Paul D. Dayton
Editor

Evidence-Based Bunion Surgery

A Critical Examination of Current and Emerging Concepts and Techniques

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Recurrence and Hallux Varus

7

Paul D. Dayton, Michael Dujela,
and Rachel Egdorf

Outcomes for HAV Surgery

Detailed search for studies specifically reporting outcomes for bunion correction reveals close to 185 manuscripts in the past 15 years. There are hundreds of additional presentations of techniques and unique perspectives on bunion surgery. A theme in the recent literature is higher than expected recurrence rates and much higher than expected patient-reported dissatisfaction especially when long-term outcomes are studied. An example of this trend is a recent long-term follow-up study comparing popular procedures. Chong et al. [16] reviewed the patient-reported and radiographic outcomes of 162 feet 5 years after undergoing either a scarf/Akin procedure (65%), chevron procedure (21%), Mitchell procedure (4%), Wilson procedure (5%), or Bunionectomy (5%). Recurrence occurred in 9.9%, and the striking finding is that 67% of the patients were still symptomatic and 25.9% of patients dissatisfied (based on MOXFQ) at the endpoint 5.2 years after surgery. They concluded that long-term results for hallux valgus surgery are much worse than short- and midterm outcomes as well as worse than they expected. Chen et al. [10] studied pain after hallux valgus surgery in 308 patients; 31% had residual pain 6 months after surgery. Seventy-one percent of all patients were pain-free by the 2-year postsurgical point; however satisfaction was only 82% for patients with pain at 6 months compared to 95% satisfaction in patients who had no pain. Chen et al. [11] in another patient series review found that a closer to normal tibial sesamoid position was a marker for improved functional results and satisfaction. They noted that in patients with a tibial sesamoid position less than IV, indicating a more complete deformity correction, there was higher patient satisfaction and associated better anatomic correction with better satisfaction. Fokter et al. [30] presented a long-term review and reported deterioration of satisfaction after the modified Mitchell procedure between midterm and long-term follow-up in the same patient population. They reported 64% good to excellent results at mean 21-year follow-up compared to 97% satisfaction at an 11-year mean in the same cohort. Results were based on both patient subjective findings and physician rating of final correction with 41% recurrence of bunion pain at the endpoint.

P.D. Dayton, DPM, MS, FACFAS (✉)
College of Podiatric Medicine and Surgery, Des Moines University, Des Moines, Iowa, USA

UnityPoint Clinic, Trinity Regional Medical Center, Fort Dodge, IA, USA
e-mail: daytonp@icloud.com

M. Dujela, DPM, FACFAS
Washington Orthopaedic Center, Centralia, WA, USA

R. Egdorf, BS
College of Podiatric Medicine & Surgery, Des Moines University, Des Moines, IA, USA

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The Effect of Bias on Reported Results

We are seeing more papers that indicate less than favorable patient-reported outcomes and higher than expected recurrence rates. Studies such as those noted above indicate poorer than expected outcomes and/or deterioration of satisfaction following HAV surgery. The interesting finding when reviewing these studies is not only the diversity of procedures but also the wide variation in methods used to evaluate clinical and radiographic outcomes. The lack of standardization of the measurement tools for patient-reported outcomes, clinical evaluation, and objective radiographic measurement makes study comparison difficult at best and systematic analysis impossible. This diversity of research methods makes it very difficult to compare results for individual procedures and to compare outcomes that allow us to draw accurate evidence-based conclusions. In some cases, poorly applied tools can result in severely biased or even incorrect conclusions. Schrier et al. [67] looked at patient-reported outcomes following HAV surgery and noted a wide variation in outcomes measurement tools. They reviewed the types of patient-reported outcomes measures (PROMs) in three categories: general quality of life, pain scale, and disease-specific outcomes measures. It is generally accepted that validated PROMs are more reliable than the physician-specific outcome scores. They further state that patient outcomes and expectations are only partially revealed by physician-based clinical outcome score examples of which would be the AOFAS and ACFAS foot scores. PROMs that are validated for use to measure outcomes in the foot following HAV surgery are the Medical Outcome Study Short Form (SF-36), Visual Analog Scale (VAS) for pain, the Manchester-Oxford Foot Questionnaire (MOXFQ), the Foot and Ankle Outcome Scores (FAOS), and Self-Reported Foot and Ankle Score (SEFAS). The AOFAS score which is the most commonly used for reporting HAV correction outcomes is not a validated PROM; therefore studies using this system are in reality reporting physician important rather than patient important outcomes data. As noted above studies that do not focus on patient perception of the outcome and instead focus on factors which are physician specific such as local examination findings mechanical findings and radiographic findings may not lead to the true answer as to whether the procedure is effective in achieving the patient's goals. The authors [67] noted that the poor patient satisfaction rates which occur in up to one third of cases are not always reflected in the outcomes parameters reported in the literature which lack uniformity and in some cases relevance to patient outcomes. Chopra et al. [15] presented a similar finding related to the inconsistency of physician-driven evaluation vs. PROM. They looked at gait function, ADL subscore of the FAAM, and the AOFAS forefoot subset. Although the preoperative gait alterations persisted postoperatively and the FAAM showed no improvement in functional status from the patient's perspective, the AOFAS subscale showed significant improvement. These studies suggest that we need to reevaluate and standardize or approach to measuring outcomes following corrective procedures so that we can gain a true understanding of the success and failure rates for varied procedures and methods based on the patient's perception.

