The Foot 20 (2010) 27–31

Contents lists available at ScienceDirect

The Foot

journal homepage: www.elsevier.com/locate/foot

Review

Radiographic measurements of hallux angles: A review of current techniques

Subodh Srivastava[a,b,*], N. Chockalingam[a], Tarek El Fakhri[b]

[a] Faculty of Health, Staffordshire University, Stoke on Trent ST4 2DF, United Kingdom
[b] Orthopaedics & Trauma Department, Mid Staffordshire NHS Foundation Trust, Stafford ST16 3SA, United Kingdom

ARTICLE INFO

Article history:
Received 26 October 2009
Accepted 10 December 2009

Keywords:
Radiographic angles
Hallux valgus
Computer methods

ABSTRACT

Background: Radiographic angles are commonly used in patients with hallux valgus deformity to assess the severity, plan surgery, assess outcome and compare results. Many different manual methods have been used, but are prone to error. More recently computer-assisted methods using software have become available.
Objective: To review the different methods that have been used to measure radiographic angles in hallux valgus.
Method: A general literature search using relevant key words was undertaken using databases such as Medline, Embase, Cinahl and Cochrane Library.
Review findings and discussion: The manual methods used are prone to errors. The reliability can be improved by using standardised radiographic technique and measurement technique using specific reference points. Computer-assisted methods using software, might improve reliability of measurements. Further studies are needed to assess if these methods are easy to use, and to compare different software's that are available. Specifically designed software for the foot might further improve the reliability of radiographic measurements in hallux valgus.

Contents

1. Background

Hallux valgus is a common deformity seen in foot and ankle practice and its aetiology is multifactorial. The wearing of constricting and high heel shoes are extrinsic factors, which are important in the development of hallux valgus [1,2]. Heredity is likely to be a major predisposing factor in some patients, with up to 68% of

Abbreviations: AOFAS, American orthopaedic foot and ankle society; DMAA, distal metatarsal articular angle; HVA, hallux valgus angle; IMA, intermetatarsal angle; IPA, interphalangeal angle; MTPJ, metatarsophalangeal joint.

* Corresponding author at: Westview, Newcastle Road, Loggerheads, Shropshire TF9 4PH, United Kingdom. Tel.: +44 7825179339.
E-mail address: subodhs64@googlemail.com (S. Srivastava).

0958-2592/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foot.2009.12.002

patients showing a familial tendency [3]. Hyper mobility of the first tarsometatarsal joint is thought by some to be a causative component in some cases of hallux valgus [4,5]. Anatomical factors such as increased varus of first metatarsal may contribute in some patients. Other causes include rheumatoid arthritis and disorders such as cerebral palsy.

The clinical presentation is related to symptoms of big toe as well as lesser toes. Mann et al. [6] have shown that 80% of patients present with restriction in wearing of shoes, 70% with pain over the medial eminence (bunion), 60% with cosmetic concerns and 40% with second toe problems such as clawing and pain under the second metatarsal head, corns and calluses [6].

Clinical assessment of the deformity is done by performing a systematic physical examination. The patient is examined standing and lying down, with all components of the deformity documented. The plantar aspect of the sole, lesser toe deformities, range of motion in the first metatarsophalangeal joint and presence of hyper mobility of the first ray are noted. Weight-bearing radiographs of the foot are used for radiological assessment of hallux valgus, plan surgery and compare results.

The treatment of Hallux valgus depends on clinical and radiological assessment of the deformity. Initial treatment is non-operative, and if patient has no relief in symptoms operative intervention is indicated.

2. Method

A general literature search using relevant key words was undertaken using databases such as Medline, Embase, Cinahl and Cochrane Library. All papers found which investigated radiographic measurements of angles in hallux valgus were reviewed. Key search words used were: hallux valgus, angles, radiographic measurements.

