FOOT & ANKLE INTERNATIONAL

Angular Measurements in the Evaluation of Hallux Valgus Deformities: A Report of the Ad Hoc Committee of the American Orthopædic Foot & Ankle Society on Angular Measurements

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This ad hoc committee was appointed to evaluate the methods of measurement in quantitating pre- and post-operative hallux valgus angles and make recommendations. The previous AOFAS research committee report had also done this in 1984.[37]

The most commonly used angular measurements to assess the severity of a pre-operative hallux valgus deformity and the magnitude of the postoperative correction are the hallux valgus angle and the 1-2 intermetatarsal angle. The use of these quantitative angular measurements in assessing hallux valgus deformities is based upon the belief that they are reliable, repeatable, and provide a constant value for comparison of different studies.[33] While it has been demonstrated that both of these angles can be reliably measured from both an intra-observer and inter-observer standpoint,[9,33] there is considerable evidence that these angular measurements are obtained and reported in an inconsistent fashion.

In evaluating published reports on hallux valgus correction, the information on angular measurements presented is variable. In few instances, a precise description as well as a consistent diagram and/or representative radiograph is presented,[6,7,8] but generally there are either no recorded measurements,[2,5,10,11,17,18,19,20,21] marked discrepancies[14,16,20,26,29] or inconsistencies.[1,12,15,25,36,38,39]

Schneider and Knahr[34] reported two different methods of determining angular measurements based on distinctly different reference points:

1. a longitudinal axis of the first metatarsal using mid-diaphyseal reference points, and
2. a center-head technique using a center head (or center of the articular surface) and center-base (or center of the proximal diaphysis) as reference points.

There is substantial variability reported in the resultant postoperative axes in this study using these reference points. The measured correction of the hallux valgus angle and the 1-2 intermetatarsal angle both varied approximately 9° with the different measurement techniques on identical radiographs, differences which were determined solely on the placement of the reference points (Fig. 1 a, b, c).[34]

One specific method of measuring the hallux valgus angle was reported by Smith et al[37] using mid-longitudinal axes of the first metatarsal and hallucial proximal phalanx, each axis bisecting the respective diaphyseal region. No specific reference points were recommended. For the 1-2 intermetatarsal angle, the AOFAS committee referenced five distinct measurement methods reported in the literature,[4,13,28,29] but recommended longitudinal axes bisecting the shafts of the first and second metatarsals as proposed by Hardy and Clapham.[13] No specific reference points were recommended.

Smith et al[37] also recognized that the intermetatarsal angle does not change substantially following a distal metatarsal osteotomy, but recommended using a reference point in the center of the first metatarsal head (center-of-head) for both preoperative and postoperative radiographs. They recognized that a center-of-head technique may spuriously demonstrate a reduction of the intermetatarsal angle following a substantial resection of the medial eminence and recommended in the postoperative radiograph that the reference point be located an identical distance from the first metatarsal lateral cortex to avoid this problem. Other than this point, no other reference points were specifically defined for any of the axes.

The published recommendations of this committee[37] have not been uniformly utilized by all reports on hallux valgus surgery. Our objective was to define the location of reference points as this is the key to the drawing of

