Measurement of Mid-Calcaneal Length on Plain Radiographs : Reliability of a New Method

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〈 Clinical Research 〉

Measurement of Mid-Calcaneal Length on Plain Radiographs

Reliability of a New Method

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Abstract: *The authors present a new method to reliably measure the length of the mid-portion of the calcaneus. The authors defined the "mid-calcaneal length" as the line connecting the high point of the convex arc of the posterior subtalar joint facet and the low point of the concave arc of the calcaneocuboid joint. Statistical analysis of 810 measurements taken by 6 observers confirmed high intraobserver reliability, interobserver reliability, and internal consistency (Cronbach coefficient α = .98) and low error rate (Pearson correlation coefficient = .0001). The authors have used this measurement as a tool to determine the change in calcaneal length after osteotomy lengthening procedures and present it as a tool for clinical practice and research.*

Level of Evidence: Diagnostic, Level III

Keywords: calcaneus; Evans; length

Gross changes in lateral column length can be interpreted by midfoot and hindfoot positional changes on standing x-ray. However, a method for fine measurement of calcaneal length on clinical radiographs has not yet been described. A reliable technique to measure calcaneal length before and after surgical lengthening of the lateral column is needed for both research and clinical practice. We propose a new method to assess change in mid-calcaneal length before and after lengthening osteotomy of the anterior and mid calcaneus.

A review of the literature produced minimal information on calcaneal length measurement. We found no existing radiographic method to quantify the amount of gain or loss in calcaneal length after mid-calcaneal osteotomy. Ari and Kafa[1] examined 160 calcanei excavated from an archeological site in Turkey. They selected 10 bony landmarks and measured lengths to determine whether a reliable ratio existed for overall length of the calcaneus. The observational study used digital photographs of unarticulated calcanei and applied digital measurements. They found that the maximum length of the calcaneus correlated to a statistically significant extent with the load arm length, or the distance between the most anterior point of the calcaneus and the most posterior point of the posterior articular facet. Although this measurement may be acceptable when measuring an unarticulated calcaneus in the laboratory, it is not applicable to measurement of plain radiographs or in clinical practice.

> "A new method [is proposed to measure] the "mid-calcaneal length" by measuring the line from the low point of the concave arc of the calcaneal–cuboid joint to the high point of the convex arc of the posterior facet on lateral plain films"

Sangeorzan et al[2] examined the effect of surgical calcaneal lengthening on several radiographic angles and relationships, including the length of the calcaneus. They measured the length of the calcaneus by using the longest anterior

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to posterior points on the calcaneus on a lateral view. Neither of these studies tested the reliability or validity of the measurement technique they used to determine the length of the calcaneus.

We propose a new method of measuring the "mid-calcaneal length" by measuring the line from the low point of the concave arc of the calcaneal–cuboid joint to the high point of the convex arc of the posterior facet on lateral plain films. In a previous investigation (P. Dayton, unpublished data), we noted this method to be useful and consistent. The purpose of this study is to determine if this measurement has acceptable intraobserver and interobserver reliability and acceptable internal consistency using standard weight-bearing clinical radiographs done at different times.

Methods

Fifteen patient radiographic records were randomly selected from thousands of files available at Trinity Regional Medical Center. Criteria for acceptable records to be included in the study were the following: 3 lateral weight-bearing foot/ankle radiographs taken within 2 to 15 weeks of each other, skeletal maturity of the subject, and absence of calcaneal or subtalar joint pathology. No attempt was made to select normal anatomic specimens other than omitting those that had evidence of trauma or surgery. Patients selected included a variety of foot types, including rectus, cavus, and pronated foot types. No attempt was made to select a particular foot type. Sidedness and sex of subject radiographs were not criteria for inclusion.

A total of 45 weight-bearing lateral films were selected (3 films each, from 15 separate patients). A technologist experienced in lower extremity weight-bearing views had taken all radiographs. Selected radiographs were de-identified, randomized, and each assigned a research number. Six observers were asked to participate in the investigation. Observers included 2 attending physicians, 3 residents of different postgraduate years, and 1 medical student. Observers were instructed to measure "the length of the line from the low point of the concave arc of the calcaneal–cuboid joint to the high point of the convex arc of the posterior facet" for each of the 45 radiographs (15 patients with 3 radiographs each) and record their results. A sample radiograph indicating proper landmarks was reviewed with each observer prior to measuring. Observers were then asked to perform measurement of the 45 lateral radiographs 2 additional times on separate occasions. Observers were blinded as to their initial measurements, and all observations were made in isolation. The same metric ruler was used for all measurements (see Figures 1 and 2).

Following recording and collection of all measurements, individual x-rays were re-identified, and radiographic measurements were grouped by patient. Data were evaluated using Statistical Analysis Software (SAS/STAT, SAS Institute Inc, Cary, NC) to determine reliability of the method and error rate.

Results

Six observers, all on different dates and at different times, recorded a total of 810 calcaneal length measurements. Three original weight-bearing lateral radiographs taken between 3 and 15 weeks apart for 15 patients were used for measurement. All patients were skeletally mature. Right or left side was not recorded. All measurements entered into the log by the observers were used in the calculations. No measurements were omitted.

Cronbach coefficient α (CCA) was calculated for raw and standardized data. CCA values were .98 for both data sets (Table 1). Six other data sets were run using different x-ray and observer variables. CCA remained high for all data sets at >.97 for all runs, confirming high consistency of the measurements. *P* value remained <.0001 for all data sets indicating low likelihood of error in the method (Tables 2 and 3).

