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Reliability of Two Smartphone Applications for Radiographic Measurements of Hallux Valgus Angles

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ABSTRACT

The objective of the present study was to assess the reliability of 2 smartphone applications compared with the traditional goniometer technique for measurement of radiographic angles in hallux valgus and the time required for analysis with the different methods. The radiographs of 31 patients (52 feet) with a diagnosis of hallux valgus were analyzed. Four observers, 2 with >10 years' experience in foot and ankle surgery and 2 in-training surgeons, measured the hallux valgus angle and intermetatarsal angle using a manual goniometer technique and 2 smartphone applications (Hallux Angles and iPinPoint). The interobserver and intermethod reliability were estimated using intraclass correlation coefficients (ICCs), and the time required for measurement of the angles among the 3 methods was compared using the Friedman test. A very good or good interobserver reliability was found among the 4 observers measuring the hallux valgus angle and intermetatarsal angle using the goniometer (ICC 0.913 and 0.821, respectively) and iPinPoint (ICC 0.866 and 0.638, respectively). Using the Hallux Angles application, a very good interobserver reliability was found for measurements of the hallux valgus angle (ICC 0.962) and intermetatarsal angle (ICC 0.935) only among the more experienced observers. The time required for the measurements was significantly shorter for the measurements using both smartphone applications compared with the goniometer method. One smartphone application (iPinPoint) was reliable for measurements of the hallux valgus angles by either experienced or nonexperienced observers. The use of these tools might save time in the evaluation of radiographic angles in the hallux valgus.

Measuring the angles on radiographs is a valuable tool in the planning and evaluation of outcomes in hallux valgus surgery. Most of the protocols used for classification of the severity of the deformity and to guide the choice of the surgical technique are determined by the magnitude of the hallux valgus angle (HVA) and the first and second intermetatarsal angle (IMA). The distal metatarsal articular angle has not been universally accepted in choosing the surgical technique, and its reproducibility is debatable (1–3).

The most used method for the measurement of these angles on nondigital radiographs is performed using a goniometer. Although a gradual replacement of hard-copy radiographs by digitally processed images is occurring, many surgeons still use this former modality in clinical practice, especially in underdeveloped countries. An alternative method to the goniometer is the use of smartphone applications for angle measurement that can be practical and save time. One of these applications (Hallux Angles) has already been tested and proved to be reliable compared with digital measurement software (4,5). Recently, a comparison between a smartphone application and manual measurement was performed, including the time required for by each method in performing the measurements (6). However, to the best of our knowledge, no study has assessed another application (iPinPoint) and the reliability of measurements among observers with different levels of training.

The primary objective of the present study was to assess the reliability of 2 smartphone applications, the Hallux Angles App and the iPinPoint App, compared with the goniometer method for measuring radiographic angles in the hallux valgus. The secondary

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objectives were to compare the time required by the 4 observers to measure the angles using the different methods and the effect of the level of training on the reliability of the measurements.

Patients and Methods

After approval by our hospital's institutional review board, we retrospectively reviewed the radiographs of 31 consecutive patients (52 feet) who had been referred with a diagnosis of hallux valgus without previous surgery procedures. Dorsoplantar weightbearing foot radiographs were taken with the x-ray beam centered on the midfoot and inclined at 20° from vertical in the sagittal plane at a source-to-image distance of 100 cm. Four observers, 2 with >10 years' experience in foot and ankle surgery and 2 in-training foot and ankle surgeons, measured the HVA and the IMA, using a manual goniometer method and 2 smartphone applications: Hallux Angles App, version 1.0 (Ockendon.net, 2010; WG Healthcare, Letchworth Garden City, UK) and iPinPoint, version 1.5 (i-SmartSolutions, 2010; available at www.i-smartsolutions.com).

Manual measurements were taken on photographic copies of radiographs using a plastic goniometer and a marker pen according to the guidelines of the ad hoc committee of the American Orthopaedic Foot and Ankle Society (7). The smartphone measurements were performed using an Apple iPhone model 5S (Apple Inc., Cupertino, CA). Both applications were downloaded free from the Apple iTunes store.

The angular measurements using the Hallux Angles App were performed with the smartphone parallel to the x-ray film. After selecting the angle to be measured (HVA, IMA), a target line was lined up along the diaphysis of 1 of the bones (metatarsal or phalange) used as a reference. Next, the smartphone was rotated, in the same plane parallel to the x-ray, to align the target line to the second reference bone segment, and the angle formed between them was automatically measured (Fig. 1).

The iPinPoint is a tool that uses the built-in camera of the smartphone for angular measurement. First, a photograph was taken, pointing straight to the radiograph. To measure the magnitude of the angles, 3 reference points of the photograph were marked for each angle. The second point was the angle vertex (Fig. 2).

