Comparison of Intraoperative Fluoroscopy to Postoperative Weight-Bearing Radiographs Obtained 4 to 6 Weeks After Bunion Repair With A Chevron Osteotomy

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ABSTRACT

Background: During operative treatment of bunions, an attempt is made to correct the hallux valgus angle (HVA) and the intermetatarsal angle (IMA). In this study, the HVA and the IMA were measured using intraoperative C-arm fluoroscopic images obtained during surgical treatment of a bunion with chevron osteotomy. These angles were again measured using weight-bearing radiographs obtained 4 to 6 weeks postoperatively.

Methods: At our institution, we reviewed medical records of patients who underwent a bunion repair with chevron osteotomy between January 2013 and October 2017. A total of 26 feet from 24 patients were included. Three authors (ALP, TMH, and RAM) measured the HVA and IMA using intraoperative fluoroscopic images and postoperative weight-bearing radiographs (4 measurements per foot; total, 104 measurements). The authors were blinded to their previous angular measurements and to measurements made by the others. An intraclass correlation coefficient was calculated for the HVA and IMA measurements between groups (ie, intraoperative fluoroscopic images and postoperative radiographs) to determine interobserver reliability. We compared the angles measured by the authors between groups and used a paired *t* test for statistical evaluation.

Results: Interobserver difference of the HVA and IMA was low between intraoperative fluoroscopic images and postoperative weight-bearing radiographs (0.98 and 0.79; 0.78 and 0.95, respectively). The measured IMAs were relatively consistent between groups (6.21° and 6.37°, respectively); only two patients had a difference > 3°. There was a greater difference in HVAs between groups (11.5° and 14.2°, respectively). In 11 feet, the HVA was > 5° (range, 5.3-12.7°) in the postoperative radiograph compared to the fluoroscopic image. In one foot, we noted a 7° decrease of the HVA on the postoperative radiograph. The average difference of HVA between groups was 2.6° ($P < 0.0001$), whereas the IMA was 0.16° ($P = 0.002$).

Conclusions: Interobserver measurements of the HVA and IMA were reliable on both the intraoperative fluoroscopic images and the postoperative weight-bearing radiographs. The IMA was similar between groups; however, the HVA was often greater on the postoperative weight-bearing radiographs.

Keywords: Hallux Valgus, Fluoroscopy, Intermetatarsal Joint, Bunion Surgery

INTRODUCTION

During operative treatment of bunions, the objective is to correct the hallux valgus angle (HVA) and the intermetatarsal angle (IMA). Correction of these angles decreases the chance of reoccurring deformity.[1] Intraoperative imaging is necessary to assess great toe alignment during surgical treatment. Fluoroscopic images or plain weight-bearing radiographs can be obtained during the procedure. Intraoperative fluoroscopy has the advantage of decreased operating time compared with obtaining plain weight-bearing radiographs. This eases the ability to make intraoperative adjustments.

Chevron osteotomy is one of the most common procedures for treating a bunion.[2] During this procedure, an osteotomy is made in the first metatarsal

head, which is then translated laterally to decrease the IMA. The location of the osteotomy distorts the relationship between the metatarsal head and neck, which might make radiographic interpretation difficult.

This study aimed to determine whether intraoperative C-arm fluoroscopic images, with the foot held in a simulated weight-bearing position, gives an accurate assessment of the bunion correction. Specifically, we evaluated 1) any difference in HVA and IMA measurements between the three examiners and 2) any difference in HVA and IMA measurements between intraoperative fluoroscopic images and weight-bearing radiographs obtained 4 to 6 weeks postoperatively. We hypothesized that HVA and IMA measurements would be similar between groups.

METHODS

After obtaining approval from our institutional review board (HRRC #17-451), we reviewed medical records of patients who underwent a bunion repair with a chevron osteotomy performed by the senior author (RAM) between January 2013 and October 2017. We included patients who had intraoperative fluoroscopic images, with the C-arm in a simulated weight-bearing position, and weight-bearing radiographs at 4 to 6 weeks postoperatively. The intraoperative fluoroscopic images were obtained with the knee bent and the foot flat against the operating room table to simulate a weight-bearing position. These images were saved to the IntelliSpace PACS program (Philips Healthcare, Andover, MA) and were available to review electronically. A total of 26 feet from 24 patients were included in the study.

