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Digital Planning for Foot and Ankle Deformity Correction: Evans Osteotomy

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ABSTRACT

Preoperative planning is commonly performed for many foot and ankle procedures. The purpose of the present study was to prospectively determine the preoperative digital planning accuracy of predicting the calcaneal graft size used during the "Evans" calcaneal osteotomy. Preoperative digital deformity correction planning, using a standard planning method (TraumaCad® software), was performed on 10 feet scheduled to undergo an Evans procedure. Of the 10 patients, 6 were female and 4 were male, with an average age of 43 ± 22 years. Digital planning was used to predict the Evans graft size. The surgeon was unaware of the predicted graft size, which was then compared with the actual graft size inserted during the procedure. In addition, the pre- and postoperative radiographic angles were recorded and compared (anteroposterior view, talo–first metatarsal angle, calcaneocuboid abduction; lateral view, calcaneal inclination angle; and axial view, tibial–calcaneal angle). The average preoperative talo–first metatarsal angle, calcaneocuboid angle, calcaneal inclination angle, and tibial–calcaneal angle measured 21° ± 9.6°, 28.3° ± 9.0°, 13.8° ± 5.7°, and 15.3° ± 8.2°, respectively. The preoperative tibial–calcaneal position was 2.8 ± 1.2 mm. The radiographic weightbearing angles measured at an average follow-up of 7.4 (range 6 to 12) months improved to 6.3° ± 7.4° (p = .0015), 12.3° ± 6.1° (p < .001), 21.3° ± 7.7° (p = .0122), and 2.2° ± 3.6° (p = .0019) for the talo–first metatarsal, calcaneocuboid abduction, calcaneal inclination, and tibial–calcaneal angles, respectively. The final tibial–calcaneal position measured 1.4 ± 0.7 mm (p < .001). The preoperative Evans graft measurement (11.8 ± 2.6 mm) compared with the actual graft (12.2 ± 1.3 mm) placed was within 0.4 ± 1.8 mm (p = .51). Preoperative digital planning for Evans calcaneal osteotomy has been shown to be a valuable tool for predicting the surgical graft size for accurate pedal realignment.

Preoperative surgical planning is commonly performed for various orthopedic procedures (1–3). Traditional planning methods have included tracing paper drawing cutouts from standard radiographs, drawing measurements on radiographs, and acetate templates (4). Recently, computer-based planning software has been introduced to allow for preoperative planning. The software has been routinely used in complex pediatric deformity planning, orthopedic trauma, and joint arthoplasty (2–5). Determining the placement of the osteotomies, implants, and bone fragments before entering the operating room will be advantageous for the patient and increase surgical accuracy. Digital templating has been commonly used in orthopedic surgery, with preloaded implants in a computer software program. Preoperative radiographs from a facility are obtained by a picture archiving and computer system and uploaded into the software program. The implants and their respective components can thus be preoperatively predicted precisely according to the individual patient's anatomy (Fig. 1). Digital planning uses software in the same method as templating; however, the software is used for surgical planning as it relates to deformity correction, grafting, and osteotomies. Recent studies of hip replacements have highlighted the accuracy and benefits of digital templating (6,7). However, no reports on digital radiographic planning for foot surgery have been published. The reasons are likely multifactorial and could have been because of the limited applications of the software, especially regarding the foot. The multiple joints and anatomy of the foot bones have limited the ability of the program to correct deformities compared with the long bones of the human body. However, despite the limitations of the program, we have devised a method to use the software routinely for computer-