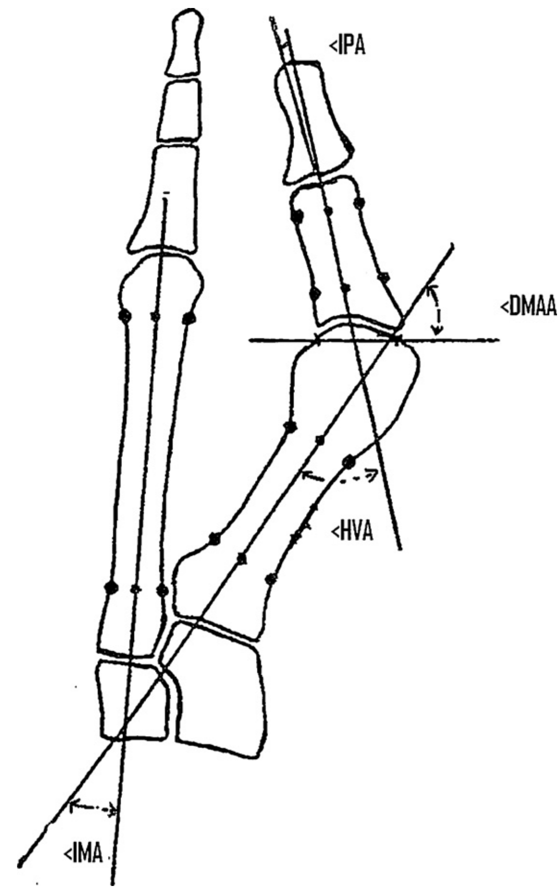

Fig. 1. Radiographic angles in hallux valgus.

3. Review findings

3.1. Role of radiographic angles in management of hallux valgus

Radiographic angles are frequently used by orthopaedic surgeons to make clinical decisions in patients with hallux valgus. Smith et al. [7] described the various radiographic measurements used in hallux valgus: hallux valgus angle (HVA), intermetatarsal angle (IMA), interphalangeal angle (IPA), distal metatarsal articular angle (DMAA), sesamoid position, arthritic changes in the first metatarsophalangeal joint, first metatarsal proximal articular surface angle, bunion soft tissue thickness and relative lengths of the first and second metatarsals.

These measurements help the surgeons in all aspects of management including:

- Classifying the deformity.
- Follow the progression of deformity.
- Operative decision making – various authors have described treatment algorithms [8–10].
- Assess the results of surgical treatment.

3.2. Manual measurements of radiographic angles

The commonly used angular measurements for hallux valgus in clinical practise are (Fig. 1):

- Hallux valgus angle (HVA) – angle between first and second metatarsal axis.
- Intermetatarsal angle (IMA) – angle between first and second metatarsal axis.
- Interphalangeal angle (IPA) – angle between the first metatarsal and proximal phalanx first toe axis.
- Distal metatarsal angle (DMAA) – angle between first metatarsal axis and distal articular surface of the first metatarsal.

These angles have traditionally been measured using manual technique. This involves use of marker pens and goniometer and identifying:

- The first metatarsal axis.
- The second metatarsal axis.
- The proximal phalanx first toe axis.
- The medial and lateral extent of the distal articular surface of the first metatarsal.

There are many studies that have shown poor inter- and intra-observer reliability with manual measurements of radiographic angles [11–15], especially measurements carried out after surgery. Such errors can be minimised in a clinical situation by using standardised technique of weight-bearing dorsoplantar radiographs and standardising the technique of angular measurements.

3.2.1. Standardised weight-bearing radiographs

The technique of weight-bearing dorsoplantar radiographs has been standardised by Smith et al. [7] in the report of the Research committee of AOFAS. The patient is weight bearing to document the maximum deformity in standing position. A 15° angulation of the X-ray tube toward the ankle compensates for the inclination of the medial metatarsals relative to the weight-bearing surface of the foot [16] and the X-ray beam is centered on the midfoot.

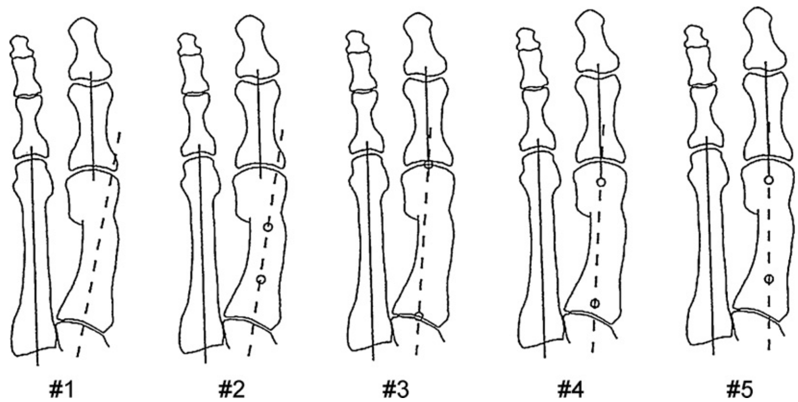

Fig. 2. The five different methods for drawing the axis of the first metatarsal [23].

