Do Intra-operative Simulated Weight Bearing Images Predict Postoperative Multi-planar Alignment in Flatfoot Reconstructive Surgery: A Retrospective Comparison to Assess Clinical Utility

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STATEMENT OF PURPOSE

- Establish a reliable and reproducible intra-operative simulated weight bearing (WB) imaging technique (Figure 1) during flatfoot reconstructive surgery to assess alignment before and after placement of final fixation.
- Evaluate calcaneal inclination angle, Meary's angle, and calcaneal-1st metatarsal angle, intra-operatively on simulated WB imaging and post-operatively on full WB X-rays to verify the reliability and reproducibility of the simulated WB imaging technique.
- Determine the predictive value and accuracy of the simulated WB imaging technique in anticipating final alignment of flatfoot reconstructive surgery while full WB (Figure 2).

LITERATURE REVIEW

Flatfoot deformities affect the sagittal plane, frontal plane, and transverse plane to varying degrees. Reconstructive flatfoot surgeries often involve multiple procedures including multiple joint fusion, osteotomy, soft tissue balancing, and biomechanical manipulation to address the triplanar deformity that occurs. Ensuring proper alignment is imperative to avoid potential post-operative complications, including lateral column overload with overcorrection, medial arch collapse with undercorrection, and adjacent joint arthritis (1-5). Objective radiographic measurements have been described to analyze the biomechanical structure of the foot in the sagittal plane including Meary's angle, calcaneal inclination, calcaneal – 1st metatarsal angle, talar declination, and cyma line. The strongest association between clinical and radiological measures occurs with the normalized navicular height and calcaneal first metatarsal angle, and medial longitudinal arch pathology is more strongly associated with abnormal calcaneal pitch and Meary's angle (6,7). The intra-operative simulated WB technique employed in this study was found to be predictive of the post-operative outcome regarding sagittal plane position of the first ray in Lapidus midfoot fusion (8).

METHODOLOGY

This IRB approved retrospective study included 42 patients (46 feet) who underwent rearfoot fusion with ancillary procedure (42 cases) or rearfoot osteotomies with ancillary procedures (4 cases) for reconstruction of flatfoot deformity. Hindfoot fusions included: subtalar joint fusion, talonavicular fusion, and calcaneocuboid fusion. Hindfoot osteotomies included: Evan's osteotomy, Cotton osteotomy, and medial sliding calcaneal osteotomy. Accessory procedures included a combination of: gastrocnemius recession, Achilles tendon lengthening, posterior tibial tendon repair, resection of tarsal coalition, and FDL transfer. All procedures imaging were performed by the primary author. Sagittal plane alignment was compared through Meary's angle, 1st metatarsal-calcaneal angle, and calcaneal inclination angle between the intra-operative simulated WB and 10 week post-operative WB lateral radiographic images (Figures 3&4).

PROCEDURE

A standardized imaging technique was used to ensure that simulated WB images maintained the characteristics of a standard lateral WB radiograph including: a singular talar dome, clear visualization of the fifth metatarsal styloid process, and mild superimposition of the navicular and cuboid (Figure 5). This is achieved by:

- Rotating toes to the ceiling for proper lateral view
- Image intensifier close to the foot to show as much of the foot as possible (calcaneus to metatarsal heads)
- Use of large cutting board (not mallet) to load the whole foot (Figure 1)

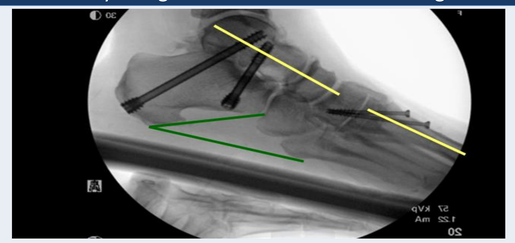
Figure 1. Intraoperative Simulated Weight Bearing Imaging

The image intensifier is positioned close to the foot (a) rather than far away (b) to minimize magnification / small field of view on lateral imaging. The flat plate is positioned at 90° to the image intensifier, and the foot is loaded with the palm of the surgeon's hand with the ankle dorsiflexed to 90° and toes to the ceiling. A large C-arm (b) is needed to image from heel to metatarsals on one screen.

Figure 2. Comparison if Intra-operative Simulated WB Image and 10 Week Post-operative Full WB Lateral Xray

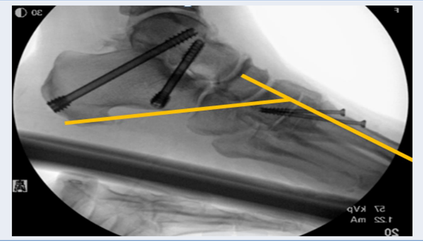
Intra-operative simulated WB imaging (a) allows a surgeon to confirm the desired result before and after placement of final fixation and between each surgical procedure. Without a reliable and reproducible imaging technique one would have to wait until full weight bearing films are obtained 10 weeks post-operatively (b) to view final surgical correction.

