Revisit of Broden’s View for Intraarticular Calcaneal Fracture

Dae Gyu Kwon, MD, Chin Youb Chung, MD*, Kyoung Min Lee, MD*, Tae Won Kim, MD*, Ki Hyuk Sung, MD*, Dae Ha Kim, MD†, Moon Seok Park, MD*

Department of Orthopaedic Surgery, Inha University Hospital, Incheon, *Department of Orthopaedic Surgery, Seoul National University Bundang Hospital, Seongnam, †Department of Orthopaedic Surgery, Seoul National University Hospital, Seoul, Korea

Background: This study was performed to investigate the relationship between coronal computed tomography (CT) and Broden’s view in terms of location of the fracture line and fracture pattern.

Methods: Forty-five feet of 45 patients with intraarticular calcaneal fractures were evaluated. The mean age of the patients was 46.3 years (standard deviation, 18.1; range, 15 to 80 years), and there were 34 men and 11 women. The Broden’s views were acquired using the ray sum projection, reviewed, and correlated with the coronal CT image to determine the location of the fracture on the posterior facet and fracture pattern described by the Sanders classification. The quantified location of the fracture line was defined as the distance between the medial margin of posterior facet and the fracture line divided by the whole length of the posterior facet, which was expressed as a percentage.

Results: The fracture line on the Broden’s view was positioned at 22.3% (standard deviation, 29.6) laterally compared to that on coronal CT (p < 0.01). Although all cases showed posterior facet involvement on the CT scan, the fracture line was positioned lateral to the posterior facet in 6 cases (13.3%) in the Broden’s view. The coronal CT and Broden’s view showed a low level of agreement in the fracture pattern according to the Sanders classification, with kappa values of 0.23.

Conclusions: Surgeons should consider that the fracture line on the Broden’s view shows positioning laterally compared to coronal CT and they should consider that the fracture line at the lateral to posterior facet on the Broden’s view might be an intraarticular fracture line. There are some limitations when applying the Sanders classification with the Broden’s view.

Keywords: Broden’s view, Calcaneal fracture, Computed tomography

A calcaneal fracture is the most common of all tarsal fractures comprising 1% to 2% of all fractures. A fracture of the calcaneus often results from high energy axial loading mechanisms. Displaced intraarticular fractures are associated with several architectural deformities, including a loss of calcaneal width, height, length, and incongruity of the posterior facet. These often result in some form of significant permanent functional disability, regardless of the treatment. Recently published, randomized control trials, comparing operative and nonoperative management, show slightly better outcomes in certain groups of patients treated operatively. In addition, restoration of the posterior subtalar facet might be one of the main predictors of the functional outcome.

It is important to clarify the fracture pattern for management decisions, which can be assessed by the axial, lateral radiography, and Broden’s views. The Broden’s views are used widely to assess the articular surface of a posterior facet, because they can demonstrate placement of a fracture, the degree of displacement, and step-off. However,
computed tomography (CT) has been shown to visualize the various fracture lines more accurately.\textsuperscript{9-20} Moreover, it is believed that CT scanning is the single most important advance in the treatment of calcaneal fractures,\textsuperscript{19} and is essential for preoperative planning.

Despite its accuracy, CT is not available intraoperatively and the diagnostic value of CT is decreased by artifacts from the metal used for fracture fixation postoperatively. Accordingly, the Broden’s views are often used to make an intraoperative and postoperative evaluation of the reduction and fixation of calcaneal fractures. Therefore, surgeons need to understand the relationship between the CT images and Broden’s view. Few studies have evaluated the relationship between CT and the Broden’s view for intraarticular calcaneal fracture. This study examined 2 components of the relationship between CT and Broden’s view: 1) location of the fracture line and 2) fracture pattern by the Sanders classification.

**METHODS**

This study was approved by the institutional review board at our institute. Informed consent was waived because of the retrospective nature of the study. The study inclusion criteria were consecutive patients who underwent a three-dimensional (3D) CT scan prior to open reduction and internal fixation at our institute. The exclusion criteria were fractures that did not include a posterior facet in the CT scan, and previous calcaneal surgery that might have altered the normal anatomy.

**Image Acquisition**

CT scans were acquired using a Philips Mx8000IDT unit (Philips Medical Korea, Seoul, Korea) at a thickness of 1 mm. Multidetector CT was performed and a 3D reconstruction including multiplanar reformation was carried out using Xelis ver. 1.0.2.2 (Infinitt, Seoul, Korea).

First, the ray sum projection in Xelis software was used to acquire the Broden’s views. The ray sum projection displays the sum of the pixel values from the CT data along the observer’s line of sight or ray projected through the calcaneus. The ray sum view is most analogous in appearance to the conventional radiographs,\textsuperscript{21-24} and Broden’s view was reconstructed from the CT scan (Fig. 1). In our pilot study, we tested the equivalency between the reconstructed Broden’s view of CT and the conventional Broden’s view of X-ray by correlating the quantitative location of the fracture line on both images for 12 patients whose conventional Broden’s views were available. To ensure reproducibility, each Broden’s view from the CT scans was acquired uniformly by internally rotating the foot approximately 30 degrees and the direction of the projector was nearly perpendicular to the intermalleolar line.