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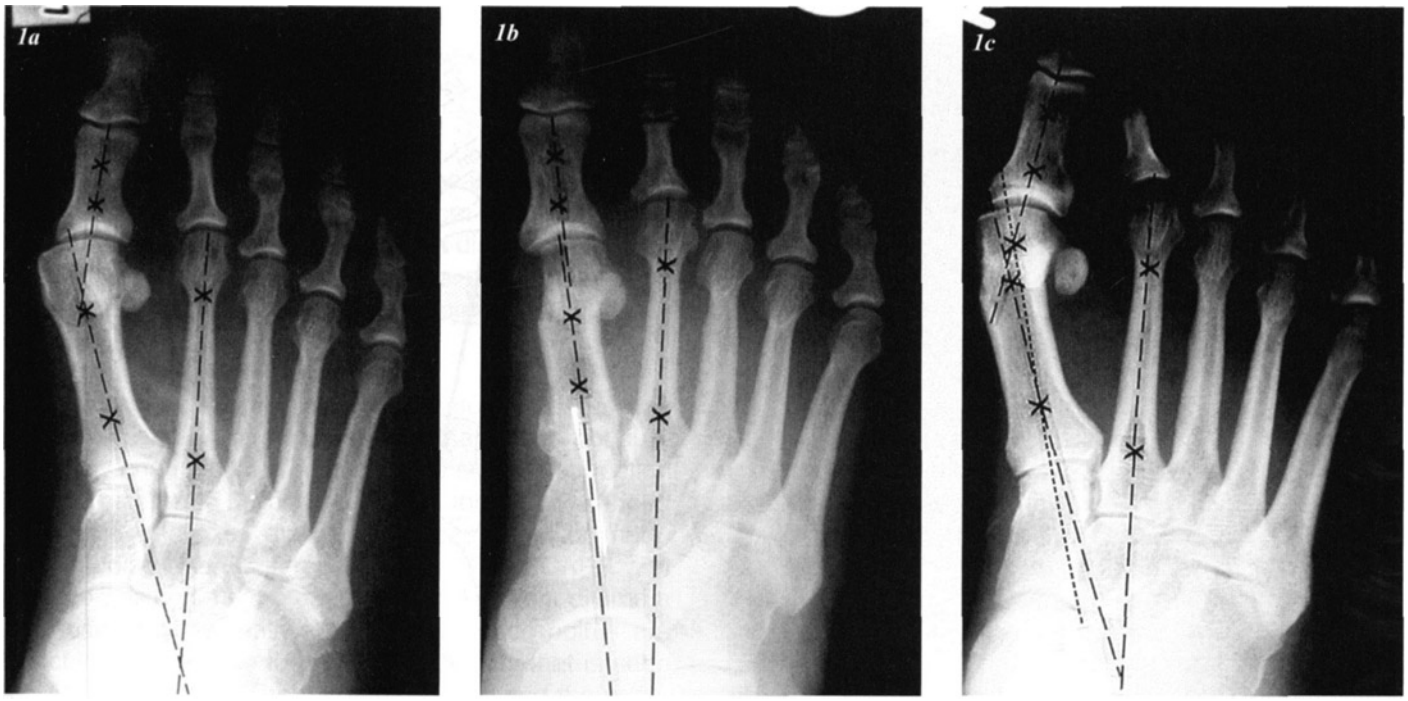


Fig. 1a: Preoperative radiograph demonstrating moderate hallux valgus deformity. (Using metaphyseal/diaphyseal references points, the hallux valgus angle equals 25°, intermetatarsal angle equals 19°.) The patient had identical bilateral deformities.

Fig. 1b: Postoperative radiograph following distal soft tissue repair with proximal first metatarsal osteotomy. The hallux valgus angle equals 2° and the intermetatarsal angle equals 9°.

Fig. 1c: Postoperative radiograph of left foot. (This has been reversed so that 1a, 1b and 1c can be compared.) Using metaphyseal/diaphyseal technique of measurement, the hallux valgus angle equals 27°, the intermetatarsal angle equals 19°. Using the center-of-head technique, the hallux valgus angle equals 22°, the intermetatarsal angle equals 13°. The difference in these measurement techniques re-enforces the point that in the case of 1b an acceptable realignment has been achieved. With 1c, the deformity is actually worse (as judged by sesamoid subluxation as well as the metaphyseal/diaphyseal measurements) yet with the center-of-head measurements, one would infer that the result is a slight improvement over the preoperative radiograph (Fig. 1a).

all resultant axes. The easier the reference point is to define, the more reliable the resultant axes.

METHODS

A large cross-section of preoperative radiographs with hallux valgus deformities and postoperative radiographs following surgical correction of the bunion were evaluated. These included distal osteotomies (Chevron, Kramer, SCARF), excisional arthroplasties (Keller procedure), proximal osteotomies, rheumatoid foot reconstructions, and postoperative hallux varus deformities. Radiographs in which lesser metatarsal osteotomies or metatarsal head excisions had been performed were also assessed.

