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ORIGINAL RESEARCH

Assessing Precision of the Radiographic Metatarsophalangeal Angle in Hallux Valgus

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ABSTRACT

Introduction: Radiographic measurement of the first metatarsophalangeal (MTP) angle is critical in selecting a procedure for the treatment of hallux valgus deformity and a major criterion of postoperative success. The current five methods of measurement utilize a first metatarsal axis based on reference points within the first metatarsal. Previous studies have not been able to account for imprecision produced by anatomic variation and/or surgical correction of the first metatarsal. In this study, we adapted a recently published radiographic method for measuring the first interphalangeal angle to calculate the MTP angle without using reference points within the first metatarsal. The aim of this study was to assess the reproducibility of this method.
Methods: Using interobserver variances in 42 sets of anteroposterior weight-bearing radiographs of our patients who underwent distal chevron osteotomy, we compared the preoperative and postoperative reproducibility of this method to an existing means of measuring the MTP angle that is currently described by literature as having the greatest reproducibility.
Results: The existing method was shown to differ from our method with regard to interobserver variability, with 10 times greater variance in the preoperative case, 3 times greater variance in the postoperative case, and 6 times greater variance when both categories were combined.
Discussion: This study supports the hypothesis that a method that does not rely on reference points within the first metatarsal for measuring the MTP angle is more precise than a method that does.
Keywords: Hallux valgus; Metatarsophalangeal radiography; Interobserver reliability.

INTRODUCTION

More than 100 surgical procedures have been described to correct hallux valgus deformity (1). No one method of measuring the 1,2 intermetatarsal angle or the metatarsophalangeal (MTP) angle pre- and postoperatively has been deemed the most reproducible (2). The current methods of radiographic measurement of these angles rely on accurate placement of reference points in various positions throughout the first metatarsal to define its longitudinal axis (3). The use of reference points within the first

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metatarsal can create several problems. Osteotomies of the first metatarsal, such as the chevron, scarf, or Ludloff, alter the relative geometry of the metatarsal at the site of the osteotomy. This shift in the metatarsal alters the reference points used during postoperative measurements and can lead to inaccurate measurements.

Five radiographic methods of determining the MTP angle have been published and differ in their definition of the first metatarsal axis. The first method, described by Hawkins et al. (4) in 1945, defines it as a line drawn through the long axis of the first metatarsal. The second, defined by Venning and Hardy (5) in 1951, uses a line connecting two points that each bisect the shaft of the first metatarsal, the line extending in both directions. The third, defined by Mitchell et al. (6) in 1958, uses a line that connects the center of the proximal and distal articular surfaces of the first metatarsal. The fourth, defined by Miller (7) in 1974, uses a line that connects the center of the first metatarsal head and the center of the first metatarsal base.

The fifth method, defined by Nestor et al. in 1990, uses a line that connects the center of the head and the center of the proximal shaft of the first metatarsal (8). Schneider et al. in 2003 reported that of these five methods, Miller's produced the greatest reproducibility when angular correction of hallux valgus was measured in the transverse plane (3).

Elliot and Saxby (9) in 2010 proposed a new method for measuring the first interphalangeal angle, a related angle used in hallux valgus assessments. This method accounted for deformity distal to the MTP joint and defined its axes without using the proximal phalanx as a reference. We adapted the method by applying its reference points to the first metatarsal and the proximal phalanx to measure the first MTP angle. We then compared the reproducibility of this new method, demonstrated in Figures 1A and 2A, with that of Miller's method, demonstrated in Figures 1B and 2B, during preoperative and postoperative measurements. We hypothesized that a method that does not rely on reference points within the first metatarsal for measuring the MTP angle would be more precise than a method that does.

MATERIALS & METHODS

We randomly selected 42 patients who had undergone distal chevron osteotomy. Both preoperative and postoperative anteroposterior radiographs were used to assess the reproducibility of using each method. The measurements were calculated using digital radiographs on GE Healthcare's Centricity PACS-IW, our institution's modality of radiographic imaging.

Before the lines were drawn for the first metatarsal as determined by each of the two methods, the axis of the proximal phalanx (a line through the center of the proximal and distal articular surfaces) was drawn and left unaltered for all 42 sets of radiographs. Two observers separately calculated the MTP angles by using Miller's method and our method—an axis through the proximal phalanx and an axis intersecting a line at the base of the metatarsal at 90 degrees (9,10). The differences between corresponding measures by the two observers were used as the basis for the interobserver variance.

The Brown-Forsythe version of the Levene (BFL) test of the homogeneity of variance was used to test for equality of variances of the interobserver differences in the preoperative, postoperative, and

combined cases. Additionally, the ratios between the variances of the compared methods were determined, as well as the 95% confidence intervals (CIs) for those ratios.

RESULTS

The mean, variance, and standard deviations of interrater differences for separate preoperative and postoperative measurements are provided in Table I. In the case of Miller's method preoperatively vs our method preoperatively, the BFL test showed a significant difference between the variances (p=0.0087). The ratio between the variances ($Var_{Miller\ Method}/Var_{Our\ Method}$) was estimated as 9.7 (95%CI: 5.2, 18.1), which corresponds to a ratio between the standard deviations of 3.1 (95%CI: 2.3, 4.2). For Miller's method postoperatively vs our method postoperatively, the BFL test showed a significant difference between

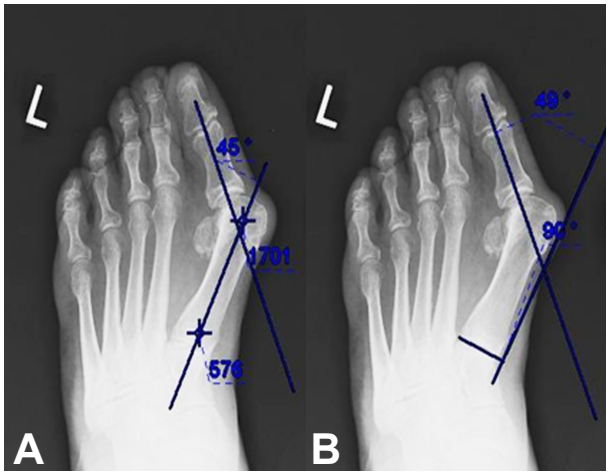

Figure 1. (**A**) Our new method is shown preoperatively with a line at the articular base of the first metatarsal with an intersecting line at 90 degrees, which intersects an axis line through the proximal phalanx. (**B**) Miller's method is shown preoperatively with reference points centered at the head/base of the first metatarsal with a longitudinal line intersecting an axis line through the proximal phalanx.