Figure 1.

Illustration of the concept of using the midpoint of the concave arc of the calcaneocuboid joint and the midpoint of the convex arc of the most posterior aspect of the posterior subtalar facet.

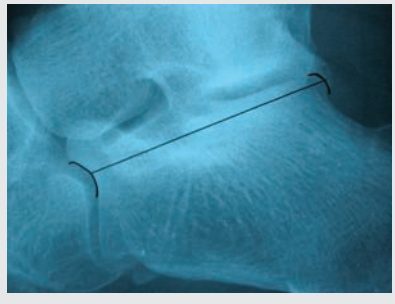

Figure 2.

Points for measurement marked on lateral x-ray view.

Discussion

When comparing techniques or procedures in an experimental design, reliable instruments are needed to measure the results. Results will be compromised if the measurement instrument is not reliable and consistent. A good measurement instrument will use standard technology, be intuitive to a variety of observers, use easily identifiable landmarks, and be reproducible.

Table 1.

Simple Statistics

Variable	N	Mean	Standard Deviation	Sum	Minimum	Maximum
Observer I	135	44.85185	3.10156	6055	40.00000	53.00000
Observer II	135	42.87407	3.47793	5788	37.00000	51.00000
Observer III	135	45.43704	3.56100	6134	37.00000	54.00000
Observer IV	135	43.94815	3.42362	5933	37.00000	52.00000
Observer V	135	44.02222	3.53757	5943	38.00000	52.00000
Observer VI	135	44.52593	3.53221	6011	39.00000	53.00000

Cronbach Coefficient α	
Variables	α
Raw	.978850
Standardized	.979336

Table 2.

Cronbach Coefficient α With Deleted Variable

Deleted Variable	Raw Variables		Standardized Variables	
	Correlation With Total	α	Correlation With Total	α
Observer I	.913896	.976542	.914613	.976830
Observer II	.947950	.972870	.948629	.973551
Observer III	.888937	.979039	.887922	.979379
Observer IV	.972615	.970439	.972581	.971220
Observer V	.955138	.972194	.955173	.972916
Observer VI	.904486	.977119	.904771	.977773

In a recent comparison study to determine the potential loss of length of the calcaneous following lengthening osteotomy, we had to develop a measurement instrument for our comparison. No appropriate techniques were available from the current techniques. We developed the "mid-calcaneal length" measurement for the study and undertook this work to test the reliability of the method.

This method of measurement uses standard weight-bearing radiographic views and requires no special equipment. The intraradiograph consistency was very good, indicating that if standard radiographic views are used, the small variations expected between each study should not affect the validity of the measurement.

We chose landmarks we considered to be easily identified and intuitive. The proximal landmark was the midpoint of the arc of the most posterior aspect of the subtalar joint posterior facet. Finding the midpoint of a small arc is quite easy for most observers. The posterior facet, although inconsistent in shape, is constant in position. In the situation of posterior facet fusion, arthritis, or significant trauma, this measurement may not be possible, especially if the contour of the posterior most surface of the facet is lost. The anterior landmark was the lowest point of the concave arc of the calcaneous at the calcaneal–cuboid joint. Again this point was easily identified and intuitive to the observers. Slight variations in radiographic position did not affect the ability to identify this point.

Our results and analysis show that this method is consistent between observers (CCA = .98; $P < .0001$). It is also consistent and reproducible for the same observer on different days.

One shortfall of this technique is that it does not include the posterior calcaneous or landmarks farther forward on the lateral column. Therefore, this method cannot be used to measure changes is the posterior body length. Additionally, it will not be useful in measuring the overall lateral column length for such procedures at distraction arthrodesis of the calcaneal–cuboid joint. This method is most applicable to anterior and mid calcaneal osteotomy changes. The focused area of measurement is a benefit as it limits variability inherent in larger anatomic spans that cross joints. The fact that no joints are crossed and a short span is measured may be the reason for the excellent reproducibility we noted.

Conclusion

A new method of measuring mid-calcaneal length is presented. This technique was found to be reliable and reproducible when performed by a variety of observers. This method will be useful for clinical research and comparison of procedures that alter

Table 3.

The CORR Procedure: Pearson Correlation Coefficients, N = 45[a]

	Observer I	Observer II	Observer III	Observer IV	Observer V	Observer IV
Observer I	1.00000	.90706, $P < .0001$	0.79316, $P < .0001$	.91501, $P < .0001$	.89938, $P < .0001$	.86022, $P < .0001$
Observer II	.090706, $P < .0001$	1.00000	.85687, $P < .0001$	.094339, $P < .0001$	.93106, $P < .0001$	.87216, $P < .0001$
Observer III	.79316, $P < .0001$	.85687, $P < .0001$	1.00000	.90396, $P < .0001$	.088353, $P < .0001$	.82959, $P < .0001$
Observer IV	.91501, $P < .0001$	.94339, $P < .0001$	.90396, $P < .0001$	1.00000	.94597, $P < .0001$	.89674, $P < .0001$
Observer V	.89938, $P < .0001$	.93106, $P < .0001$	.88353, $P < .0001$	.94597, $P < .0001$	1.00000	.87652, $P < .0001$
Observer VI	.86022, $P < .0001$	.87216, $P < .0001$	.82959, $P < .0001$	.89674, $P < .0001$	.87652, $P < .0001$	1.00000

[a]Prob > | r | under HO: Rho = 0.

the length of the mid-portion of the calcaneus.

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