We wished to determine whether a linear measurement technique rather than angular measurements might be feasible as Resch et al[31] had concluded. A linear measurement using the medial border of the second metatarsal and measuring the distance to the medial border of the first metatarsal would quantitate the narrowing of the medial aspect of the foot with the hallux valgus correction, taking into account the medial eminence resection as well as translation of the metatarsal head. Because of the problems of radiographic magnification or different patient foot sizes, linear measurement requires a constant reference value on the radiograph to normalize the value to allow meaningful comparisons. The length of the second metatarsal (or another lesser metatarsal) was a logical reference choice. However, this requires a measurement of the second metatarsal from the distal articular surface to the proximal articular surface. Following a rheumatoid foot repair with lesser metatarsal head excisions or following lesser metatarsal osteotomies, the distal end point is lost. It was therefore concluded that a linear measurement could not be reliably applied across the spectrum of surgeries currently performed for forefoot disorders.

It has been recommended that the center of the articular surfaces be used as reference points to determine axes.[34] Poor intra- and inter-observer reliability has

Fig. 2: All reference points should be located on a transverse line perpendicular to the longitudinal axis at a point equidistant from the outer border of the medial and lateral cortices of the respective bone.

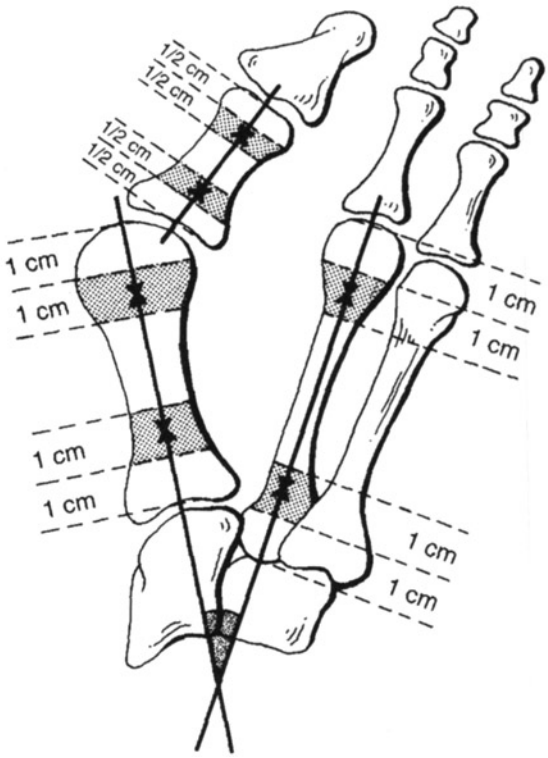


Fig. 3: The location of the reference points for the first and second metatarsals are between 1 and 2 cm from the distal articular surface and the proximal articular surface of each metatarsal. Because of the shorter length of the hallux, reference points are placed between 1/2 and 1 cm from the proximal and distal articular surface of the proximal phalanx.

been demonstrated in estimating the articular surface of the distal metatarsal articular surface.[9,40] The proximal first metatarsal articular surface is also easily misinterpreted on radiographic examination.[3] The proximal metatarsal articular surface is obliterated following a first metatarsal-tarsal fusion, and the distal metatarsal articular surface is obliterated following a metatarsophalangeal joint fusion. Using the articular surface of the proximal second metatarsal as a reference point is also unreliable as often a substantial portion of this area is obscured. Thus, the use of the articular surfaces as reference points was felt to be unreliable.

Reference Points

All reference points (first metatarsal, second metatarsal, hallucial proximal phalanx) should be located on a transverse line perpendicular to the longitudinal axis at a point equidistant from the outer border of the medial and lateral cortices of the respective bone (Fig. 2).

Second Metatarsal Reference Points

We concluded for the second metatarsal that metaphyseal/diaphyseal reference points were preferable. This avoids the distal region, where there may have been a metatarsal head excision or osteotomy. It eliminates the proximal region which, as noted above, is unreliable. We recommend that the metaphyseal/diaphyseal reference points be placed 1-2 cm proximal to the distal articular surface and 1-2 cm distal to the proximal articular surface. The 1 cm (between 1 and 2 cm) range allows for various sized feet. In general the reference point is ideally placed as close to the diaphysis as possible (Fig. 3).