Figure 3. Meary's Angle & Calcaneal Inclination Angle



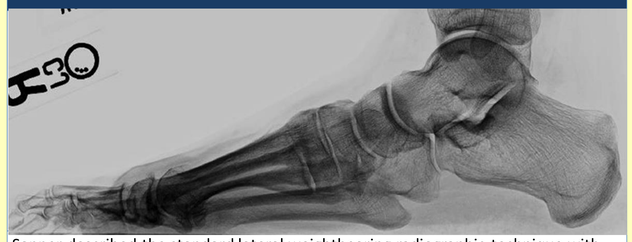
Meary's angle (in yellow) is defined as the angle between a line originating from the center of the body of the talus, bisecting the talar neck and head, and a line through the longitudinal axis of the 1st metatarsal. Calcaneal inclination angle is defined as the angle between the inferior surface of the calcaneus and the supporting surface.

Figure 4. Calcaneal – 1st Metatarsal Angle



Angle formed between the inferior surface of the calcaneus and a line parallel to the dorsum of the mid-shaft of the first metatarsal.

Figure 5. Definition of Lateral Weight Bearing (9)



Sanner described the standard lateral weightbearing radiographic technique with the patient standing in a natural angle and base of gait, with the film parallel to the medial side of the foot, the tube head angulation position at 90 degrees from vertical, and the central ray directed at the lateral cuneiform and cuboid. Visual assessment for proper lateral alignment involves a singular talar dome, clear visualization of the fifth metatarsal styloid process, and mild superimposition of the navicular and cuboid. Note how we are able to achieve this same image in 4a.

Table 1. Patient Characteristics

Sample Size	42 patients (46 procedures)
Average Age	58 (16-82)
Male – Female	22 – 28
Time to full weight bearing	10.4 weeks (9.4 – 18.5)

Table 2. Mean Difference Between Pre-operative, Intra-operative & Post-operative

Angle of Interest	Pre-operative Mean ± SD	Intra-operative Mean ± SD	Post-operative Mean ± SD
Meary's	13.33 ± 8.89	5.08 ± 3.29	5.13 ± 2.9
Calcaneal – 1st metatarsal	146.88 ± 5.29	135.37 ± 6.40	136.55 ± 6.63
Calcaneal inclination	12.54 ± 4.24	18.70 ± 4.32	16.63 ± 4.25

Table 3. Mean Difference Between Intra-operative Simulated WB and 10 Week Post-operative Full Weight Bearing Lateral Images

Angle of Interest	Mean ± SD	p < .05
Meary's	1.09 ± 1.87	Not Statistically significant
Calcaneal – 1st metatarsal	2.61 ± 2.37	Not Statistically Significant
Calcaneal inclination	2.62 ± 1.16	Not Statistically Significant

Table 4. Mean Difference Between Intra-operative Simulated WB Imaging and 10 Week Post-operative Full WB Lateral X-ray

Angle	Within 1°	Within 2 °	Within 5°
Meary's	70%	87%	89%
Calcaneal – 1st metatarsal	12%	65%	85%
Calcaneal inclination	12%	35%	88%

RESULTS

- 46 patients involving 26 left and 20 right feet were evaluated retrospectively (Table 1).
- All patients had intra-operative simulated WB radiographs taken with a large C-arm, and all had final WB lateral radiographs taken at an average of 10.4 weeks post-operatively (Table 1).
- Each of the angles of interest displayed a statistically significant amount of surgical correction when comparing pre-operative to intra-operative simulated weight bearing (Table 2).
- Average change in Meary's angle between intra-operative and post-operative is 1.09°, which was not statistically significant, with a positive predictive value within 1° of 70% (Tables 3 & 4).
- Average change in calcaneal – 1st metatarsal angle between intra-operative and post-operative is 2.61°, which was not statistically significant, with a positive predictive value within 1° of 12% (Tables 3 & 4).
- Average change in calcaneal inclination angle between intra-operative and post-operative is 2.62°, which was not statistically significant with a positive predictive value within 1° of 12% (Tables 3 & 4).

ANALYSIS & DISCUSSION

The practice of simulating WB intra-operatively to assess surgical alignment is widespread and considered to be good practice; however, there is little to no data supporting this claim. The results of the present study support the hypothesis that intra-operative simulated WB lateral foot imaging technique is predictive of the postoperative outcome regarding the sagittal plane position of a reconstructed flatfoot. This is especially the case with Meary's angle as it is predictive for more accurate readings. While the intra-operative and full WB differences for calcaneal inclination and calcaneal – 1st metatarsal angle were not found to be statistically significant, it was noted that there is only reliable predictive value within 5°. Considering that many of the documented post-operative complications associated with flatfoot reconstruction involve undesirable alignment in the sagittal plane, it is imperative that the surgeon has a reliable intra-operative assessment tool for predication of the final result. Use of the same cutting board allowed the imaging technique to be standardized and easily reproducible for all cases and avoided interference with the radiographic assessment. One of the main limitations of this study include the inherent variability of inter-observer and intra-observer error in radiographic angle measurements. In conclusion, the results of the present study confirm the clinical utility of intra-operative simulated WB lateral imaging as a useful tool in predicting the postoperative sagittal plane position for patients undergoing flatfoot reconstruction.

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