# CHAPTER 53

# COMPARISON BETWEEN MANUAL AND DIGITAL FOOT ANGLE MEASUREMENTS

*Loren Spencer, DPM*
*Phillip Wrotslavsky, DPM*

## INTRODUCTION

The Federal government continues to push for a transition from paper to electronic medical records to allow doctors the ability to share laboratory results, images, computerized orders, and prescription information with hospitals and other health facilities. Currently it is estimated that 8% of the nation's 5,000 hospitals and 17% of 800,000 physicians use a common computerized record keeping system.[1] As part of the evolution of modern medicine, many hospitals and private practices are converting from standard to digital radiography.

Surgeons use radiographic measurements to assist with making important clinical decisions. These measurements help them better follow the progression of a deformity, determine the need and types of treatment, and assess the results of conservative or surgical therapy. Previous studies have shown that computer measurements for the hallux valgus angle (HVA), intermetatarsal angle (IM), distal articular set angle (DASA), and proximal articular set angle (PASA) are as reliable and accurate as measurements made with a universal goniometer.[2,3] The purpose of this study was to examine the accuracy and validity of measuring additional foot angles using digital and manual techniques. Our hypothesis was that foot angles measured with digital software would not be as accurate as measurements made manually due to pixelation limitations for drawing and calculating digital angles.

## MATERIALS AND METHODS

A total of 47 digital foot images were randomly selected for retrospective review from the Scripps Mercy Hospital Picture Archiving and Communication System (PACS). Inclusion criterion was to have had a non-weight bearing digital foot radiograph taken between January and July of 2008. A power analysis was performed using G power 3 software to determine that a total number of 37 patient images would be required to produce a study with a power of 0.80 and a type 1 error of 0.05. The following nonweight-bearing foot measurements were taken from Cobb angles of dorsal-plantar and lateral radiographs (Figure 1) using the Dominator Diagnostic Reading digital software version 8.1: HVA, IM, Engle's angle, and calcaneal inclination angle (CIA) (Table 1). The same 47 digital images were then printed on paper using a Hewlett Packard LaserJet 1320 printer and on radiographic film. The foot angles aforementioned were then measured manually on both paper and radiographs with an angle finder (Figure 2) after proper calibration was confirmed by measuring computer generated known angles. All angles were measured by the primary author to limit inter-observer variation in technique. Following preliminary data analysis, intraobserver variability was assessed for the Engle's Angle by taking 2 repeat measurements of each patient with each technique. The study was approved by the Scripps Mercy San Diego institutional review board.

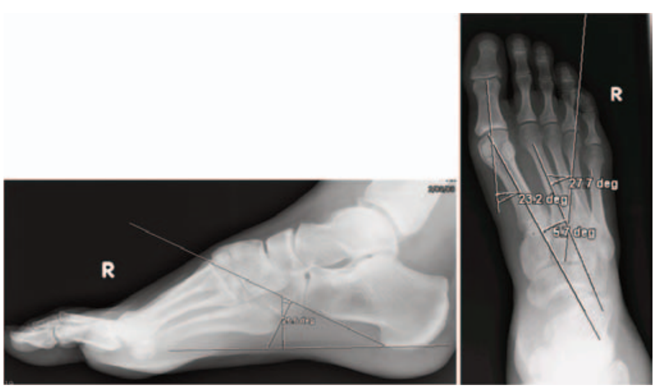


Figure 1. Examples of digital measurements taken on AP and Lateral radiographs with the Cobb Angle function.

Figure 2. Angle finder.

Table 1

## DESCRIPTION OF METHOD USED TO MEASURE FOOT ANGLES IN THE STUDY WITH NORMAL WEIGHT-BEARING VALUES.

| Angle | Measured | Normal |
|---|---|---|
| | **Anterior-Posterior radiographic measurements** | |
| **Hallux valgus** | Angle formed between the longitudinal bisection of the proximal phalanx of the hallux and the longitudinal bisection of the 1st metatarsal | 0-15 |
| **Intermetatarsal** | Angle formed between the longitudinal bisection of the 1st metatarsal and the longitudinal bisection of the 2nd metatarsal | 8-12 |
| **Engle's** | Angle formed between the longitudinal bisection of the intermediate cuneiform (lesser tarsal axis) and the longitudinal bisection of the 2nd metatarsal | 24 |
| | **Lateral radiographic measurements** | |
| **Calcaneal inclination** | Angle created between a line from the inferior surface of the 5th metatarsal head and the most anterior plantar point of the calcaneal tubercle to the most anterior inferior point of the calcaneus at the calcaneal cuboid joint | 24.5 |