Statistical Analysis

The interobserver and intermethod reliability was estimated using intraclass correlation coefficients (ICCs) for the 4 orthopedic surgeons. Poor reliability was considered present with values of 0 to 0.20, fair reliability with values of 0.21 to 0.40, moderate reliability with values of 0.41 to 0.60, substantial or good reliability with values of 0.61 to 0.80, and nearly perfect or very good reliability with values of 0.81 to 1.0 (8). The time required by the observers for measurement of the angles among the 3 methods was compared using the Friedman test. SPSS Statistics for MAC, version 22.0 (IBM Corp., Armonk, NY) was used for analysis. Values of $p \leq .05$ were considered statistically significant.

Results

Very good interobserver reliability was found among the 4 observers for measurement of the HVA (ICC 0.913; $p < .01$) and IMA (ICC 0.821; $p < .01$) using the goniometer method. When using the Hallux Angles App, the reliability among the 4 observers was poor for measurements of the IMA and fair for measurement of the HVA. However, among the more experienced observers, the interobserver reliability for measurements of IMA (ICC 0.935; $p < .01$) and HVA (ICC 0.962; $p < .01$) was very good. Using the iPinPoint App, the reliability was very good among the 4 observers for measurement of the HVA (ICC 0.866; $p < .01$) and good for measurement of the IMA (ICC 0.638; $p < .01$; Table 1).

The analysis among the methods for measurement of the HVA showed very good reliability among the 3 methods for the more experienced observers (observers 1 and 2, ICC 0.941 and 0.929, respectively; $p < .01$) and good reliability for 1 of the less experienced observers (observer 4, ICC 0.638; $p < .01$). The analysis among the methods to measure the IMA showed very good reliability among the 3 methods for 1 of the experienced observers (observer 1, ICC 0.826; $p < .01$), good reliability for another experienced observer (observer 2, ICC 0.805; $p < .01$), and moderate agreement for 1 of the less-experienced observers (observer 4, ICC 0.461; $p < .01$; Table 2).

The average time required for the angle measurements with the Hallux Angles App was 64.25 seconds (95% confidence interval [CI] 27.96 to 100.54), with the iPinPoint App, it was 64 seconds (95% CI 36.13 to 91.87), and with goniometer method, it was 168.50 seconds (95% CI 73.47 to 263.53). Comparing the time required among the 3 methods, no significant difference was found between the smartphone measurements ($p > .05$); however, the time required was significantly longer for the goniometer method than for the Hallux Angles App and iPinPoint App ($p = .05$).

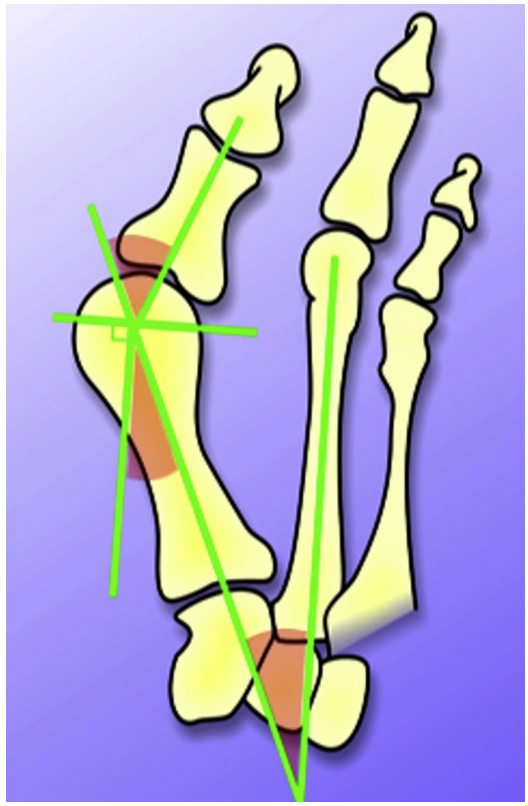

Fig. 1. Image of the smartphone screen showing the angle displayed by the Hallux Angles App. HalluxAngles App developed by WG Healthcare. Used with permission.

Discussion

Angular measurements are a valuable tool for planning and outcome evaluation of hallux valgus surgery. Although digital imaging processing and angle measuring software are helping to decrease the time required for these measurements and have proved to be reliable and valid (9–11), these systems are not always available in clinical practice. Smartphones applications can be useful for angular measurements either on film radiographs or directly on computer screens. In the present study, we assessed the interobserver and intermethod reliability of 2 smartphones applications used for angular measurement and the time required in this process compared manual measurement. We also evaluated the effect of training level on the reliability of the measurements. To analyze reliability, we used the ICCs among the observers. Although no absolute value is available to classify the reliability as acceptable, an ICC of ≥0.6 indicates that the measurement is useful (12).

The parameter used for comparison was manual measurement using a goniometer. With this method, very good agreement was found among the 4 observers for measurement of the HVA and IMA.

The Hallux Angles App showed very good interobserver reliability among experienced surgeons for measurement of the HVA and IMA. This corroborates the findings of 2 previous studies in which this smartphone application showed good (5) and excellent (4)