Four angular measurements were made for each foot. The HVA and the IMA were measured using intraoperative fluoroscopic images. The HVA and IMA were measured again using weight-bearing radiographs obtained in clinic 4 to 6 weeks postoperatively (Figures 1 and 2). To obtain the postoperative radiographs, the patients stood and placed their foot on the radiographic plate.

The HVA and IMA measurements were made independently by three of the authors. One author was a second-year orthopaedic resident (ALP), one a third-year orthopaedic resident (TMH), and one a foot and ankle fellowship-trained orthopaedic surgeon (RAM). Each examiner made 104 measurements. Several days after measuring the HVA and IMA using the intraoperative fluoroscopic images, the examiners measured the same angles on the postoperative weight-bearing radiographs. The examiners were blinded to their previous angular measurements and to the measurements made by the others. Comparisons were made between the HVA and IMA measured by the examiners. In addition, we compared the HVA and IMA

Figure 1. *Radiograph showing the hallux valgus angle in a patient who underwent bunion repair with chevron osteotomy. The angle is formed between a line drawn down the center of the great toe proximal phalanx and a line from the center of the metatarsal head to the center of the base of the first metatarsal.*

Figure 2. *Radiograph showing the intermetatarsal angle in a patient who underwent bunion repair with chevron osteotomy. The angle is formed between two lines: one line from the center of the first metatarsal head through its base, and the other line from the center of the second metatarsal head through its base.*

***Table 1**. Results of the interobserver reliability test, showing the cumulative difference of measurements between examiners (by degrees) and corresponding intraclass correlation values*[a]

Imaging modality used for measurement	No. times different by 0-4°	No. times different by 5°	No. times different by > 5°	ICC[b]
Fluoroscopic intraoperative radiograph				
HVA	24	1	1	0.98
IMA	24	2	0	0.78
Postoperative weight-bearing radiograph				
HVA	25	1	0	0.79
IMA	26	0	0	0.95

ICC, intraclass correlation coefficient; HVA, hallux valgus angle; IMA, intermetatarsal angle.
[a]Each of the three examiners measured the hallux valgus angle and intermetatarsal angle of 26 feet using intraoperative fluoroscopic images and postoperative weight-bearing radiographs. Four measurements were made per foot, totaling 104 measurements. The groups of 0-4°, 5°, and >5° difference were arbitrarily assigned on the basis of the senior author's (RAM) discretion.
[b]Intraclass correlation coefficient values of < 0.5 indicate poor correlation, 0.5-0.75 indicate moderate correlation, 0.75-0.9 indicate good correlation, and 0.9-1 indicate excellent correlation between examiners.[11]

measurements between intraoperative fluoroscopic images and postoperative weight-bearing radiographs. The PACS angular measurement function was used to make all measurements electronically.

Statistical analyses were performed using Statistical Analysis Software 9.4 (Cary, North Carolina). Comparisons of HVA and IMA measurements between intraoperative fluoroscopic images and postoperative weight-bearing radiographs were completed using a paired *t* test. Interobserver reliability for each group of angles measured by the examiners was determined by calculating an intraclass correlation coefficient.

RESULTS

The interobserver difference for the four measurements was low. On four of the 104 measurements, one examiner was 5° different from the others (3.8%). Only once was an examiner more than 5° different from the other two. For the other 99 angles measured, the three examiners measured less than 5° different from one another (Table 1).[3] On six occasions, the same angle was measured by all three examiners. Two of the three examiners had the same angle 46 times. On another 28 occasions, the examiners each measured a different angle with a spread of 2°. Overall, the interobserver reliability for each group of angle measurements was good to excellent, ranging from 0.78 to 0.98.

