The Journal of Foot & Ankle Surgery 59 (2020) 44–47

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

The Influence of Radiograph Obliquity on Böhler's and Gissane's Angles in Calcanei

A. Siebe De Boer, MD, PhD[1], Esther M.M. Van Lieshout, MD, PhD[2], Leonie Vellekoop, MD[1], Dennis Den Hartog, MD, PhD[3], Gert Jan Kleinrensink, MD, PhD[4], Michael H.J. Verhofstad, MD, PhD[5]

[1] *Resident Surgery, Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands*
[2] *Assistant Professor and Research Coordinator, Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands*
[3] *Trauma Surgeon, Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands*
[4] *Professor, Department of Anatomy and Neurosciences, Erasmus MC, Rotterdam, The Netherlands*
[5] *Professor, Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands*

A R T I C L E I N F O

Levels of Clinical Evidence: 5

Keywords:
angular variation
Böhler
calcaneal
Gissane
malposition
obliquity

A B S T R A C T

In calcaneal fractures, Böhler's and Gissane's angles are considered important parameters to guide treatment strategy and provide prognostic information during follow-up visits. Therefore, lateral radiographs have to be accurate. The aim of this study was to evaluate the effect of craniocaudal and posteroanterior angular variations (i.e., simulate lower leg malposition) from the true lateral radiograph on Böhler's and Gissane's angles. In this radioanatomical study, 15 embalmed, skeletally mature, human anatomic lower limb specimens were used. Using predefined criteria, a true lateral radiograph (i.e., 0° angular variation) was obtained. Angular variations from this true lateral radiograph were made from −30° to +30° deviation in the craniocaudal and posteroanterior direction at 5° intervals. Böhler's and Gissane angles were independently assessed by 2 experienced trauma surgeons. Böhler's angle decreased with increasing caudal angular variations (maximum −4.3° deviation at −30°). With increasing of the posterior angular variations, Böhler's angle increased (maximum 5.0° deviation at +30°) from the true lateral radiograph, but all deviations were within the measurement error. The deviation of the angle of Gissane was most pronounced in the cranial direction, with the mean angle decreasing by −8.8° at +30° angular variation. Varying angular obliquity in the caudal and posteroanterior direction hardly affected Gissane's angle. Foot malpositioning during the making of a lateral radiograph has little influence on Böhler's and Gissane's angles. If used for clinical decision-making in initial treatment and during follow-up of calcaneal fractures, these parameters can reliably be obtained from any lateral radiograph.

The presence of a calcaneal fracture is based on radiologic examinations, which initially consist of a lateral and an axial radiograph of the foot (1). In case of a fracture, management can be surgical or nonoperative. The decision to perform an open reduction and internal fixation is merely based on the amount of dislocation. Although a computed tomography scan provides better visualization of the extent of the fracture, the number of fragments and their displacement, the amount of height loss, broadening of the calcaneus and the subtalar joint congruency (2,3), the decision of whether to operate is still predominantly based on plain radiographs. Loucks and Buckley (4) and Shuler et al (5) showed that the initial Böhler's angle at the time of trauma still guides this treatment decision.

From the lateral radiograph, 2 angles are used to estimate the degree of depression and displacement of the subtalar joint. Böhler's angle is determined by drawing lines from the tip of the processus anterior calcanei to the most cranial point of the posterior facet and from the top of the tuber calcanei to the most cranial point of the subtalar joint. Normally, this angle is between 25° and 40° (6) (Fig. 1*A*). Those with a decreased Böhler's angle are more likely to undergo fracture reduction and internal fixation to restore congruity of the posterior facet (4,7). Furthermore, the angle of Gissane is used. It runs along the posterior side of the processus anterior calcanei and the anterior side of the subtalar joint (Fig. 1*B*). Normally, this angle is between 120° and 145° (8).

Research has shown that the standard lateral and axial views often depict the main joint—the posterior facet—only partially (9). In

Financial Disclosure: None reported.
Conflict of Interest: None reported.
Address for correspondence: Esther M.M. Van Lieshout, MSc, PhD, Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, P.O. Box 2040, 3000 CA Rotterdam, The Netherlands.
E-mail address: e.vanlieshout@erasmusmc.nl (E.M.M. Van Lieshout).

