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Original Article

Reliability of intraoperative radiographic visual assessment of the hallux interphalangeal angle after hallux valgus correction

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Abstract

Objective: The aim of this study was to evaluate the reliability and reproducibility of visual estimation of the hallux interphalangeal angle (IPA). As a secondary aim we assessed for change in the IPA before and after hallux valgus (HV) correction.

Methods: A total of 50 surgically treated HV deformities were included in the study. Two surgeons visually estimated the IPA on intraoperative fluoroscopy after correcting HV. The fellow then measured the IPA formally on a printout of the fluoroscopic image. Pre-and intraoperative HVI angles were compared to assess for change after HV correction.

Results: The researchers found the interobserver reliability of radiographic visual assessment of the IPA to be 78% and intraobserver reliability to be 76% and 80% for surgeon 1 and 2, respectively. It was found that the preoperative IPA is on average 5.5 degrees less than IPA after HV correction.

Conclusion: Radiographic visual assessment of the IPA of the hallux was found to be reliable intraoperatively, thus aiding in the amount of correction required by Akin osteotomy. HVI can be masked by hallux pronation in HV deformity and should be assessed intraoperatively after HV correction.

Level of Evidence II; Therapeutic Studies; Prospective Comparative Study.

Keywords: Hallux valgus; Akin; Interphalangeal angle; Visual assessment.

Introduction

Lateral deviation of the interphalangeal joint of the hallux was investigated for the first time by Daw[(1)] in 1935, who coined the term hallux valgus interphalangeus (HVI). The method of assessing HVI was described by Burry in 1957[(2)]. The pathophysiology of HVI was first described by Sorto and Balding[(3)]. They suggested that this deformity is due to phalangeal condyle hypoplasia. There is no other study to support this theory[(3-8)].

Strydom et al.[(9)] reported that the interphalangeal angle (IPA) correlates inversely with the other angular measurements for hallux valgus (HV). Therefore, the more severe HV deformity, the smaller the IPA. These findings may be due to pronation of the hallux in HV deformities, which then masks true HVI. The more severe the HV deformity, the greater the hallux pronation, leading thus to a perceived decrease in measured IPA. Strydom et al.[(9)] also defined accurate reference points for the distal phalanx to standardize the method of measurement of the IPA.

The radiographic measurement of the IPA is measured as the angle between the long axes of the proximal and distal phalanges. The normal angulation in the axial plane between these two bones is less than 10 degrees[(3)]. The IPA is used to assess the severity of HVI deformity[(3,10-13)] (Figure 1).

The magnitude of the surgical procedure required to correct HVI deformity is based on the IPA on weight-bearing radiographs[(12,14)]. Akin osteotomy is primarily indicated for

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correction of HVI deformity and was first described in 1925[15]. In conjunction with the other osteotomies for HV correction, Akin osteotomy can assist with total HV deformity correction. Shannak et al.[16] found that for a 15-degrees correction, an osteotomy with a 3-mm base is needed. Akin osteotomy is also used to correct any residual pronation of the hallux[14].

Since the preoperative IPA can be underestimated in moderate to severe HV deformities due to hallux pronation (Figure 2A-B), the surgeon reassesses the IPA intraoperatively after correcting HV. As it is not practical to formally measure the IPA intraoperatively, the surgeon visually estimates the IPA using fluoroscopy, while simulating weight-bearing. The size of wedge resection for Akin osteotomy is dependent on accurate assessment of the IPA. Surgeon's estimation intraoperatively needs to be reasonably accurate and reproducible.

The aim of the study was to evaluate the reliability and reproducibility of visually estimating the IPA after correction of HV deformity by comparing it with the formal measurement. As a secondary aim, the authors hypothesized that preoperative HVI deformity can be underestimated due to hallux pronation and surgical correction of HV deformity can unmask true HVI.

Methods

Ethics approval was given by the Human Ethics Committee of the university. The study included 50 consecutive feet of 39 patients who underwent surgical correction of a HV deformity by two foot and ankle surgeons. Of the 39 patients, 11 had bilateral surgery. Exclusion criteria were patients under the age of 18 years and incomplete records. Hallux pronation was assessed clinically and documented by looking at the orientation of the nail (Figure 2A). All patients underwent

Figure 1. Reference points and method for measuring the interphalangeal angle.