Second, a coronal image, which is the most frequently used image in the 2 most common intraarticular calcaneal classification systems,\textsuperscript{8,9,19} was acquired. The selected coronal image had the widest undersurface of the posterior facet of the talus.\textsuperscript{19}

**Consensus Building and Assessing Reliability**

Consensus building sessions were held before measuring the radiographs by 3 orthopedic surgeons with 10 (MSP), 8 (KML), and 7 (DGK) years of experience. The following measurements were taken. To assess the location of the fracture, the ratio of the total width of the posterior talar calcaneal articulation and the width to the first fracture line from the medial margin in posterior facet were measured in each image (Fig. 2). The ratio was expressed as a percentage, 0% and 100% indicates a medial margin fracture and a lateral margin fracture, respectively. Therefore,

**Fig. 1.** Xelis ver. 1.0.2.2 enables the user to simulate different positions of the model, and gain the ray sum projection, which is most analogous in appearance to conventional radiographs from three-dimensional computed tomography (3D-CT) scans. This function was used to acquire the Broden’s view. (A) After the ray sum projection to the foot and ankle model with an internal rotation of 30° was simulated, and an image similar to a conventional radiograph was gained. (B) The matched 3D-CT image is shown.
> 100% indicates an extraarticular fracture.

The Sanders classification, which is based on the number of articular fragments and the location of the fracture line, was used to assess the fracture pattern. The subclasses of the Sanders classification were not used in this study.

Following consensus building, reliability sessions were carried out before the main measurements. The interobserver reliability of the location of the fracture line and fracture pattern by the Sanders classification was calculated by the intraclass correlation coefficient (ICC) and kappa (κ) statistics, respectively, by the 3 observers (MSP, KML, and DGK). Four weeks later, one of the observers repeated the above radiographic assessments to determine the intraobserver reliability. Each examiner was blinded to the other measurements and patients’ data. The order of the measurements was assigned randomly to each observer.

Radiographic Measurements

A measurement by one of the authors (DGK) was used to show the relationship between the Broden’s view and CT scans. The location of the fracture line in the Broden’s view and fracture pattern between the Broden’s view and coronal CT image was compared.

Statistical Analysis

Prior sample size analysis was performed to determine the minimum number of patients required. Precision analysis was performed using the ICCs at a target value of 0.8 and a 95% confidence interval (CI) of 0.2, and the minimum sample size was estimated using a Bonett’s approximation. In this assumption, 36 feet were representative of the radiographic measurements (i.e., the cases were considered to be random factors) from a population.

The one-sided data was included to ensure statistical independence, even in bilateral calcaneal fractures. The selection was carried by block randomization. Data normality was tested using the Kolmogorov-Smirnov test. To test the equivalency between the reconstructed Broden’s view of CT and the conventional Broden’s view of X-ray, Pearson’s correlation coefficient was analyzed.

For reliability testing, ICC was used for continuous variables and kappa statistics for categorical variables. To determine the reliability of the location of the fracture line (continuous variable), the ICC and their 95% CIs were used to summarize the intra- and interobserver reliability, which were calculated in the setting of a 2-way random effect model, assuming a single measurement and absolute agreement. The kappa statistics were used to assess the intra- and interobserver reliability in the qualitative grouping (categorical variable), i.e., the Sanders classification.

A paired t-test was used to compare the location of the fracture line between the Broden’s view and CT scans, and the agreement between the Broden’s view and coronal CT image was assessed using kappa statistics. The classic interpretation of kappa statistics is as follows: 0.00 to 0.20, poor; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, substantial and 0.81 to 1.00, almost perfect agreement.

Statistical analyses were performed using SPSS ver. 15.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

The CT scans of 45 feet in 45 consecutive patients with intraarticular calcaneal fractures were evaluated. Five patients had bilateral calcaneal fractures, but only one side was included to ensure statistical independence. The mean age of the patients was 46.3 years (standard deviation [SD], 18.1; range, 15 to 80 years), and there were 34 men and 11 women.

In our pilot study, quantitative location of fracture line showed significant correlation between the reconstructed Broden’s view and the conventional Broden’s view.
For the reliability of fracture line measurement, both the Broden's view and CT image showed favorable reliability in terms of the ICC values (Table 1). However, the interobserver reliability of each rater for the fracture pattern by Sanders on coronal CT showed a kappa value ranging from 0.35 to 0.54, respectively. The interobserver reliability on the Broden's view showed a kappa value ranging from 0.16 to 0.53, respectively (Table 2). The intraobserver reliability of the coronal CT and Broden's view for the classification system showed a kappa value of 0.74 and 0.62, respectively.