Further complicating review of the existing literature is patient selection bias and radiographic reporting bias which are present in many published case series, both of which leave us with an incomplete understanding of the true surgical outcomes. Underreported recurrence in some cases is a product of measurement technique bias and in other cases may be due to collecting data at short-term follow-up. When looking at deformity recurrence, we must recognize a major methodology issue, which is the common practice of using dual measurements to assess preoperative and postoperative intermetatarsal angle (IMA), HVA, and TSP. Multiple researchers have noted the discrepancy between measurements following metatarsal osteotomy using the anatomic intermetatarsal angle (aIMA) before surgery and the mechanical intermetatarsal angle (mIMA) after surgery. In the normal state, the anatomic and mechanical axes of the first metatarsal are collinear, and therefore true anatomic correction of the first metatarsal requires alteration of the mid-diaphysis axis (aIMA) (Fig. 7.1). In other words, the deformity

Fig. 7.1 In the normal state, the first metatarsal is straight; therefore the anatomic axis of the first metatarsal (mid-diaphysis bisection) is collinear with the mechanical axis (center of MTPJ to center of TMTJ)

is not within the first metatarsal but is in fact a deviation of the entire metatarsal relative to the adjacent structures. Once the first metatarsal is cut and angulated or translated, as is common in many bunion surgeries, a new deformity is created and added to the original deviated metatarsal deformity. Measurement of the aIMA before the procedure and subsequent measurement of the mIMA postoperatively represent an unacceptable observation bias if one considers normal anatomy (Figs. 7.2 and 7.3).

Alteration of the reference points and axis lines for the first metatarsal from the aIMA preoperative to the mIMA postoperative overestimates the correction achieved for the first metatarsal. In fact, this practice hides the fact that a new deformity has been created while the original anatomic axis deviation persists. One could argue that the center of distal joint (MTPJ) to center of proximal joint (TMTJ) system should be used for both preoperative and postoperative measurements due to the ease of locating landmarks with this method. However, this represents the exact same bias of measurement as the dual measurement technique since in the normal first metatarsal, the anatomic axis and the mechanical axis are collinear (the bone is straight) and following an osteotomy the metatarsal is no longer straight. It is impossible to draw accurate conclusions regarding deformity correction using these two measurements in the now deformed metatarsal for the same reason as using dual measurements as noted above (Fig. 7.4).

When reviewing study results, it is vital for the reader to understand which measurement techniques were used and what the effect of measurement technique has on the values reported [66]. Coughlin et al. [20] discussed the observed differences in IMA reported based on measurement technique. They showed how this convention of dual measurements affects the validity of radiographic outcomes by overestimating the correction. Despite the recognition that dual measurements lead to inaccurate reporting, they recommended that center of head and center of base technique be used (i.e., mechanical axis) due to the difficulty in identifying landmarks in a metatarsal in which osteotomy has been performed. This recommendation builds bias and error into the method of measurement as noted above because in the normal condition, the mechanical and anatomic axes are collinear. Ravenell et al. [61] explored the unreliability of the intermetatarsal angle in choosing a hallux abducto valgus surgical procedure. Radiographs measured postoperatively in a variety of osteotomy procedures showed no difference in the amount of angular correction achieved regardless of the procedure chosen. They called into question the common convention on choosing procedures based on the severity of the angular measurements on AP radiographs and commented that using the IMA to select an appropriate procedure is not reliable. An interesting study looking at intra- and interrater reliability of IMA, HVA, and TSP, Saro et al. [65] added an additional five-point rating scale to assess the normality of the cosmetic appearance of the postoperative radiographs. Consistent with other similar measurement reliability studies, they showed good reliability for