First Toe, Proximal Phalanx Reference Points

The proximal phalanx is substantially shorter, which leaves more room for error in angular measurements. Metaphyseal/diaphyseal reference points 1/2 to 1 cm. proximal or distal to the articular surface are recommended. In general, the reference points are ideally placed as close to the diaphysis as possible. On occasion, recommendations must be modified (i.e., for a short proximal phalanx, following a surgically shortened phalanx after a Keller procedure) (Fig. 4b) or with a very small foot (Fig. 4a). Authors must use recommended reference points when possible, and note modifications when they are necessary. There is no question that a phalangeal wedge osteotomy (Akin) distorts the proximal phalanx, but we accept the fact that it does help to

correct the hallux valgus angle. The reference points typically are proximal and distal to the osteotomy site (Fig. 4c).

First Metatarsal Reference Points

The reference points should be located in the metaphyseal/diaphyseal region, 1 to 2 cm proximal to the distal articular surface and 1 to 2 cm distal to the proximal articular surface. The reference points should be placed as close to the diaphysis as possible (Fig. 2).

Distal Metatarsal Osteotomies

Following distal first metatarsal osteotomies, the hallux valgus and intermetatarsal angles are often not substantially changed.[22,37] The measured angular correction is quite different[6,22,27] when comparing the center-of-head technique with axes drawn using diaphyseal or metaphyseal/diaphyseal reference points. The SCARF and Chevron osteotomies present a measurement dilemma because metaphyseal/diaphyseal reference points are difficult to locate due to the double density that is seen on AP radiographs. The metatarsal head and the proximal metatarsal metaphyses are clearly seen, however, and reference points are easily placed in these areas.

For a distal osteotomy we recommend reporting dual measurements using both a center-of-head technique and a metaphyseal/diaphyseal reference point. Dual measurements have been reported in the past[6,22,27] and allow comparison of proximal and distal osteotomies. There is very little variability in the preoperative radiograph when using either one of these methods, but there is a substantial difference that occurs in the use of these techniques postoperatively.[34]

It is recommended that the center-of-head technique be used (a line drawn from a reference point 1 to 2 cm distal to the metatarsocuneiform articular surface to a point representing the center of the metatarsal head), as well as the previously recommended metaphyseal/diaphyseal reference points for determining the first metatarsal axis thus giving two separate angular measurements.

The Mose sphere is a common geometric device which is used to define the center of cylindrical structures (femoral head). This can accurately place a reference point in the center of the first metatarsal head on the pre-operative radiograph (Fig. 5). This reference point is equidistant from the medial, distal, and lateral osseous surface of the metatarsal head.