1067-2516/$ - see front matter
https://doi.org/10.1053/j.jfas.2019.02.004

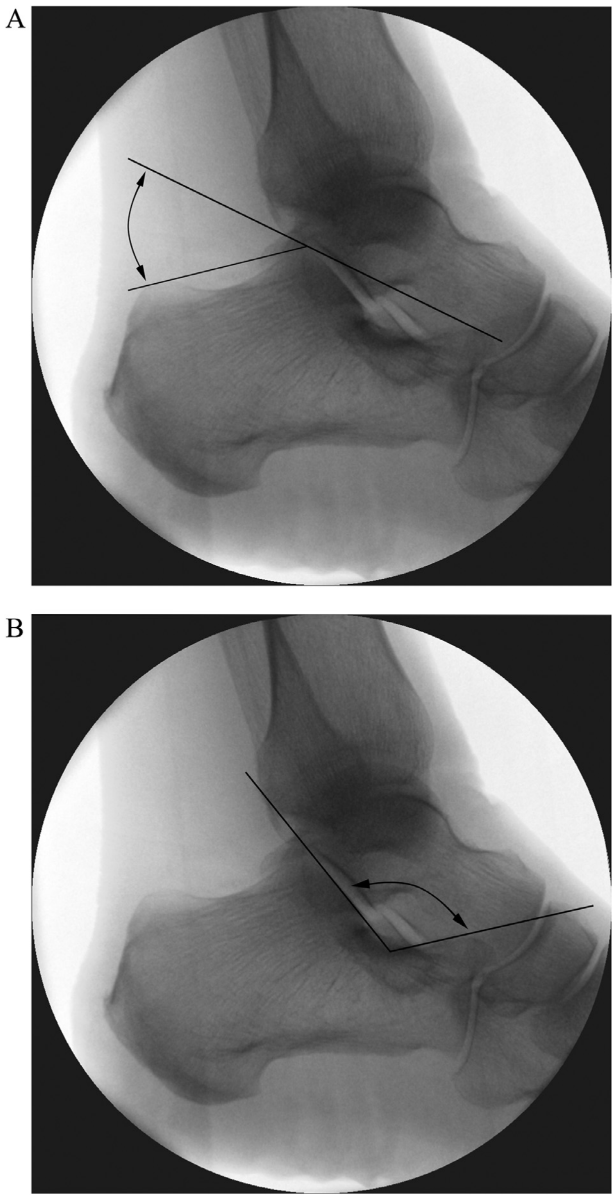

Fig. 1. (*A*) Böhler's angle. (*B*) Gissane's angle.

clinical practice, these views can be difficult to assess, especially as a result of positioning the patient's foot with discomfort, pain, soft tissue swelling, and associated injuries. For example, varus deformity of the foot (e.g., due to swelling) while obtaining radiographs may affect the radiographic measurements (e.g., Böhler's angle decreases), which in turn might result in opting for surgical treatment. In addition, the expertise of the radiologic technologist influences the diagnostic value of the lateral and axial radiographs. In the course of years, several additional radiographs (Brodèn, Isherwood, Anthonson, and Harris Beath) were developed to fully identify the subtalar joint (2,3). However, these radiographs are currently rarely used. If both therapeutic decisions and prognostic information rely on Böhler's and Gissane angles, the radiographic measurements should be accurate (10−13). Inaccurate measurements could lead to inadequate treatment decisions and consequently to suboptimal outcomes and disability. Moreover, reliable radiographic measurements are required to be able to adequately compare research results. To what extent malposition of the foot influences these quantitative radiographic parameters is unknown.

The aims of this study were to evaluate the effect of craniocaudal and posteroanterior angular variation in 2-dimensional, lateral radiographs on both Böhler's angle and the Gissane's angle.

Methods

Fifteen AnubiFiX™ embalmed, human anatomic specimens of the leg (including at least 10 cm proximal from the knee) were used. All specimens were from persons with a known age of 18 years or older (mean 87 ± 9 years). Specimens were excluded if an osseous anomaly or a deformity affecting anatomy of the hindfoot was present. Specimens with visible scarring suggesting previous injury, with visible or known previous fractures in the hindfoot or midfoot or with prosthetic or fixation material in situ in the ankle, hindfoot, or midfoot, were excluded as well. Radiographs of the foot were made to exclude any osseous pathology of preexisting disease or trauma. Age, sex, side, and presence of evident preexistent (traumatic) injuries in the foot and/or ankle region were noted as demographic characteristics.