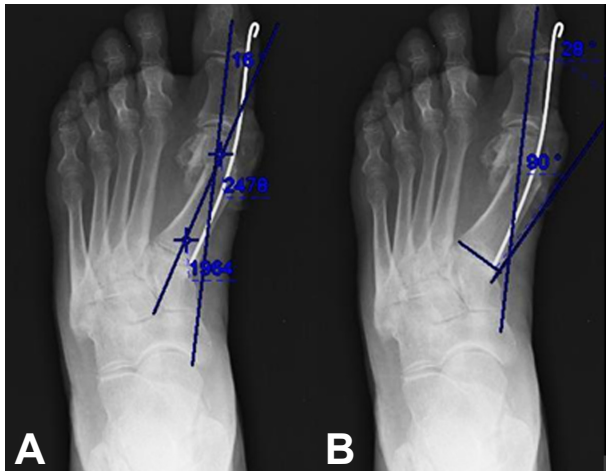

Figure 2. (**A**) Our new method is shown postoperatively with a line drawn at the base of the first metatarsal with an intersecting line at 90 degrees after a distal chevron osteotomy. (**B**) Miller's method is shown postoperatively with reference points centered at the head/base of the first metatarsal after a distal chevron osteotomy.

Table 1. Inter-repeatability of hallux valgus measurements.

Interrater	Miller Method Preop	Miller Method Postop	Miller Method Preop+ Postop	New-Method Preop	New-Method Postop	New Method Preop+ Postop
Mean	-1.02	-1.43	-1.23	-0.07	0.55	0.24
Variance	9.63	9.37	9.43	3.34	3.52	3.48
Std Dev	3.10	3.06	3.07	1.83	1.88	1.87

our method postoperatively, the BFL test showed a significant difference between the variances (p=0.0087). The ratio between the variances was estimated as 2.7 (95%CI: 1.4, 5.0), which corresponds to a ratio between the standard deviations of 1.6 (95%CI: 1.2, 2.2). Combining the preoperative and postoperative measurements, there was a significant difference between the combined variances (p=0.0003), with the ratio between the variances estimated as 5.9 (95%CI: 3.9, 9.2), which corresponds to a ratio between the standard deviations of 2.4 (95%CI: 2.0, 3.0).

DISCUSSION

The most appropriate method for measuring the first MTP angle remains a matter of debate. No previous method measures this angle without relying on reference points within the first metatarsal. Miller's method was recently reported to be the most reproducible of the current five methods of measurement and was originally described to measure hallux valgus by using the intermetatarsal angle (3). His method was not originally described with the use of a distal chevron osteotomy, as all referenced studies have tested. Reproducibility of all five methods of measurement against a variety of surgical osteotomies has not been studied.

Schneider's team in 1998 published a study that showed significant preoperative and postoperative differences in MTP angle measurements among the five methods (2). They deemed the wide ranges unacceptable and speculated that the discrepancies could be found in the different relations of the points of reference to the anatomic outline of the metatarsal and the site of osteotomy. This led them to recommend a line connecting the center of the articular head of the metatarsal and the center of the proximal articulation, a method published by Mitchell et al. (6), as the most appropriate method for measurement of the first MTP angle. Since the proximal point of reference will always be proximal to the osteotomy and the distal point of reference will always be distal to the osteotomy site, the line connecting these two points should remain unaltered by surgery (2). Subsequently, Schneider's team compared the five methods and concluded that Miller's yielded the greatest reproducibility, especially postoperatively (3). The findings of these two studies suggested that the use of reference points in the metatarsal shaft for determining the first metatarsal axis is not appropriate for precise calculation of the MTP angle, as their use resulted in poorer reproducibility and they were most likely to be affected by surgical intervention and anatomic variations involving the first metatarsal.

The aim of our study was to assess the precision of a method that did not use any aspect of the first metatarsal as a reference in calculating the MTP angle, specifically in the context of a distal chevron osteotomy. To do this, we compared interobserver variances both preoperatively and postoperatively using Miller's method and Elliot and Saxby's method adapted by us for calculating the MTP angle. Our study's finding of higher interobserver variances in MTP angles determined by Miller's method suggest its lesser reproducibility compared with the new method.

There are several factors that may account for the findings in our study. When Miller's method is used, the reference point within the first metatarsal must be placed based on the observer's estimation of the point that bisects the head. The method adopted

in this study uses a delineated articular surface on the base of the metatarsal, which eliminates the need for estimation during determination of the first metatarsal axis.

Furthermore, the effects of anatomic variations and surgical interventions in the first metatarsal have been cited in the literature as potential factors affecting the reproducibility in MTP angle measurement among different methods used (2). Using points of reference that are not located in any portion of the first metatarsal eliminates the possibility of these influences.

The method used in our study is shown here to be applicable in distal chevron osteotomy. There is a need to assess it in the contexts of other types of osteotomy. Additionally, no standard was created during this study for patients who have no hallux valgus deformity.

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