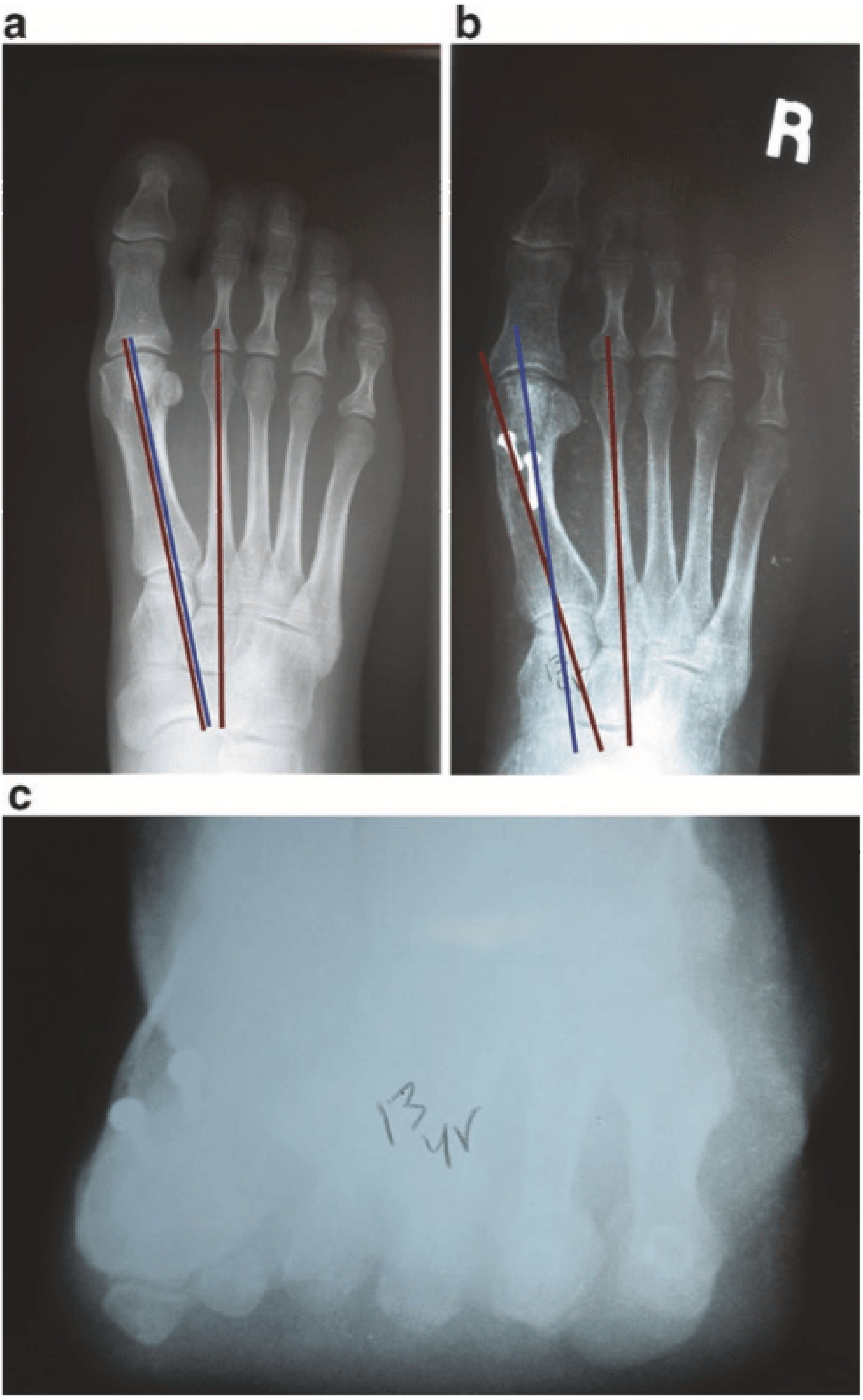

Fig. 7.2 (**a**) Preoperative AP radiograph showing the aIMA and mIMA in their normal collinear orientation. The IMA would be measured the same with both lines. (**b**) Post metatarsal osteotomy showing the mismatch of the mechanical and anatomic axes. The measurement of aIMA indicates increase in the reported IMA, while the mIMA suggests decrease of the reported IMA. There has been a severe new deformity created in the first metatarsal. Also note the residual AP signs of metatarsal frontal plane eversion and the corresponding axial view showing residual eversion of the metatarsal. (**c**) Rotation makes the sesamoids appear displaced from the metatarsal head on the AP, while they are in fact located medial and lateral to the crista. This is an additional bias of observation that causes misinterpretation and reporting of results