The IMA measurement was similar between the groups (ie, intraoperative fluoroscopic images and postoperative weight-bearing radiographs). Using the average angle of the three examiners, we noted a 4° difference between groups in only one foot. Another foot had a 3° difference, and the remaining 24 feet had less than a 3° difference of IMA measured between groups. The mean HVA measurements between groups were 11.5° and 14.2° respectively, with a mean difference of 2.6° ($P < 0.0001$). The mean IMA measurements between groups were 6.21° and 6.37° respectively, with a mean difference of 0.16° ($P = 0.002$).

The HVA measurement had a greater difference between groups. Using the average of the three examiners, a total of 11 feet (42%) showed an HVA greater than 5° on the postoperative weight-bearing radiographs compared to the intraoperative fluoroscopic images (range, 5.3-12.7°). One foot had a 7° improvement of the HVA on the postoperative weight-bearing radiograph.

DISCUSSION

The IMA and HVA are important to assess the bunion deformity. Weight-bearing radiographs reveal the deformity more clearly than non–weight-bearing radiographs.[4] In the current study, we found a small but statistically significant difference in IMA and HVA measurements between intraoperative fluoroscopic images that simulated weight bearing and postoperative weight-bearing radiographs. A post hoc power analysis was completed ($P = 0.002$ and 0.001, respectively). The difference in angle measurements was relatively minor (HVA, 2.6° and IMA, 0.16°).

Previous studies have shown a high reliability of interobserver measurement of these angles on plain radiographs.[5-7] Using photographs of radiographs, Coughlin et al[8] showed that 96.7% of IMAs were repeatedly measured within a range of 5° or less. The measurements were less reliable for the HVA, with 86.2% of photographs measured within 5° or less. These findings are consistent with those of our own study. We found good to excellent interrater reliability between the three examiners despite different levels of experience.

Kuyucu et al[9] noted that foot position changes the HVA to a greater extent than that of the IMA. This might explain the greater difference noted in HVA compared to IMA between the intraoperative fluoroscopic images and postoperative weight-bearing radiographs. Another possible explanation could be stretching of the medial

capsular repair, resulting in some reoccurrence of deformity seen on the postoperative radiograph at 4 to 6 weeks.

There are few studies comparing intraoperative fluoroscopic images to postoperative radiographs in operative treatment of bunions. Elliot et al[10] reviewed fluoroscopic images and 6-week postoperative radiographs of 28 patients after bunion correction with a scarf osteotomy. The IMA increased an average of only 1.2°; however, the HVA increased an average of 9.1° between the groups. Gutteck et al[11] found no difference in the angles between fluoroscopic images and 8-week postoperative radiographs of patients who underwent Lapidus bunion repair.

We found the intraoperative fluoroscopic images to be adequate to measure the HVA and the IMA. The angles measured correlated between examiners. Similarly, there was good interobserver correlation with the angles measured using the postoperative weight-bearing radiographs. The IMA measurement was similar between groups. There was worsening HVA of greater than 5° seen on the postoperative radiographs of 11 feet, with improvement greater than 5° in one foot.

This study was limited by small sample size. Despite this, there was sufficient statistical power. All patients were treated by the same surgeon (RAM) at a single hospital, limiting the variability and generalizability of the data. In this study, one examiner was a fellowship-trained, board-certified foot and ankle surgeon (RAM), while the other examiners were second-year (ALP) and third-year (TMH) orthopaedic residents. However, the interrater variability of measured angles was very low, indicating that angle interpretation can accurately be performed at various levels of training. Follow-up studies may benefit from measurements made by additional specialty-trained foot surgeons compared with a larger pool of examiners.

Previous research has shown that weight-bearing radiographs are more reliable in measuring HVA and IMA, with high intraobserver reliability.[4-7] In this study, we hoped to show that HVA and IMA measurements from intraoperative fluoroscopic images with simulated weight bearing would be comparable to those of postoperative weight-bearing radiographs. Although we saw a statistically significant difference between the angle measurements, the difference was clinically insignificant. Fluoroscopic images obtained intraoperatively may be adequate for measuring HVA and IMA. Subsequently, immediate postoperative radiographs may not always be necessary in assessing HVA and IMA of patients undergoing bunion repair.

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