The embalming method AnubiFiX™ combines long-term high-quality embalming of human bodies with almost normal flexibility and plasticity. The body can be kept operational as long as conventionally embalmed human specimens (14). All measurements were performed in the anatomic dissection room at Erasmus MC (Department of Anatomy and Neurosciences).

Lateral Radiographs

The anatomic specimens were positioned on a radiolucent table resting on the lateral femur condyle, the lateral malleolus, and the lateral foot edge (metatarsal-phalangeal fifth articulation) and with the tibiotalar joint in plantigrade position. All radiographs were made using a C-arm (SIEMENS Arcadis Orbic 3D®; SIEMENS, Munich, Germany, manufactured November 2013, Model No. 08079233, Serial No. 7140) to obtain radiographs. The C-arm was positioned exactly perpendicular to the axis of the tibia. Radiographs were made in automatic mode by using 56 kV and 0.4 mA as exposure values. A series of freehand, lateral 2-dimensional radiographs were made by an experienced radiologic technologist (L.V.). The mediolateral projection was centered on the middle of the calcaneus, 3 cm caudal and 1 cm posterior of the medial malleolus. The true lateral radiograph or neutral position (i.e., 0° angular variation) had to meet the following criteria: (1) 90° dorsiflexion of the foot, (2) calcaneus depicted in its entirety, (3) lateral malleolus projected posteriorly of the medial malleolus, (4) an open projected subtalar joint, (5) no double contours in the posterior talocalcaneal facet, and (6) base of the fifth metatarsal depicted in profile. The position of the leg and/or C-arm was adapted until a perfect lateral view was available.

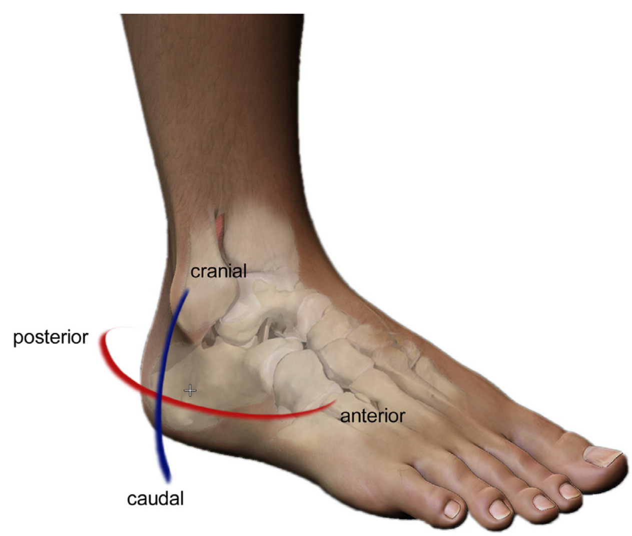

Fig. 2. Red line: posteroanterior angular variation in radiographic projections (anterior and posterior angular variation representing respectively internal and external rotation of the foot). Blue line: craniocaudal angular variation in radiographic projections (cranial and caudal angular variation representing respectively valgus and varus malposition of the foot).

With this image as a starting point, angular variations with 5° intervals were made from +30° to −30° deviation in a craniocaudal and posteroanterior direction (Fig. 2). Cranial and caudal angular variation represent, respectively, valgus and varus malposition of the foot. Variation in the anterior direction represents internal rotation and variaton in the posterior direction represents external rotation. Angular variations toward a posterior or cranial direction were given a connotation of "+"; variations toward the anterior and caudal direction were considered as "−."

Böhler's angle and Gissane's angle were measured in all radiographs independently by 2 trauma surgeons who are experienced in the surgical and nonoperative treatment of calcaneal fractures (D.D.H. and M.H.J.V.), with an open-source Digital Imaging and Communications in Medicine compliant viewer (RadiAnt DICOM Viewer 1.9.14; Medixant, Poznan, Poland). Angles were averaged between the observers, and the angular deviation from the neutral position (0°) was calculated for each radiograph, by dividing the observed measurement from the true lateral (neutral) radiograph. A negative deviation means a smaller observed angle pertaining to the true lateral; a positive deviation is a greater observed angle.

