 0.765$).

Table 1. Results of the primary outcome in 111 feet*

	First intermetatarsal angle)	Metatarsus adductus angle	Engel's angle	Paired student t-test
Descriptive statistics of subcohort with metatarsus adductus (degrees)	11.40 ± 3.25 (4-22)	19.97 ± 5.15 (9-41)	22.99 ± 4.38 (10-37)	
Calculation of the true first intermetatarsal angle (degrees)		1st IMA + MAA - 15 degrees = 16.37 ± 6.33 (2-40)	1st IMA + Engel's- 24 degrees = 10.39 ± 4.96 (-3-22)	5.98 ($P < 0.001$)

*Values are the mean ± SD (range), unless indicated otherwise.

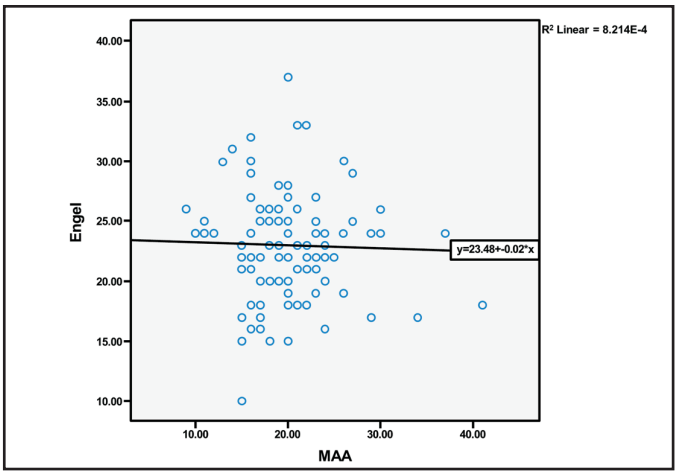

Figure 4. Correlation between the metatarsus adductus angle and Engel's angle.

DISCUSSION

As with any scientific investigation, critical readers are encouraged to review the study design and specific results in order to reach their own conclusions, while the following represents our conclusions based on the data. As scientists, we also never consider data to be definitive, but do think that these results are worthy of clinical attention and further investigation. First, results of this investigation indicate that the metatarsus adductus angle might be a more sensitive diagnostic measure of metatarsus adductus deformity compared to Engel's angle in adult patients with pathology of the first metatarsophangeal joint. In our subcohort, 54.1% of patients had an increased metatarsus adductus angle with a normal Engel's angle. Conversely, only 7.2% of patients had an increased Engel's angle with a normal metatarsus adductus angle. A total of 38.7% of patients demonstrated increases in both measurements.

With that being said, one limitation of this or any investigation involving radiographic parameters is the definition of normal values. We choose to define metatarsus adductus as a metatarsus adductus angle >15 degrees, but some sources have defined the diagnostic threshold based on this angle as low as 10 degrees or as high as 20 degrees (1-5). Utilizing 10 degrees or 20 degrees instead of 15 degrees as a diagnostic threshold would have changed the outcomes of this investigation. In the same way, Engel's original study found a mean measurement of 21 degrees (which does not necessarily imply "normal") and did not utilize any quantitative means to define an "abnormal" measurement of 24 degrees.

Second, results of this investigation demonstrate that calculation of the true first intermetatarsal angle based on the metatarsus adductus angle lead to a higher result than calculation of the true first intermetatarsal angle based on Engel's angle (16.37 degrees versus 10.39 degrees; $P < 0.001$). This finding was both statistically significant and likely would be considered clinically significant as one measurement fell in the "severe" deformity category and the other within the "moderate" deformity category (1). This implies that it would be more clinically conservative to calculate the true first intermetatarsal angle based on the metatarsus adductus angle when compared to Engel's angle.

Third, we observed little correlation between measurement of the metatarsus adductus angle when plotted against measurement of Engel's angle. We considered this a surprising finding as both radiographic parameters aim to evaluate for the same structural deformity.

We embrace the fact that all investigations have limitations, and this study had several important ones to consider. First, data was collected from a limited amount of subjects from a single institution, and thus these results might not be representative of a broader population sampling. Second, our primary outcome was derived from radiographic analysis dependent on consistent patient positioning. It is difficult to control for this with a

retrospective design. And third, this investigation provides no information with respect to clinical, functional or surgical outcomes. In conclusion, we hope that the results of this investigate add to the body of knowledge with respect to the radiographic evaluation of the forefoot, particularly as it related to the HAV and metatarsus adductus deformities.

REFERENCES

1. Martin DE, Pontious J. Introduction and evaluation of hallux abductovalgus. In Banks AS, Downey MS, Martin DE, Miller SJ: McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, Williams and Wilkins, Philadelphia; 2000, p.485-91.
2. Coughlin MH, Mann RA. Hallux valgus. In Mann RA: Surgery of the Foot and Ankle. Mosby Elsevier, Philadelphia; 2007. p. 183-362.
3. Sanner WH. Foot segmental relationships and bone morphology. In Christmas RA (ed) Foot and Ankle Radiology. Churchill Livingstone, St. Louis; 2003, p.272-302.
4. Yu GV, Johng B, Freireich R. Surgical management of metatarsus adductus deformity. Clin Podiatr Med Surg 1987;4:207-32.
5. Engel E, Erlick N, Krems I. A simplified metatarsus adductus angle. J Am Podiatry Assoc 1983;73:620-8.