angular measurements of IMA using the center of head to center of base technique. However, there was poor consistency for the overall rating of cosmetic appearance of the foot. We think this highlights the bias introduced by using dual measurements, i.e., the measurements suggest correction is adequate but the agreement on the "normal" appearance of the foot is questionable (the foot did not look normal). Van Ho et al. [73] attempted to determine the most reliable way to measure IMA. Measurements made by bisecting the first shaft were compared to bisecting the head and base of the first metatarsal and measuring the angle from the tangent of the first and second metatarsal shaft from the medial or lateral aspect. Measurements were then compared to those made by a computer program using ten points on the medial and lateral aspects of the first and second

Fig. 7.3 A second case

a

b

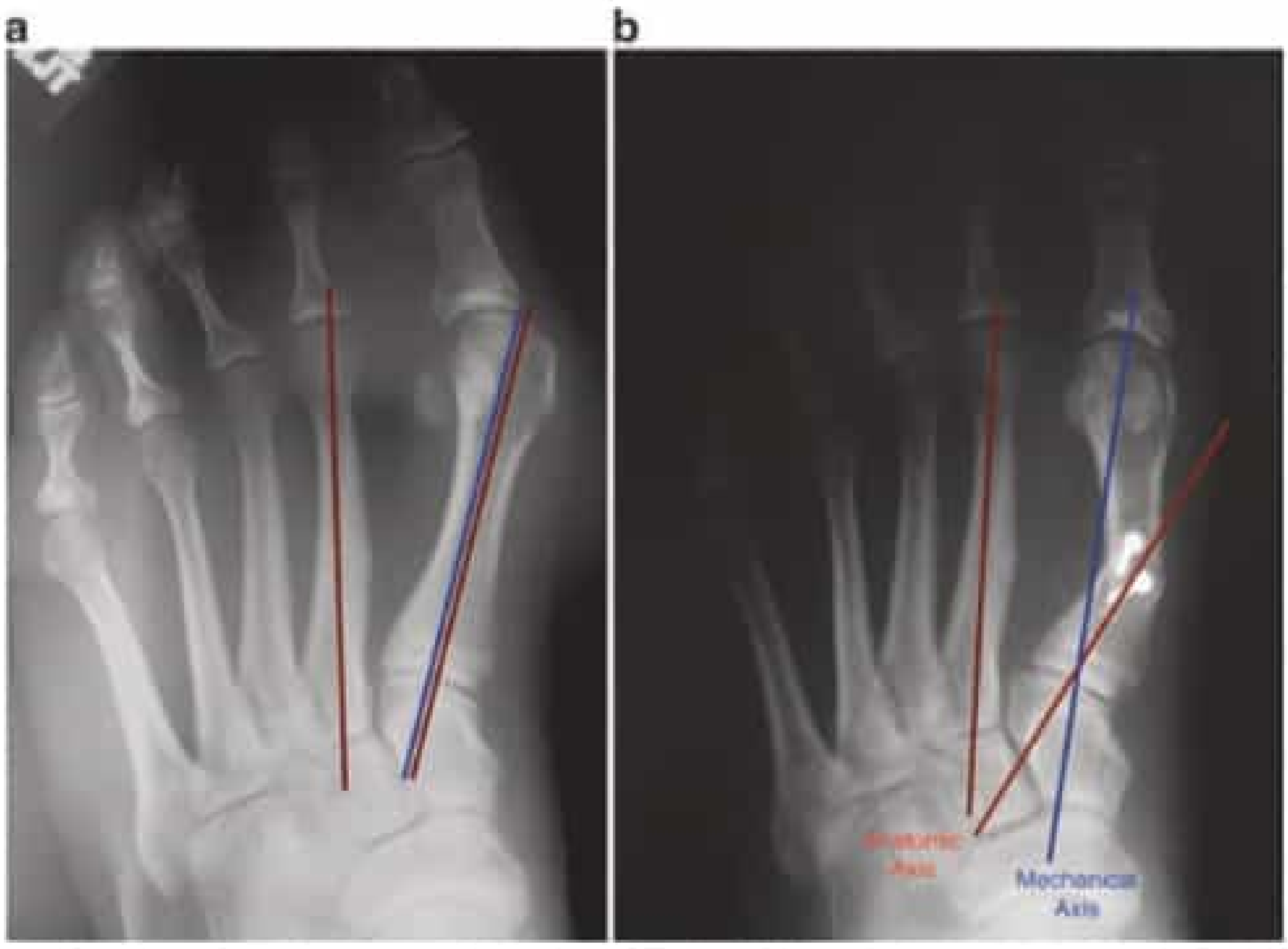

Fig. 7.3 A second case showing the mismatch of the axis's pre- (**a**) and post-operation (**b**) illustrating the reporting bias introduced by using dual measurements. Note the marked difference in the angular relationship when using mIMA vs. aIMA

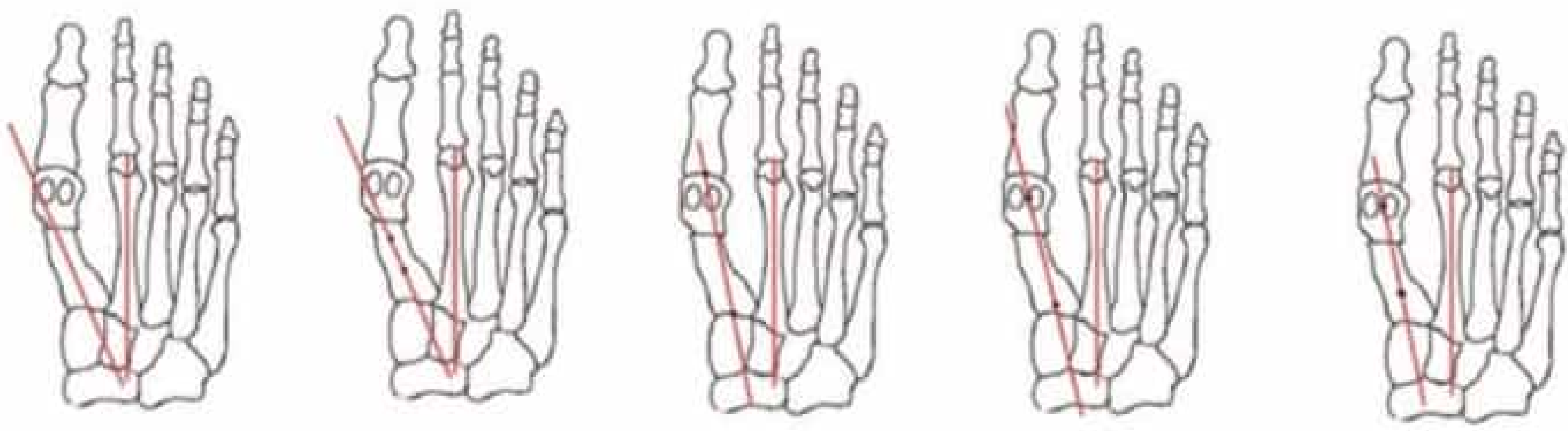

Fig. 7.4 Five different methods of first metatarsal axis as reported in the literature (Adapted from Schneider and Knahr). The two methods on the left measure using the longitudinal axis of the first metatarsal – the anatomic intermetatarsal angle (aIMA). The other three methods do not assess the anatomic axis of the metatarsal, rather they use a mechanical axis (mIMA) identified by the center of the metatarsal head or distal articular surface. In the normal state, the aIMA and the mIMA are collinear in the first metatarsal calling into question the use of mIMA

metatarsal. Bisecting the shaft had the smallest absolute mean (2.8%) which translates to the lowest amount of error of any of the computerized measurements. An example of the effect of using dual measurements on reported radiographic outcomes was presented by Akpinar et al. [5]. The authors analyzed the distal chevron osteotomy in 29 feet for proximal intermetatarsal divergence following corrective osteotomy which would indicate a medial deviation of the first metatarsal. Proximal intermetatarsal divergence was defined as an increase in postoperative aIMA or maximum intermetatarsal distance (MID). Patients with a mild deformity were noted to have a decrease in postoperative mIMA (10.91–7.00 mm); however the aIMA and MID actually increased by 11.8–13.55 mm and 17.97–20.60 mm, respectively. The mIMA for patients with severe deformity also decreased, and the postoperative aIMA showed very little change. This clearly shows the bias that exists when using dual measurements. In other words, even in patients where the separation of the first and second metatarsal proximal shafts increased, they could measure and report an artificial decrease in IMA using dual measurements.