3.2.2. Standardising measurement technique of radiographic angles – first metatarsal axis

The first metatarsal axis is key to measurement of three angles (HVA, IMA, DMAA). Different methods have been described to identify the first metatarsal axis (Fig. 2).

Method 1: A line is drawn through the long axis of the first metatarsal, as described by Hawkins et al. [17].

Method 2: A line is drawn to bisect the shaft of the metatarsal at two levels, with the points of bisection joined and the line extended, as described by Venning and Hardy [18].

Method 3: A line is drawn to connect the center of the articular surface of the metatarsal head and the center of the proximal articulation, as described by Mitchell et al. [19].

Method 4: A line is drawn from the center of the head of the first metatarsal head through the center of the base of the first metatarsal, as described by Miller [20].

Method 5: A line is drawn through the center of the head and the center of the proximal shaft, as described by Nestor et al. [21].

These methods to identify the axis can be summarised into three groups: mid-diaphyseal points distally and proximally, center of head and center of base points, and center of distal and proximal articular surfaces. Similar methods have been used to identify the axis of second metatarsal and proximal phalanx first toe.

Schneider et al. noted that the accuracy improved if manual measurements were done using specific guidelines to identify anatomic landmarks and reference points [22]. In another study Schneider et al. [23] evaluated the measurement accuracy of the five different methods described to define the longitudinal axis of the first metatarsal. They found the method described by Miller [20] to be the most precise method and least biased by post-operative effects.

3.2.3. Standardising measurement technique of radiographic angles – using reference points for first metatarsal, second metatarsal and proximal phalanx first toe

The different methods used do not describe the precise way of defining the axis or any specific reference points. Coughlin et al. [24] published a paper recommending the technique of defining reference points to identify the axis of the first metatarsal, as well as the second metatarsal and proximal phalanx first toe. This was the report of the ad hoc committee of the AOFAS on angular measurements. They postulated that reliability of measurement of radiographic angles could be improved by having reference points that can be easily defined and are repeatable.

They noted that reference points placed on articular surfaces are not very reliable and suggest that the reference point is placed as close as possible to the diaphysis. The midpoint on the transverse line joining the reference points proximally and distally is taken and joined to give the longitudinal axis (Fig. 3).

3.2.3.1. First metatarsal reference points. The reference points should 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. The 1 cm range allows for various sized feet.

3.2.3.2. Second metatarsal reference points. The reference points should 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.

3.2.3.3. First toe, proximal phalanx reference points. The proximal phalanx is substantially shorter, which leaves more room for errors in angular measurement. They recommended metaphyseal/diaphyseal reference points 1.5–1 cm proximal or distal to the articular surfaces. Similar points can be placed on the distal phalanx of first toe.

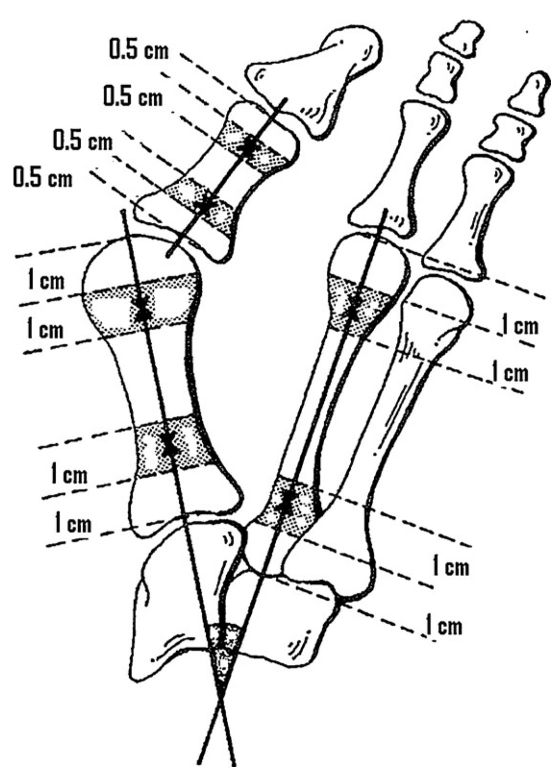

Fig. 3. The location of reference points for first metatarsal, second metatarsal and proximal phalanx as described by Coughlin et al. [24].

3.2.3.4. Technique for angular measurement after distal metatarsal osteotomy. Distal osteotomies such as the SCARF and Chevron osteotomies present measurement dilemma because metaphyseal/diaphyseal points are difficult to locate due to the double density that is seen on anteroposterior radiographs.