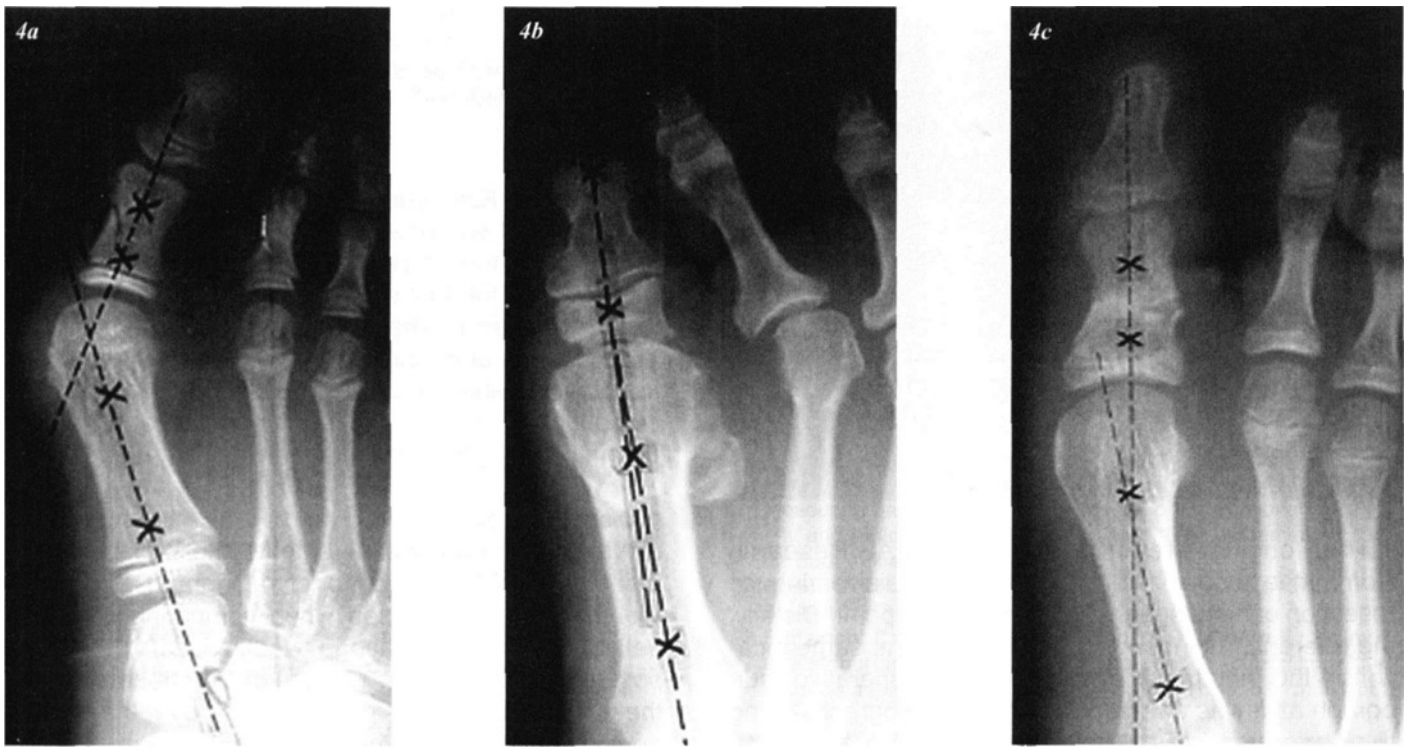
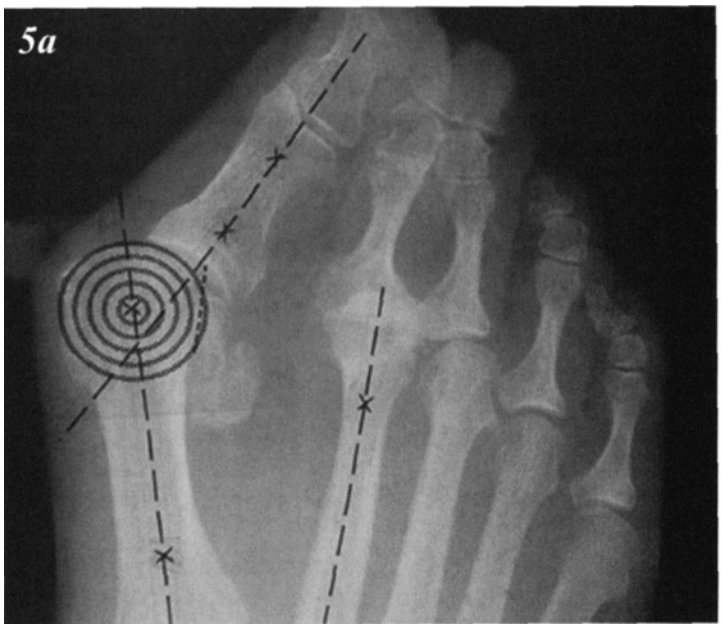
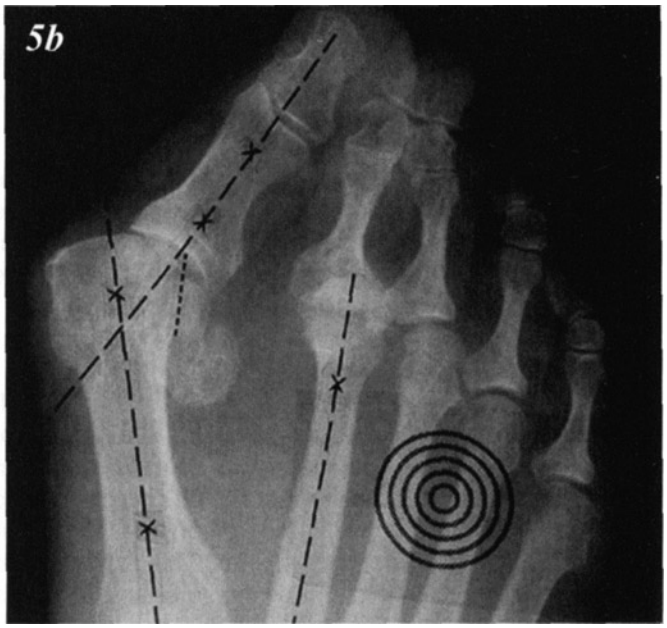