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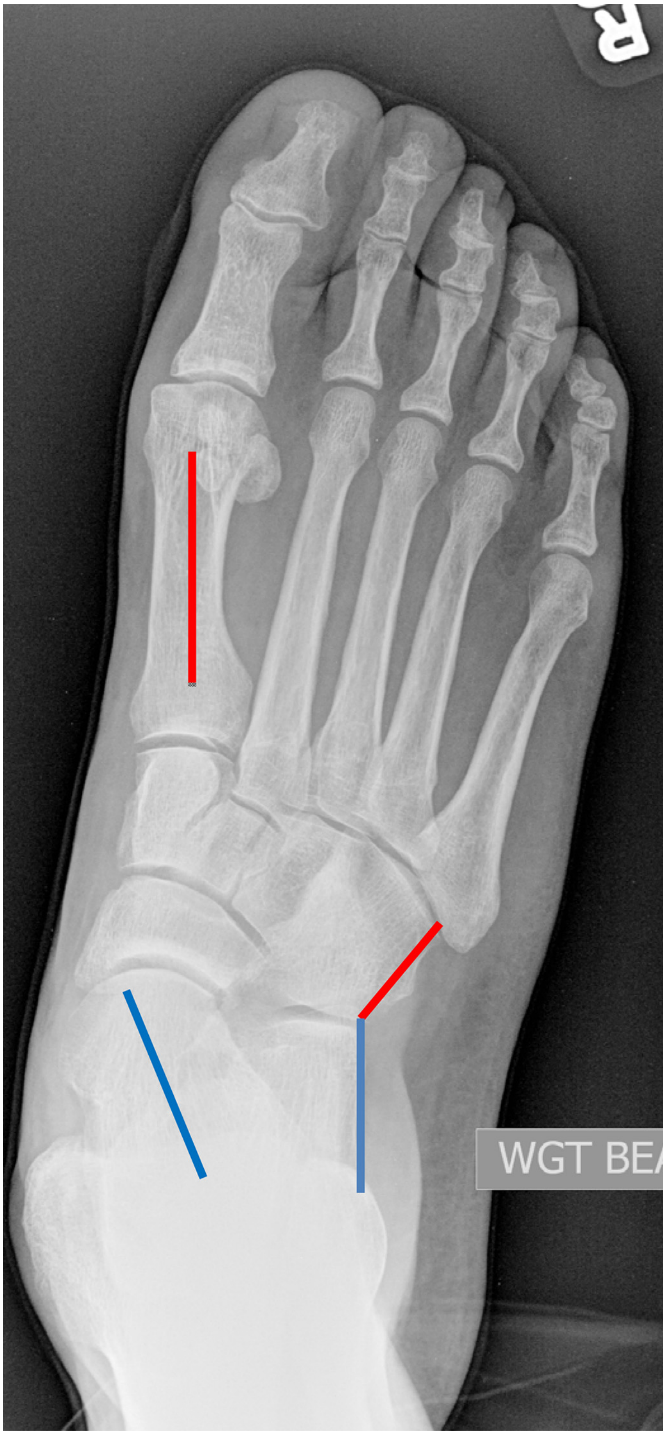

Fig. 1. The talo–first metatarsal and calcaneocuboid abduction angles were measured on anteroposterior radiographs. (Reprinted with permission from Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore.)

based preoperative planning for the foot and ankle. The purpose of the present study was to prospectively determine whether preoperative digital planning can accurately predict the calcaneal graft size used during the "Evans" calcaneal osteotomy.

Patients and Methods

Preoperative digital planning was prospectively performed for 10 patients undergoing surgery for flexible flatfoot deformity from July 2011 to June 2012. Of the 10 patients, 6 were female and 4 were male, with an average age of 43 ± 22 years. One surgeon (N.A.S.) measured all pre- and postoperative angles and positions on the standard anteroposterior, lateral, and axial radiographs. On the anteroposterior radiograph, the talo–first metatarsal angle (TFA) and calcaneocuboid abduction angle were measured. On a standard lateral radiograph, the calcaneal inclination angle (CIA) was measured. On the axial hindfoot alignment view, the tibial–calcaneal position and tibial–calcaneal angle were measured (Fig. 2*A*). The TFA was obtained by measuring the angle created by the anatomic bisection of the talus and first metatarsal. The calcaneocuboid abduction angle was determined by the intersection of lines outlining the lateral border of the calcaneus and cuboid bones. The CIA was determined by a line marking the plantar border of the calcaneus and a horizontal line parallel to the weightbearing surface of the foot. The tibial–calcaneal angle and tibial–calcaneal position were best assessed on the hindfoot alignment view. This radiograph allows the observer to view the frontal plane relationship of the tibia to the hindfoot. The tibial–calcaneal angle was measured by the intersection of the mid-diaphyseal tibial and calcaneal bisection lines. In a normal foot, the relationship will be 0° (Fig. 2*A*–*D*). The calcaneal position was the measured distance from the mid-diaphyseal line to the calcaneal bisection. In a normal foot, the distance will be 10 mm laterally (Fig. 2*A*–*D*).