The metatarsal head and proximal metaphysis are clearly seen, however, and reference points should be placed in these areas. The center-head technique is used distally, to determine a point representing the center of the metatarsal head (Mose sphere is used for this). The proximal reference points are placed using the above mentioned metaphyseal/diaphyseal technique. A line is drawn from the point representing the center of the metatarsal head to the midpoint of the proximal reference points to give the longitudinal axis of the first metatarsal.

3.2.4. Technique for identifying distal articular surface of first metatarsal

The reference points are placed on the most medial and lateral extent of the distal articular surface of first metatarsal and a line is drawn joining the two points.

The most errors have been noted with measurement of the DMAA. Poor intra- and inter-observer reliability has been demonstrated in estimating the articular surface of the distal metatarsal articular surface, suggesting that there may be limited value in the DMAA as a clinical measure using conventional methods of measurement [14,25,26].

3.3. Computer-assisted measurement of radiographic angles

Recent technologic advances now allow the radiographs to be digitised, stored electronically and retrieved with a computer [27]. Computer software available creates opportunities for more reliable, quick and easy angular measurements, potentially reducing errors with manual measurement such as use of marker pens, difficulty in drawing lines and corrections, and errors in measuring angles with protractor.

Angular measurements of digitised images using computer software have been reported by various authors for angles in hallux valgus [28–30]. Most of the software available uses a generic digital protractor, which measures the desired angle. A specially designed software for the foot, using reference points to identify the metatarsal and phalangeal axis would offer more reliable measurements.

Chockalingam et al. [31] used specially designed software to measure and quantifying the magnitude of spinal curvature in scoliosis. This study demonstrated that the reliability improved when compared to manual methods. Such an approach could be employed to make an accurate and reliable measurement of hallux valgus angles to improve the effectiveness of clinical intervention.

4. Discussion

To summarise, radiographic angles are commonly used to assess severity of hallux valgus, in planning type of surgery, assessing outcome and to compare results.

Manually measuring the angles on weight-bearing radiographs of the foot is the traditional method. The use of these quantitative angular measurements is based upon the belief that they are reliable, repeatable and provides a constant value for comparison of different studies.

It has been demonstrated that inter- and intra-observer reliability is poor [11–15], especially with DMAA [14,25,26]. The errors can be reduced to some extent by using standardised X-ray technique [7,16] and having well defined guidelines in identifying anatomical landmarks and placing reference points to draw the axis for the first metatarsal, second metatarsal, proximal phalanx and distal phalanx of the big toe [22,24].

With the availability of digital workstations and software, computer-assisted measurement is now possible. Studies in the recent years suggest that computer-assisted methods can reduce the error in measurement of the angles in hallux valgus [28–30].

However, none of the reported studies have looked at all four angles or compared time taken between manual and computer-assisted methods.

The reliability of computer-assisted method could be further enhanced by using specially designed software that involves placing reference points on relevant bones in the foot and measuring the angles. Furthermore, studies are needed to compare the reliability of different software available to perform angular measurements.

Conflict of interest statement

There were no conflicts of interest, which would influence the writing of this paper.

Acknowledgements

This work was sponsored by the Mid Staffordshire NHS Foundation Trust. The sponsors had no involvement in the study design or in the writing of the manuscript.