Fig. 4a: With a very small foot in this skeletally immature individual, these reference points barely fall within the suggested guidelines, but in some cases, small bones may require a modification in the location. **4b**: Following substantial excision of the proximal phalanx, the guidelines for the proximal phalanx cannot be closely followed. An example given of a modification that might be used in this situation. (All modifications should be described when they deviate from the recommended method.) **4c**: Following an Akin osteotomy, the proximal phalanx has been distorted, but reference points are easily placed following the described methods. Note that the reference points are proximal and distal to the osteotomy site.





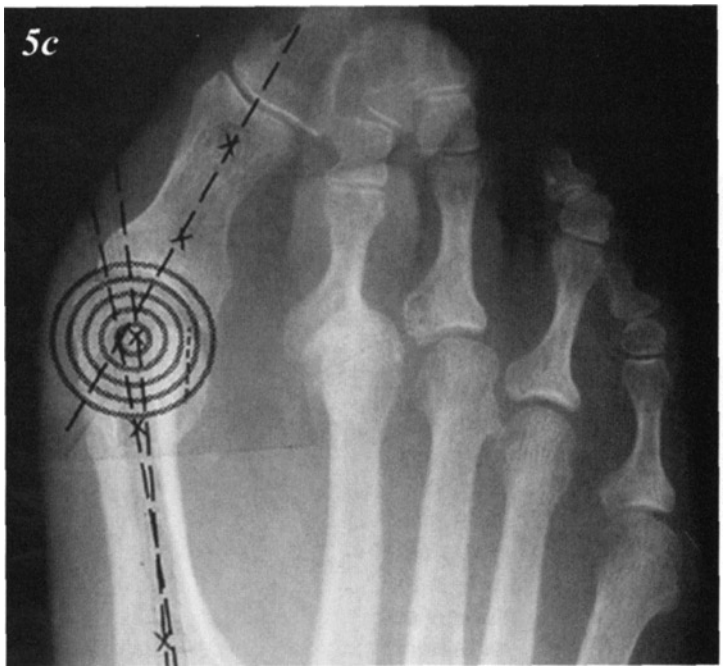


Fig. 5: (a) Preoperative hallux valgus deformity using Mose sphere to place reference point in the center of the metatarsal head. **(b)** Removal of template. Small dotted line marks the lateral border of the first metatarsal head. Preoperative hallux valgus angle equals 40°. **(c)** Following removal of template, one can see the two different axes that can be drawn using a similar proximal reference point and both a center-of-head and mid-diaphyseal reference point. Using center-of- head technique, the postoperative angle is 36° and using the metaphyseal/diaphyseal reference points, the postoperative angle is 38°.

The original report of the AOFAS Research Committee recognized that a larger medial eminence resection can change the distal reference point. Distally, the reference point should be placed in the same location in the metatarsal head on the post-operative radiograph as it was on the preoperative radiograph. Using this approach, the longitudinal axis of the first metatarsal should not be affected by the magnitude of the medial eminence resection. Postoperatively, a Mose sphere utilizes the distal articular surface and the lateral cortical surface of the metatarsal head to locate the distal reference point.

Standardized Radiographs

The patient should stand with the knees in full extension and with the medial borders of the feet adjacent. For a single foot, the foot should be pointed straight forward in neutral rotation. The X-ray tube should be positioned at a distance of 40 inches from the foot with the beam inclined cephalad 20° and centered at the level of the tarsometatarsal joint. If both feet are included in the radiograph, the beam is centered between the feet.