To better understand the effect of dual measurements on outcomes reporting accuracy, we received IRB approval to assess the difference in measurement values when using the anatomic and mechanical axis of the first metatarsal for radiographic assessment of hallux valgus in patients that underwent a first metatarsal osteotomy at any level for correction of hallux valgus. Seventeen patients returned to our clinic for clinical evaluation and standard weight bearing AP and axial radiographs at a mean of 10.4 years post surgery. The hallux valgus angle (HVA), aIMA, and tibial sesamoid position (TSP) were measured pre- and postoperatively in a standard fashion. Additional postoperative measurements were made using the mIMA to study the difference in one to three IMA, HVA, and TSP difference between the two measurements. All preoperative measurements of IMA were made with the anatomic axis only as compared to the anatomic second metatarsal axis.

The mean aIMA using the mid-diaphysis bisection was 13.32 degree preoperatively and 13.58 degrees postoperatively. This is in contrast to a mean mIMA measured postoperatively of 3.72 degrees (sd2.76). The difference in postoperative measurements when using the dual measurements, anatomic axis (aIMA) and mechanical axes (mIMA), was significant for all measurements ($p < 0.005$). In contrast there was no significant difference between the preoperative aIMA when compared to the postoperative aIMA ($p = 0.984$). In other words the procedure did not correct the original deformity, but if using dual measurements, we could erroneously report an improvement. Additionally, using the mechanical axis postoperatively, we noted significantly lower mean values for HVA and TSP than those noted with the anatomic axis despite the anatomy being the same in both measurements. Although these improved postoperative measurements using the mechanical axis method may suggest better correction, the difference was erroneous and was based on alteration of axis placement and measurement technique, not improvement of anatomic alignment. The use of dual measurements can lead one to the conclusion that the true IMA, HVA, and TSP position have been corrected when in reality the original deformity is maintained, and new metatarsal deformities have been introduced (Fig. 7.5).

Fig. 7.5 Pre- and postoperative radiographs 4 years after metatarsal osteotomy. Before surgery the metatarsal is straight (anatomic axis collinear with mechanical axis). After surgery measuring angles with anatomic axis of the first metatarsal (*red line*), we see worsening of all of the angular relationships. If we use the mechanical axis (*blue line*), the angular relationships are reported as improved despite the fact the true anatomic position has worsened. Note despite an abnormal appearance of the sesamoids on the AP view, the axial position shows the sesamoids normally located medial and lateral to the metatarsal plantar crista showing the effect of metatarsal pronation on alignment (this is discussed in detail in Chap. 6)

Review of HAV Recurrence

When we separate studies that used dual measurements from those using aIMA, a more complete picture of the incidence of recurrence can be drawn. We reviewed all peer-reviewed published studies looking at bunion deformity correction at the time of writing this review and found deformity recurrence rates of between 4% and 73%. Those that reported measurements based on the aIMA both pre- and postoperatively were considered first and considered to provide the most accurate data on recurrence. Those who measured pre and post center of head and base (mIMA) or used dual measurements (first the aIMA and then the mIMA) were considered biased and are presented in the next section. A number of articles did not state the method used to measure the HVA or IMA, and they were omitted.