In assessing the location of the fracture line, the mean position of the fracture line was 79.6% of the posterior facet in the Broden's view. On the other hand, in the coronal CT image, the fracture line was on 57.3% of the posterior facet. The fracture line on the Broden's view was positioned at 22.3% (SD, 29.6) laterally compared to that on coronal CT (p < 0.01). Although all cases showed posterior facet involvement in the CT scan, the fracture line appears to be positioned at the extraarticular portion in 6 cases (13.3%) in the Broden's view.

For the fracture pattern by the Sanders classification, on the Broden's view, there were 9, 26, 5, and 5 cases of Sanders type I, II, III, and IV, respectively. On coronal CT, there were one, 27, 10, and 7 cases of Sanders type I, II, III, and IV, respectively. The kappa statistics showed fair agreement for the Sanders classification with kappa values of 0.23 for the coronal CT and Broden's views.

**DISCUSSION**

The unique anatomy of the calcaneal posterior facet with its complex, oval shaped convex surface contributes to the difficulties of both a plain radiographic and CT image. The aim of this study was to determine what Broden's views express by comparing the CT images of an intraarticular calcaneal fracture. In the present study, the fracture line on the Broden's view was positioned laterally to compare the fracture line on the coronal CT image. There was low agreement for the Sanders classification between the coronal CT and Broden's views.

This study had some limitations. First, this study was a retrospective design. A prospective design would better minimize selection bias. However, comparison of some of the demographic data of the patients with the data reported in other publications suggests that the selection bias was low. In this study, the distribution of fractures between men (75.6%) and women (24.4%), as well as the peak of the fractures between those aged 28 and 64 years old, is consistent with the literature. Second, the accuracy and validity of the reconstructed Broden’s views are uncertain. However, previous studies explained that the projected image produced by the ray sum is the digital equivalent of an X-ray image generated from a volume of CT data. In addition, we tested the correlation of quantitative location between X-ray and the reconstructed image in our pilot study and the second image was found to be significantly correlated (r = 0.972, p < 0.001). Third, although the conventional Broden's view is obtained by projecting the beam through cephalad aiming 10, 20, 30, and 40 degrees, we utilized only one image for each patient. However, the image was the most optimum one by adjusting the 3D reconstructed image with rotating image tool.

In this study, the fracture line on the Broden’s view was positioned about 20% laterally to compare the fracture line on coronal CT. The reason was identified by the 3D-CT image, which showed that the posterior fracture lines were expressed more distinctly (Fig. 3). Although the fracture line of the posterior aspect could not substitute for that of the anterior or middle aspect, the greater part of the fracture of the posterior aspect extended from the

**Table 1. Intra- and Interobserver Reliability of the Fracture Line Measurement**

|                  | Intraobserver reliability | Interobserver reliability |
|------------------|--------------------------|--------------------------|
|                  | Broden view              | Coronal CT               |
| Intraclass       | 0.87                     | 0.88                     |
| Correlation      | 0.79-0.92                | 0.82-0.93                |
| Coefficient      |                          |                          |

**Table 2. Interobserver Reliability of Sanders Classification**

|                  | Kappa (p-value)           |
|------------------|---------------------------|
|                  | Interobserver reliability | Broden view | MSP vs. DGK | MSP vs. KML | DGK vs. KML |
| Broden view      | 0.529 (< 0.001)           | 0.526 (< 0.001) | 0.474 (< 0.001) |
| Coronal CT       | 0.538 (< 0.001)           | 0.353 (< 0.001) |               |

MSP, DGK, KML: 3 orthopedic surgeons.

$\chi^2 = 0.972, p < 0.001$. The mean location of fracture line on the reconstructed Broden’s view was 74.5% (SD, 29.4), and that on the conventional Broden’s view was 74.2% (SD, 29.5). Therefore, 2 images were assumed to be identical.

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anterior to posterior aspect. Therefore, the fracture line on the Broden’s view may represent the reduction status of the posterior facet. In this study, the fracture line was positioned at the articular margin or extraarticular portion on the Broden’s view in 13% of cases, even though the fracture line was positioned in the posterior facet on the coronal CT image. Therefore, surgeons should not neglect the fracture line at the lateral to posterior facet when they acquire the Broden’s view for an intraoperative evaluation, because it might be an intraarticular fracture line.

Similar to previous studies, there was moderate inter and intraobserver reliability for the Sanders classification. Although the Sanders classification has some degree of variability and inconsistency in its interpretation among users, it showed moderate agreement among users, indicating a useful classification. There was relatively low agreement in the Sanders classification between the coronal CT and Broden’s view with a kappa value of 0.23. Therefore, there was some difficulty in assessing the fracture pattern in the Broden’s view.

In conclusion, surgeons should consider that the fracture line on the intraoperative Broden’s view is positioned laterally compared to coronal CT. In some cases, the fracture line could not be found in the posterior facet in the Broden’s view when the fracture occurred in the lateral aspect of the posterior facet.

CONFLICT OF INTEREST
No potential conflict of interest relevant to this article was reported.

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