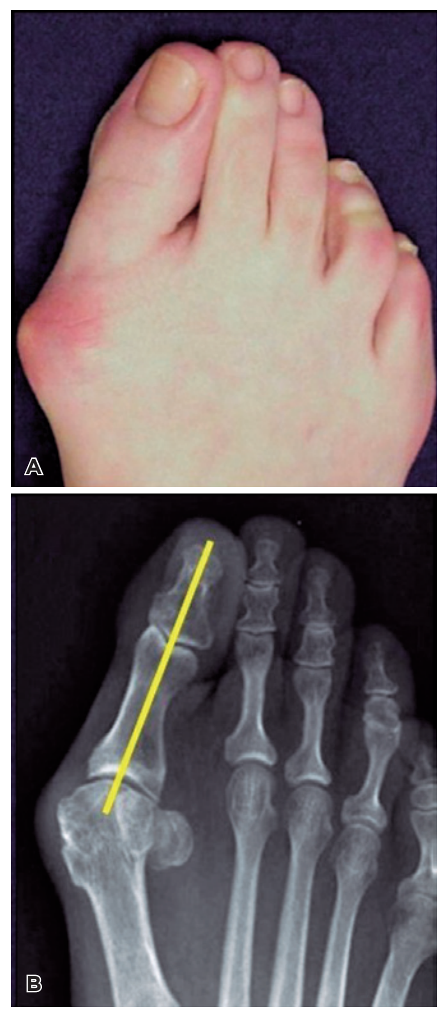

Figure 2. A) Clinical picture of Hallux valgus deformity with pronation. B) Radiographic measurement of the interphalangeal angle showing underestimation.

preoperative weight-bearing radiographs of their feet according to standard international guidelines. Preoperative radiographs were used to measure the HV angle, the intermetatarsal angle (IMA), and the IPA by a foot and ankle fellow.

HV deformity was corrected using the appropriate procedure according to the severity and cause of hallux pronation. If hallux pronation was related to first metatarsal pronation, a modified Lapidus procedure was performed to correct metatarsal pronation and HV deformity. All other deformities were corrected using the appropriate procedure which would correct the HV angle and cover the sesamoids, thereby correcting muscle imbalance (Table 1). Following HV correction with an appropriate osteotomy, the IPA angle was visually estimated using intraoperative fluoroscopy by the 2 senior authors (Observer 1 [NPS] and Observer 2 [PNF]. A mini-image intensifier was used to allow for simulated weight-bearing by pushing the foot up against the flat detector plate. The fluoroscopic image was printed, and formal IPA measured by the foot and ankle fellow, with the aid of a goniometer, using the standard measurement technique (Figure 3). Visually estimated and formally measured IPAs were assessed for reliability. Pre- and intraoperative IPAs were compared to assess for change after HV correction. Data was entered on an Excel spreadsheet and analyzed.

Statistical analysis

To measure the reliability of a test, the standard deviation of subject's true value and of measurement errors need to be calculated. Higher reliability shows smaller measurement errors of a test. Reliability values range between 0 and 1. A reliability value of 1 represents zero measurement error and vice versa[10,12]. To describe data on observers' measurement, mean and standard deviation (SD) were calculated. To determine interobserver agreement, a Pearson's correlation test was applied. All analyses were performed using STATA version 14.0. Statistical analyses were conducted at a significance level of 5% ($p<0.05$).

Results

The cohort consisted of 37 females and 2 males, with an average age of 48 (18-72) years. The mean preoperative IPA was 6.2 (0-18) degrees. The mean intraoperative (post HV correction) IPA was 11.7 (3-20) degrees. The mean difference between IPA before and after HV correction of 5.5 degrees was found to be statistically significant ($p=0.039$).

Visually estimated measurements by each observer and the formal measurements are reported in table 2. On average, Observer 2 had a higher mean measurement in comparison to Observer 1. Intraobserver reliability was 0.76 for Observer 1 and 0.80 for Observer 2. Interobserver reliability was 0.78. The Pearson's correlation test found a strong agreement between the two observers' visual measurements ($p<0.001$), as well as between observers' visual measurements and formal measurements ($p<0.001$).

Discussion

HVI is a three-dimensional deformity (pronation and valgus deformities). Treatment of HV deformity is based on physical and radiological examination. Various radiographic angles have been described for surgical planning, including IPA. These angles need to be reproducible and accurate to aid in surgical planning[6,17,18]. Coughlin et al.[3,10,12] reported that the techniques for measurement of the I-II IMA and the HV angle are reliable and reproducible.

The prevalence of HVI varies significantly in the literature. Strydom et al.[9] found a 62.1% prevalence of the HVI when they evaluated X-rays of patients with a HV deformity. They

Table 1. Summary of procedures performed to correct hallux valgus deformity

Procedure	Number
Chevron	11
Scarf	8
Proximal opening wedge	15
Modified Lapidus procedure	16

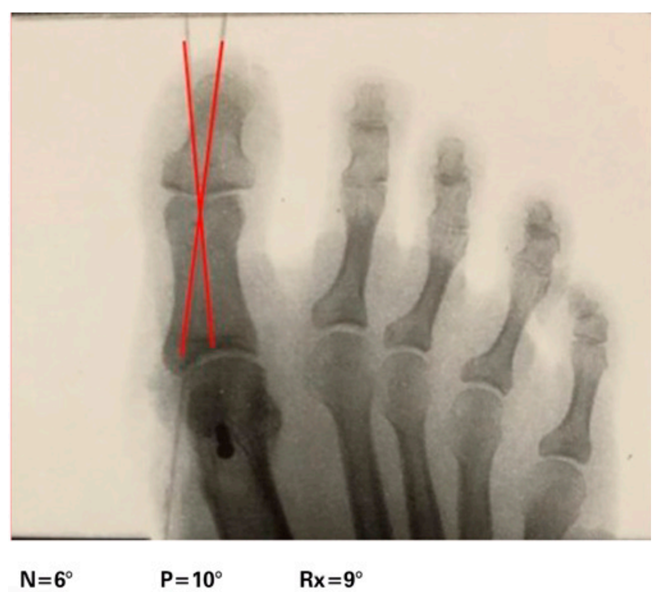

Figure 3. Intraoperative fluoroscopic image post hallux valgus correction for formal measurement of the interphalangeal angle.