References

[1] Lam SL, Hodgson AR. A comparison of foot forms among the non-shoe and shoe wearing Chinese population. J Bone Joint Surg (Am) 1958;40-A:1058–62.
[2] Kato S, Watanabe S. The etiology of hallux valgus in Japan. Clin Orthop 1981;157:78–81.
[3] Glynn MK, Dunlop JB, Fitzpatrick D. The Mitchell osteotomy for hallux valgus. J Bone Joint Surg (B) 1980;62-B:188–91.
[4] Klaue K, Hansen ST, Masquelet AC. Clinical, quantitative assessment of first metatarsal mobility in the sagittal plane and its relation to hallux valgus deformity. Foot Ankle Int 1994;15:9–13.
[5] Myerson MS, Badekas A. Hypermobility of the first ray. Foot Ankle Clin 2000;5:469–84.
[6] Mann RA, Rudicel S, Graves SC. Repair of hallux valgus with a distal soft tissue procedure and proximal metatarsal osteotomy: a long term followup. J Bone Joint Surg (Am) 1992;74-A:124–9.
[7] Smith RW, Reynolds JC, Stewart MJ. Hallux valgus assessment: report of research committee of American orthopaedic foot and ankle society. Foot and Ankle 1984;5:92–103.
[8] Mann RA, Coughlin MJ, editors. The video textbook of foot and ankle surgery. St. Louis: Medical Video Productions; 1991. p. 152.
[9] Coull R, Stephens MM. Operative decision making in hallux valgus. Curr Orthop 2002;16:180–6.
[10] Robinson AHN, Limbers JP. Modern concepts in the treatment of hallux valgus. J Bone Joint Surg (Br) 2005;87-B:1038–45.
[11] Saltzman CL, Brandser EA, Berbaum KS, et al. Reliability of standard foot radiographic measurements. Foot Ankle 1994;15:661–5.
[12] Resch S, Ryd L, Stenstorm A, Johnson K, Raynisson K. Measuring hallux valgus: a comparison of conventional radiography and clinical parameters with regard to measurement accuracy. Foot Ankle 1995;16:267–70.
[13] Schneider W, Knahr K. Metatarsophalangeal and intermetetarsal angle: different values and interpretation of postoperative results dependent on the technique of measurement. Foot Ankle 1998;19:532–6.
[14] Coughlin MJ, Freund E. The reliability of angular measurements in hallux valgus deformities. Foot Ankle 2001;22:369–79.
[15] Condon F, Kaliszer M, Conhyen D, et al. The first metatarsal angle in hallux valgus: an analysis of measurement reliability and the error involved. Foot Ankle 2002;22:717–21.
[16] Meschan I. Radiology of the normal foot. Semin Roentgenol 1970;5:327.
[17] Hawkins FB, Mitchell CL, Hedrick DW. Correction of hallux valgus by metatarsal osteotomy. J Bone Joint Surg (Am) 1945;27:387–94.
[18] Venning P, Hardy RH. Sources of error in the production and measurement of standard radiographs of the foot. Br J Radiol 1951;24:18–26.
[19] Mitchell CL, Fleming JL, Allen R, Glenney C, Sanford GA. Osteotomy-Bunionectomy for hallux valgus. J Bone Joint Surg (Am) 1958;40:41–60.
[20] Miller JW. Distal first metatarsal displacement osteotomy: its place in the schema of bunion surgery. J Bone Joint Surg (Am) 1974;56:923–31.
[21] Nestor BJ, Kitaoka HB, Ilstrup DM, Berquist TH, Bergman AD. Radiologic anatomy of painful bunionette. Foot Ankle 1990;11:6–11.

[22] Schneider W, Csepan R, Kasparek M, Pinggera O, Knahr K. Intra and inter-observer repeatability of radiographic measurements in hallux surgery. Acta Orthop Scand 2002;6:670–3.
[23] Schneider W, Csepan R, Knahr K. Reproducibility of the radiographic metatarsophalangeal angle in hallux valgus surgery. J Bone Joint Surg (Am) 2003;85:494–9.
[24] Coughlin MJ, Saltzman CL, Nunley JA. Angular measurements in the evaluation of halluxvalgus deformities: a report of the ad hoc committee of the American orthopaedic foot and ankle society on angular measurements. Foot Ankle 2002;23:68–74.
[25] Chi TD, Davitt J, Younger A, Holt S, Sangeorzan BJ. Intra- and inter-observer reliability of the distal metatarsal articular angle in hallux valgus. Foot Ankle 2002;22:722–6.
[26] Vittetoe D, Saltzman C, Krieg J, Brown T. Reliability and validity of distal metatarsal articular angle. Foot Ankle 1994;15:541–7.
[27] Tanaka Y, Takakura Y, Kumai T, Samoto N, Tamai S. Radiographic analysis of hallux valgus. A two-dimensional coordinate system. J Bone Joint Surg (Am) 1995;77:205–13.
[28] Panchbhavi VK, Trevino S. Comparison between manual and computer assisted measurements of hallux valgus parameters. Foot Ankle 2004;25: 709–11.
[29] Farber DC, DeOrio JK, Steel MW. Goniometric versus computerised angle measurement in assessing hallux valgus. Foot Ankle 2005;26:234–8.
[30] Piqué-Vidal C, Maled-Garcia I, Arabi-Moreno J, B-Stat JV. Radiographic angles in hallux valgus: differences between measurements made manually and with a computerised program. Foot Ankle 2006;27:175–80.
[31] Chockalingam N, Dangerfield PH, Giakas G, Cochrane T, Dorgan JC. Computer assisted Cobb measurement of scoliosis. Eur Spine J 2002;11:353–7.