Table 2

## RESULTS OF THE ANALYSIS OF VARIANCE AND CRONBACH'S A RELIABILITY BETWEEN EACH TECHNIQUE. NO STATISTICALLY SIGNIFICANT DIFFERENCE BETWEEN THE MEAN MEASURED ANGELS

| | Technique | Mean | ANOVA (sig) | Cronbach's α Reliability |
|---|---|---|---|---|
| **HVA** | Digital | 15.92 | 0.892 | 0.976 |
| | Paper | 15.35 | | |
| | Film | 15.60 | | |
| **IM** | Digital | 7.86 | 0.729 | 0.925 |
| | Paper | 8.11 | | |
| | Film | 8.23 | | |
| **Engle's** | Digital | 23.34 | 0.26 | 0.870 |
| | Paper | 21.73 | | |
| | Film | 23.24 | | |
| **CIA** | Digital | 25.20 | 0.915 | 0.963 |
| | Paper | 25.28 | | |
| | Film | 25.60 | | |

## RESULTS

The mean age of all the subjects in this study was 32.72 years with 24 females and 23 males. There was minimal difference in the mean angular measurements when comparing the foot angles taken digitally with those taken manually on printed paper or on radiographic films. Analysis of variance between each technique was performed and showed no statistically significant difference in angular measurements (Table 2). Paired sample tests were also performed to compare the 3 different measurement techniques. A *P* value less than or equal to 0.05 was considered significant. The Engle's angle showed a paired statistically significant difference between the mean digital (23.34°) and the mean film (23.24°) when each was paired to the mean paper (21.73°) measurements with a *P* value of 0.0165 (pair 7) and 0.0001 (pair 8), respectively (Table 3). The absolute mean

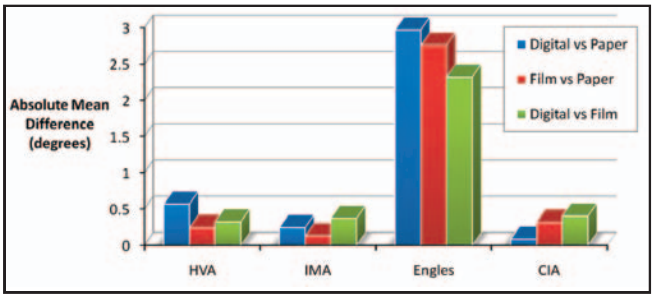


Figure 3. The absolute mean differences between measurement techniques was also greatest for measuring Engle's angle.

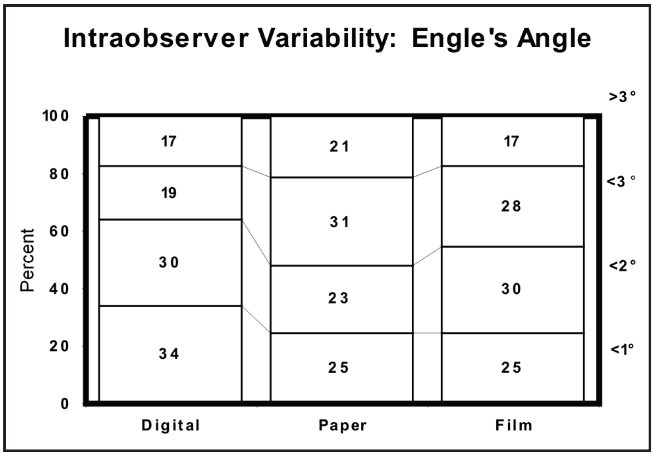


Figure 4. Intraobserver variability for the Engle's angle. This illustration shows the distribution of absolute differences in 3 measurements of the Engle's angle using 3 different measurement techniques.

difference between measurement techniques was also greatest for Engle's angle (Figure 3). Intraobserver reliability for Engle's angle showed a variance of more than 3° in 17% of digital and film techniques, versus a 21% variance between angular measurements using the paper technique (Figure 4). The reliability of the angular measurements was also assessed using Cronbach's α measures. All angular measurements (HV, IM, Engle's, and CI) exceeded the significance value of 0.78 (Table 2). Predictive Analytics software version 17.0.2 from Statistical Package for the Social Sciences was used for data analysis.

## DISCUSSION

Medical imaging is currently transitioning from plain films to digital radiography. Digital images are displayed through a combination of rows and columns of pixels, or picture elements. Radiographic plain films have 1.25 x 107 more pixels than digital images, which are displayed on a 30 cm x 36 cm monitor. Despite these pixelation differences, our research demonstrated no statistically significant difference in measuring the HV, IM, Engle's and CI angles using digital or manual methods. Some of the advantages of digital imaging include immediate observation, ability to enhance images and perform computerized linear and angular measurements, elimination of hard copy storage, and the ease of communicating results with other practitioners. Like other computerized record keeping systems the disadvantages include the cost of the device and training oneself and staff how to use the imaging system.

The measurements for the HV, IM, CI and Engle's angles showed statistically significant difference only when pairing Engle's angle digital and film techniques to paper measurements. The HV, IM, and CI angles were measured a single time by the primary author with each technique. Intraobserver variance was only assessed with the Engle's angle measurements. Interobserver reliability was not assessed in this study, it has been reported in previous articles. Intraobserver variability could explain the differences between Engle's angle measurements. The mean paper measurement for the Engle's angle was the lowest (21.73°) and intraobserver variability was highest with 21% of paper measurements differing by >4 degrees. The mean difference between the 3 measurement techniques was only 1.61 degrees (<2°), which variation corresponds with 48-64% of all measurements.