Analysis

Descriptive analysis was performed for each 5° angular variation radiograph. The mean Böhler's angle and Gissane's angle (as well as the calculated deviation) were determined with standard deviation, because all data were normally distributed (tested with a Shapiro-Wilk test). Figures were composed in GraphPad Prism 5 Software Inc.

Results

Twelve of the 15 specimens were from male donors. Eleven right feet and 4 left feet were used. An example of some radiographs with angular variations in the posteroanterior and craniocaudal direction are shown in the Supplemental Figure.

Böhler's angle deviated from the true lateral radiograph in both cranial and, most explicit, caudal directions (Fig. 3*A*). At increasing angular variation in the caudal direction, Böhler's angle decreased by a maximum of 4.3° at −30° deviation. From −15° on, the 95% confidence interval (CI) did not include 0°. With 95% CIs consistently spanning 0°, indicating no significant difference, Böhler's angle was only marginally affected by angular variation in the cranial direction (maximum 2.0°).

At +30° angular variation in the posterior direction, Böhler's angle increased from 0.3° at +10° to a maximum 5° increase (Fig. 3*B*). However, in the anterior direction (toward −30°), the maximum deviation was only marginal, 1.3°, and the 95% CI consistently contained 0°.

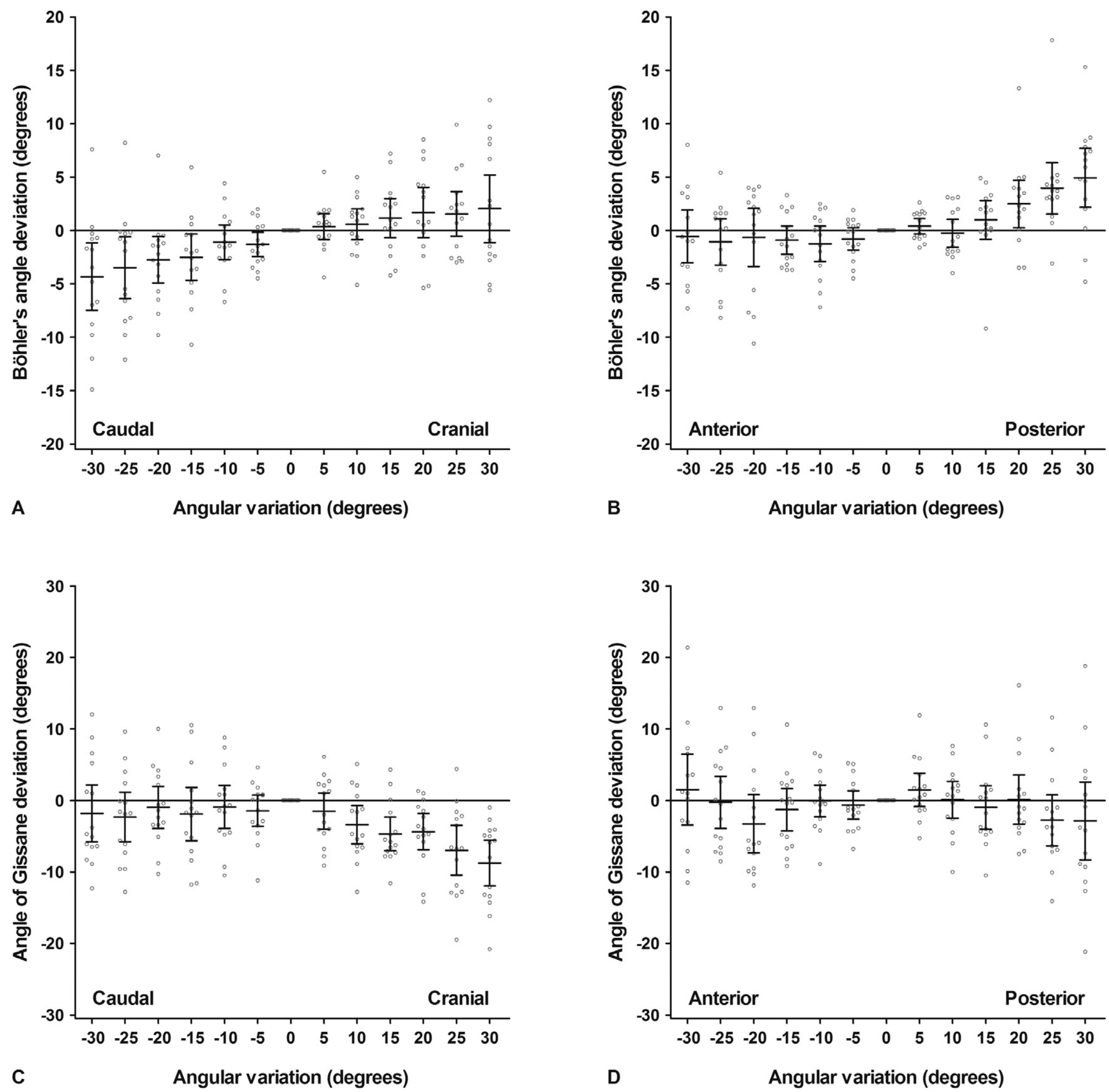

Fig. 3. Scatter dot plot and box-whiskers plot with mean and 95% confidence interval depicted. Averaged radiographic parameters with angular variation in the craniocaudal direction and posteroanterior direction. (*A*, *B*) Böhler's angles. (*C*, *D*) Gissane's angles.

In the craniocaudal direction, the deviation of Gissane's angle is most pronounced in the cranial direction (toward +30°), with the mean angle decreasing to −8.8° at +30° angular variation (Fig. 3*C*). Gissane's angle was hardly affected by deviation in the caudal direction (toward −30°); all 95% CIs spanned 0°.

Varying angular obliquity in the posteroanterior direction (Fig. 3*D*) did not evidently affect Gissane's angle, with a maximum decrease in Gissane's angle of 3.3° in the anterior direction and 2.9° in the posterior direction.

Discussion

Radiographic parameters (i.e., Böhler's angle and Gissane's angle) are both therapeutic as prognostic values in the preoperative and postoperative assessments. Surgeons should be aware that the accuracy of radiographs, and hence radiographic measurements, can be influenced by multiple factors. The aim of this study was to evaluate the effect of craniocaudal and posteroanterior angular variations from lateral radiographs on Böhler's angle and Gissane's angle. The data showed that Böhler's angle most explicitly decreased with increasing caudal angular variations and increased with increasing posterior angular variations. Gissane's angle decreased most pronounced with increasing cranial angular variation.