Measurement Devices

When performing measurements, the same measurement tool should be used for all radiographs. The same tool should also be used when comparing groups of patients or looking at change over time, as with pre- and postoperative analyses. The use of a protractor to make these measurements is recommended over the use of a goniometer, because a protractor has no estimated center of rotation and error is minimized by the use of a non-articulated device. With a goniometer, each "arm" is independently stamped thus introducing two systematic sources of error, whereas with a protractor, this process is only done once. Most protractors have 2° increments

whereas increments of goniometers vary from 2 to 5°. We therefore recommend the use of protractors for making angular measurements in the evaluation of hallux valgus deformities (Fig. 6).

SUMMARY OF RECOMMENDATION

This committee recommends that for all oral and written publications on hallux valgus deformities, the authors and presenters define the methods of measurement. We recommend that if authors need to deviate from the standardized methods described herein, the modifications in the measurement methods and rationale should be clearly described.

We recommend that second metatarsal reference points be placed 1 - 2 cm proximal to the distal articular surface and 1 - 2 cm distal to the proximal articular surface. We recommend that proximal phalanx reference points be placed 1/2 - 1 cm proximal and distal to the articular surface. We recommend that the first metatarsal reference points be located in the metaphyseal/diaphyseal region 1 - 2 cm proximal to the distal articular surface and 1 - 2 cm distal to the proximal articular surface.

For distal osteotomies, we recommend dual measurements using a center-of-head technique (using a Mose sphere and a standard protractor for the distal reference point) and metaphyseal/disphyseal reference points for the first metatarsal axis. The exact same proximal reference point is used regardless of the locatoin of the distal reference point.

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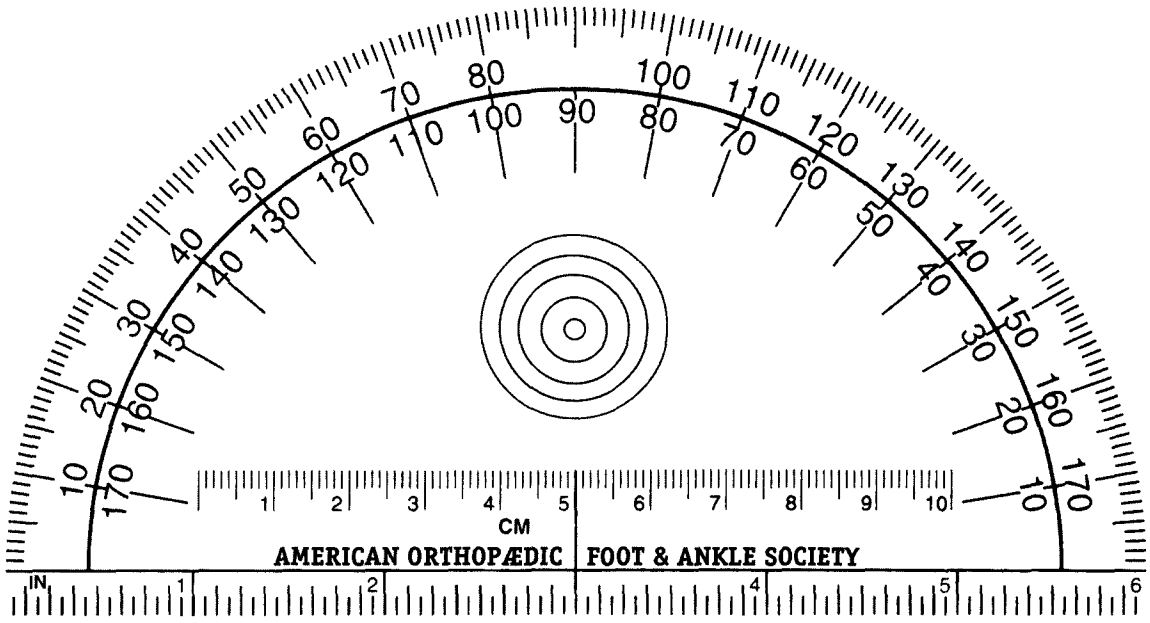

Fig. 6. A sample protractor. A protractor does not require an estimated center of rotation and eliminates a double source of error which can occur when the two arms of a goniometer are used. Furthermore, protractors typically have one-degree increments as opposed to larger scales on goniometers. A Mose sphere is located in the center of the protractor. This figure can be copied on to an acetate with the zoom function on a photocopier. It should be copied with a 1 to 1 resolution.