**Table 3**

## PAIRED SAMPLE TESTS

The Engle's angle showed a paired statistically significant difference between the mean digital (d;23.34°) and the mean film (f; 23.24°) when each was compared with the mean paper (p; 21.73°) measurements. Refer to Table 2 for mean values.

| Pair | Angles | Absolute Mean Difference | Sig (2-tailed) |
|---|---|---|---|
| **Pair 1** | dHVA - pHVA | 0.568 | 0.082 |
| **Pair 2** | pHVA - fHVA | 0.245 | 0.316 |
| **Pair 3** | fHVA - dHVA | 0.323 | 0.373 |
| **Pair 4** | dIM – pIM | 0.243 | 0.287 |
| **Pair 5** | pIM - fIM | 0.128 | 0.416 |
| **Pair 6** | fIM - dIM | 0.370 | 0.123 |
| **Pair 7** | dEngle's – pEngle's | 2.97 | 0.0165 |
| **Pair 8** | pEngle's – fEngle's | 2.76 | 0.0001 |
| **Pair 9** | fEngle's – dEngle's | 2.32 | 0.067 |
| **Pair 10** | dCIA - pCIA | 0.083 | 0.828 |
| **Pair 11** | pCIA - fCIA | 0.319 | 0.160 |
| **Pair 12** | fCIA - dCIA | 0.402 | 0.253 |

Farber et al[5] examined interobserver and intraobserver reliability of HV and IM angles by comparing measurements taken on plain films to those taken using computer imaging software. From 450 total angles measured, intraobserver and interobserver consistencies were found between both film and computer measurements although less variance in measurement was noted in the computer imaging groups. Intraobserver measurements differed by more than 3 degrees in only 14% of film and 7% of computer measured HV angles, and 10% of film and 8% of computer measured IM angles. Interobserver measurements were similar and differed by more than 3 degrees in only 18% of film and 7% of computer measured HV angles, and 11% of film and 9% of computer measured IM angles.

Shea et al[6] compared Cobb angle measurements in scoliosis patients taken on plain films and digital images. They reported a decrease in intraobserver variability of 0.7 degrees, 3.3 degrees on plain films to 2.6 degrees on digital images. Coughlin et al[7] in 2001 also demonstrated interobserver and intraobserver variability for the distal metatarsal articular angle and joint congruity.

Limitations in radiographic quality could also explain the significant differences noted within the Engle's angle measurement group. There are different methods for determining the lesser tarsal axis and then calculating metatarsus adductus. The traditional method for measuring metatarsus adductus uses specific radiographic points along the medial and lateral foot to determine the longitudinal bisector of the midfoot, which is perpendicular to the lesser tarsal axis. In order to use the digital imaging Cobb angle function, the longitudinal bisection of the intermediate cuneiform was used as the lesser tarsal axis. Accurate bisection of the intermediate cuneiform can be difficult due to image clarity and bony overlap, especially on paper radiographs. The use of less distinct radiographic points could explain some of the variation observed between techniques and the calculated significant difference of the Engle's angle.

A limitation of the study was the relatively small sample size of 47 patients. A larger sample size could show variations not identified due to lack of data. Next, only 4 foot angles were measured: HVA, IMA, Engles angle, and CIA. Further research would be necessary to assess the accuracy of digital imaging software at measuring additional angles. Another limitation of the study was that all radiographs were taken in a nonweight-bearing position. The measured angles would have more clinical relevance and more closely approximated the normal values if the images were taken in weight bearing relaxed position. Nonweight-bearing radiographs were used because they were much more readily available in the digital system and because no clinical correlation was necessary in testing the hypothesis of our study.

All digital measurements were taken using a single imaging software program, Dominator Diagnostic Reading digital software version 8.1. Conclusions made in our study may not apply to other digital imaging software programs. Further research could compare and contrast the accuracy of additional software programs. Piqué-Vidal et al[8] found that measurements of the IMA and proximal phalangeal articular angle (PPAA) with the manual and Autocad measurement techniques were different. The PPAA and IMA were on average 2.77 degrees and 1.35 degrees lower with manual measurement, respectively. Therefore, angular values that might be considered normal on conventional films were classified as moderate or severely abnormal with Autocad. Our study did not support the trend for larger digital measurements as only the HVA was smaller when taken manually on plain films.

## CONCLUSION

The computer generated foot measurements from digital radiographs for the HV, IM, Engle's, and CI angles were just as accurate as those taken manually on paper and conventional radiographs with a calibrated angle finder. It is necessary to identify differences between radiographic techniques as important clinical decisions are made based on these and other measurements.

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