To our knowledge, only 1 study described the influence of obliquity on accuracy (15). The observed Böhler's angle reported by Gonzalez et al (15) deviated with a maximum of 7° (in the anterior direction; at 10° and 15° angular variation) of the perfect lateral image. This study showed similar results concerning observed Böhler's angles; Böhler's angle deviated a maximum of 5° from the true lateral radiograph. Gonzalez et al (15) reported a measurement error for Böhler's angle of 6°.

Furthermore, in their study, the orthopedic surgeons' ability to accurately measure Böhler's angle significantly decreased with increasing obliquity of the lateral radiograph (15). Both observers in this study also experienced more difficulty in finding anatomic landmarks, in particular for Gissane's angle, with increasing angular variations (mostly from 20° deviation onward), often because of double contours in the posterior talocalcaneal facet and overprojection of different osseous structures (e.g., sustentaculum tali). For example, visualization of the processus anterior calcanei is crucial to determine Böhler's angle, which could be difficult after increasing angular variation.

Despite the difference in angles after angular variations, all mean Böhler's angles were within Gonzalez et al's (15) measurement error of 6° (95% CI: −4° to 15°). To our knowledge, the measurement error of Gissane's angle has not been established in the literature.

In contrast to Gonzalez et al (15), we did not use metallic markers to mark the relevant anatomical structures. We tried to mimic the normal clinical situation as much as possible and such markers are not used in common clinical practice.

In daily practice at an emergency department, radiographs are produced with a conventional tube with a diverging radiation beam. This differs from a 3-dimensional C-arm–based imaging device, as used in this study, which produces an exact parallel radiation beam. Because the C-arm–based imaging device is a portable unit, applicability of results theoretically might be different for overhead or standing radiographs. Although a parallel beam produces more reliable images, it is unlikely that these differences influence the deviation in Böhler's and Gissane's angles with increasing angular obliquity from the true lateral radiograph.