Surgical Planning

Deformity planning was prospectively performed preoperatively at our clinic using TraumaCad® (Voyant Health, Petach-Tikva, Israel) digital radiograph planning computer software. The program does not have dedicated foot software that allows specific foot deformity planning. Therefore, we created the Evans calcaneal osteotomy using the tools provided and predicted the graft sizes once the deformity had been aligned.

We measured the TFA and calcaneocuboid angle (CCA) using the software program (Fig. 1). Our goal was to realign the foot to match the foot's normal angular measurements (Fig. 2*A*–*C*). We chose to perform the preoperative planning osteotomy and calcaneal neck lengthening 1.5 cm (Fig. 3*A*) proximal to the calcaneocuboid joint on the anteroposterior radiograph, as described by Evans (8). We outlined the foot, using the software's "lasso" tool, to include the tarsal, metatarsal, and digital bones (Fig. 3*B*). Correction was achieved when the outlined foot was hinged on the medial calcaneal cortex and rotated about the center of the imaginary circle of the talar head until the TFA was 0° or collinear. Performing this maneuver created an opening wedge in the anterior neck of the calcaneus, which corresponded to the proposed graft size. The lateral cortical margin of the calcaneus was measured to determine the length (in mm) of the base of the Evans wedge graft.

Procedure

The surgeon (B.M.L.) was unaware of the predicted graft size and performed the neck lengthening using the following method, which is a modification of the procedure described by Evans (8). The patient was placed on the operating table in the supine position, with a bump under the ipsilateral hip to internally rotate the foot and obtain a foot-neutral position. Under fluoroscopy, a 1.8-mm wire was inserted 1.5 cm proximal and parallel to the calcaneocuboid joint near the dorsal cortex of the calcaneus. This wire was then cut short and allowed to serve as a marker for deeper dissection. A 3-cm linear incision was made in line with the dorsal lateral cortex of the calcaneus, proximal to the calcaneocuboid joint. The benefit of this incisional approach is that it typically avoids the level of the intermediate dorsal cutaneous and sural nerve. If the nerve is encountered after making a linear incision at this level, it can be protected and retracted. The peroneal tendons were identified and released from their sheath just enough to mobilize and retract them and to expose the lateral wall of the anterior calcaneus. At this point, the previously cut 1.8-mm wire will serve as a guide for focused dissection and a guide for the level and plane of the osteotomy. Extraperiosteal dissection for the osteotomy is done with an elevator, in line with the wire, over the anterior neck of the calcaneus medially, laterally, and plantarly. Limited extraperiosteal dissection should be performed, because overzealous dissection toward the calcaneocuboid articulation can lead to instability of the calcaneocuboid joint. The osteotomy was performed with an oscillating saw and completed medially with an osteotome. A laminar spreader was placed on the dorsal–lateral cortex and opened to distract the osteotomy until the hindfoot position was neutral, such that the heel position was vertical or parallel to the tibia. The vertical or neutral heel position should be confirmed by loading the foot with the "push-up" test to simulate the midstance in gait. Fluoroscopy was then used to confirm the reduction in the sagittal, transverse, and axial planes. Once satisfied with the position, the surgeon measured the opened osteotomy distance of the laminar spreader, which corresponded to the graft size needed for correction. The fibular allograft was measured and cut in a trapezoidal shape and placed into the osteotomy of the calcaneus to maintain the corrected position. Fixation was typically not used, and closure was performed in layers. Postoperatively, the patients were placed in a non-weightbearing cast in a neutral position for 6 weeks. Physical therapy was then initiated, and the patients were transitioned to protected weightbearing in an orthopedic boot for an additional 4 weeks. Subsequently, the patients were transitioned to supportive athletic shoes.