Table 2. Summary of observers' visual estimations and formal measurements of the interphalangeal angle

Measured by	Mean (SD) (Degrees)	Min–Max (Degrees)
Observer 1	10.26° (3.89)	3° – 20°
Observer 2	11.42° (3.53)	4° – 18°
Formal measurement	11.68° (4.27)	3° - 20°

also concluded that the contribution of the IPA is 37.9% to the total valgus deformity of the hallux. Interestingly, HVI decreased as the severity of HV increased. We postulated that as the severity of HV worsens, the hallux tends to pronate more, thereby masking true HVI. Preoperative IPA is thus inaccurate and misleading.

Various causes have been described for hallux pronation in HV. In some studies, the flexor hallucis longus tendon has been implicated as a causative factor. This tendon will eccentrically pull the distal phalanx causing rotation of the hallux[3-6]. More recently, research on first metatarsal pronation in HV has become popular. First metatarsal pronation is not a novel idea and was reported by Eustace et al.[19] and Saltzman et al.[20]. Okuda et al.[21] found that correcting metatarsal pronation is an important component of HV surgical correction. Kim et al.[22] reported the incidence of first metatarsal pronation in HV to be as high as 87.3%. The advent of weight-bearing computed tomography has reinforced the incidence and amount of metatarsal pronation. Wagner et al.[23] has highlighted the importance of correcting first metatarsal pronation to prevent recurrence of HV deformity. Therefore, HV correction also corrects hallux pronation, revealing true HVI. We found that the IPA increased on average by 5.5 degrees after HV correction. This supports our theory that true HVI is masked in more severe HV deformity.

It is not practical to formally measure the IPA once true HVI has been identified intraoperatively. The importance of knowing the IPA is to guide the surgeon with regards to the required wedge size when performing Akin osteotomy. Shannak et al.[16] reported that a 1-mm increase in wedge size is necessary to correct for every 5-degree increase in IPA. The surgeon therefore often estimates the IPA using intraoperative fluoroscopy. Accuracy of visual estimation of angles by physicians has been reported in the literature for various measurements. Moran et al.[24] evaluated reproducibility and reliability of visual estimation of a series of angles by orthopaedic surgeons. They found that orthopaedic surgeons can visually estimate angles to within 10 degrees 93.1% of the time and to within 5 degrees 64.6% of the time. Repeat measurements 6 weeks later were within 5 degrees of their initial responses 82.2% of the time and within 10 degrees of the initial responses 94.5% of the time. Molony et al.[25] reported that orthopaedic surgeons can accurately estimate within 5 degrees acute angles less than 30 degrees. Abu-Rajab et al.[26] reported a 70.8% accuracy in estimating degrees of elbow flexion within 5 degrees amongst 116 observers. Higashi et al.[27] evaluated accuracy of visual estimation of the I-II IMA and reported that visual estimation differed from formal measurements by 3.28 +/-1.56. They also concluded that visual estimation of angles <10 degrees was more accurate.

The current study found intraobserver reliability of visually assessing the IPA to be 76% and 80% for each observer respectively, with a margin of error of 3 degrees or less. Interobserver reliability was found to be 78%. It is therefore viable for the surgeon to visually estimate the IPA intraoperatively after HV correction.

The limitation of this study is that only 2 observers were used to visually estimate the IPA. A future multi-surgeon study would be of benefit. Another limitation was that we compared the IPA in simulated weight-bearing using a mini-image intensifier to standard weight-bearing radiographs. Boffeli and Mahoney[28] reported that intraoperative simulated weight-bearing lateral foot imaging had a direct correlation to weight-bearing radiographs. Further research is required to assess the validity of comparing simulated weight-bearing images to standard weight-bearing radiographs.

Conclusion

Inter- and intraobserver visual assessment of the IPA of the hallux was found to be reliable intraoperatively, thus aiding in planning the amount of correction required by Akin osteotomy. Furthermore, the study suggested that HVI could be masked by the amount of preoperative hallux pronation from the HV deformity and should rather be assessed intraoperatively after HV correction.

Authors' contributions: Each author contributed individually and significantly to the development of this article: PNFF *(https://orcid.org/0000-0003-4639-0326) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, statistical analysis, formatting of the article and approved the final version. NPS *(https://orcid.org/0000-0002-5566-7588) Performed the surgeries, formatting of the article and approved the final version; MK *(https://orcid.org/0000-0003-3167-7797) Data collection, interpreted the results of the study and formatting of the article. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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