Böhler's and Gissane's angles were measured in all radiographs independently by 2 trauma surgeons. Radiographs were not randomized before review; this is a limitation of this study. However, despite our appreciation of the limitations, potential bias is reduced as much as possible because radiographs were reviewed in multiple settings and several radiographs were reviewed repeatedly as controls and to prevent inconsistencies.

A methodologic strength of the current study is the use of 15 anatomic specimen to rule out anatomic variation as much as possible, whereas Gonzalez et al (15) used only 1 anatomic specimen. A total of 1680 radiographic measurements were obtained in all specimens by the 2 observers, more than double the amount of measurements that Gonzalez et al (15) reported.

In conclusion, in this study, inaccurate radiographs are simulated using standardized angular variations up to 30° from the true lateral radiograph. Böhler's angle decreased with increasing caudal and increased with increasing posterior angular variations. Gissane's angle decreased with increasing cranial angular variation. However, the error due to inaccuracy in clinical practice does not appear to be sufficient to influence reliable decision-making.

Supplementary Materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1053/j.jfas.2019.02.004.

References

1. Rammelt S, Zwipp H. Calcaneus fractures: facts, controversies and recent developments. Injury 2004;35:443–461.
2. Giachino AA, Uhthoff HK. Intra-articular fractures of the calcaneus. J Bone Joint Surg Am 1989;71:784–787.
3. Schepers T, Ginai AZ, Mulder PG, Patka P. Radiographic evaluation of calcaneal fractures: to measure or not to measure. Skeletal Radiol 2007;36:847–852.
4. Loucks C, Buckley R. Bohler's angle: correlation with outcome in displaced intra-articular calcaneal fractures. J Orthop Trauma 1999;13:554–555.
5. Shuler FD, Conti SF, Gruen GS, Abidi NA. Wound-healing risk factors after open reduction and internal fixation of calcaneal fractures: does correction of Bohler's angle alter outcomes? Orthop Clin North Am 2001;32:187–192. x.
6. Böhler L. Diagnosis, pathology and treatment of fractures of the os calcis. J Bone Joint Surg 1931:(13):75–89.
7. Knight JR, Gross EA, Bradley GH, Bay C, LoVecchio F. Boehler's angle and the critical angle of Gissane are of limited use in diagnosing calcaneus fractures in the ED. Am J Emerg Med 2006;24:423–427.
8. Essex-Lopresti P. The mechanism, reduction technique, and results in fractures of the os calcis. Br J Surg 1952;39:395–419.
9. Shereff MJ, Johnson KA. Radiographic anatomy of the hindfoot. Clin Orthop Relat Res 1983;177:16–22.
10. Bakker B, Halm JA, Van Lieshout EM, Schepers T. The fate of Bohler's angle in conservatively-treated displaced intra-articular calcaneal fractures. Int Orthop 2012;36:2495–2499.
11. Barla J, Buckley R, McCormack R, Pate G, Leighton R, Petrie D, Galpin R; Canadian Orthopaedic Trauma Society.. Displaced intraarticular calcaneal fractures: long-term outcome in women. Foot Ankle Int 2004;25:853–856.
12. Buckley RE. Evidence for the best treatment for displaced intra-articular calcaneal fractures. Acta Chir Orthop Traumatol Cech 2010;77:179–185.
13. Su Y, Chen W, Zhang T, Wu X, Wu Z, Zhang Y. Bohler's angle's role in assessing the injury severity and functional outcome of internal fixation for displaced intra-articular calcaneal fractures: a retrospective study. BMC Surg 2013;13:40.
14. Slieker JC, Theeuwes HP, van Rooijen GL, Lange JF, Kleinrensink GJ. Training in laparoscopic colorectal surgery: a new educational model using specially embalmed human anatomical specimen. Surg Endosc 2012;26:2189–2194.
15. Gonzalez TA, Ehrlichman LK, Macaulay AA, Gitajn IL, Toussaint RJ, Zurakowski D, Kwon JY. Determining measurement error for Bohler's angle and the effect of x-ray obliquity on accuracy. Foot Ankle Spec 2016;9:409–416.