Studies Reporting Anatomic Axis Data

Shibuya et al. [68] compared feet that had first metatarsal osteotomies with ($n = 73$) and without ($n = 81$) an additional Akin procedure. Hallux abductus angles (HAA) were analyzed throughout this study. The HAA of the group that had the Akin procedure was significantly greater 6 months after surgery than the group that did not have Akins. The tibial sesamoid position was also significantly more laterally deviated in the Akin group when compared to their non-Akin peers. No difference in the revision rate was noted with 17.8% of the Akin group and 11.1% of the non-Akin group needing repeat surgery. Based on their results, the authors questioned the value of adding the additional hallux procedure. Bock et al. [8] reviewed 115 feet at 124 months that had undergone the scarf osteotomy procedure. ROM, VAS, HVA, IMA, DMAA, AOFAS, and sesamoid position were all significantly improved postoperative compared to preoperative. However, there was recurrence of 30% defined as an HVA of greater than 20° at final follow-up. The authors found correlations with recurrence to be higher HVA (preoperative and 6 weeks), higher IMA (6 weeks), sesamoid bone position, and DMAA. Iyer et al. [38] studied the proximal medial opening wedge (PMOW) osteotomy in 17 patients over an average 2.4-year follow-up. IMA improved at 6 weeks but deteriorated at final midterm follow-up. HVA also was noted to be improved at 6 weeks; however at the final midterm follow-up, the HVA was not significantly different from the preoperative value indicating a high degree of recurrence (64.7%). Interestingly the DMAA increased from 10.2 degrees to 13.6 degrees after surgery. Those patients who did have recurrence had higher HVA and DMAA preoperative scores compared to their colleagues who did not have recurrence. 23.5% of patients went on to have additional revision surgeries, and 35% had continued pain at the MTPJ at final follow-up. Fakoor et al. [28] compared the chevron, scarf, and McBride procedures in 44 feet. HVA was evaluated pre- and post-operation for each surgical group. The postoperative HVA of correction for both the chevron (16.7 degrees) and scarf (18 degrees) procedures was significantly different from the McBride (11 degrees) procedure but not from each other. The IMA of correction for the chevron (4.5 degrees) and scarf (6.3 degrees) was also significantly different from the McBride (2.6 degrees) procedure but not from each other. Osteotomy procedures had significantly better radiological outcomes than the McBride procedure. Recurrence was defined as any deformity reformation and occurred in 0% of scarf, 13% of chevron, and 27% of McBride patients. Pentikainen et al. [58] analyzed radiographic results of 100 feet at 6 weeks, 6 months, 1 year, and an average of 7.9 years (range 5.8–9.4 years) after distal chevron surgery to determine factors associated with hallux valgus recurrence. Recurrence in this study was determined to be an HVA of greater than 15 degrees and was seen in 73%. The mean HVA of patients who had recurrence was 28 degrees, and the IMA was significantly greater than in those who did not have recurrence. Every patient who had an HVA of greater than 30 degrees during the preoperative X-rays had recurrence. Along with the HVA, the position of the sesamoids, DMAA, congruence, and IMA all significantly affected recurrence rates.

Choi et al. [12, 13] reviewed 24-month follow-up of 53 feet that had scarf osteotomies with soft tissue realignment. SF-36 scores had a small non-statistically significant improvement (46 pre to 52 post). It is interesting that the radiographic improvement could be reported based on the measurement technique, but the SF-36 scores pre- and post-operation did not show a statistically significant change. The complication rate was 15%, with additional operations being deemed necessary in 7.5% of feet for removal of hardware. There were no reported cases of recurrent HAV; however there was a statistically significant loss of correction of the IMA (2.2 degrees) and MSP (0.4 grades). Hallux varus occurred in 3.9%, and an additional 3.9% were noted to have first metatarsophalangeal joint arthritis. Choi et al. [12] reviewed 103 Ludloff osteotomies that were combined with other procedures. The patients were divided into three groups depending on the type of distal soft tissue procedure they underwent. Thirty percent had first web space releases, 34% had Akin osteotomies and trans-articular releases, and 36% had Akin osteotomies with supplementary axial K-wire fixation and trans-articular releases. AOFAS and VAS improved in all three groups, without a significant difference between groups. Recurrence, which was defined as an HVA greater than 20 degrees, occurred in 15.5%, with all three groups having similar amounts of recurrence. Sixty-eight percent of patients who had recurrence did not report any symptoms. Deveci et al. [23] reviewed 50 scarf procedures, at a follow-up of 26.2 months (range 18–36 months). Ten percent of patients reviewed were found to recurrence of the deformity which defined as an HVA of greater than 15 degrees. Incongruity of the joint, which was the authors' hypothesized cause of recurrence, was found to be a statistically significant risk factor for recurrence. George et al. [31] examined outcomes 37.6 months following scarf osteotomies performed in 19 adolescent feet (average age of 14.3 years). IMA, HVA, and DMAA improved significantly at 6-week postoperative evaluation; however only IMA was maintained throughout the 3-year follow-up, and deterioration of the other measures was noted. 36.8% had pain and recurrence after surgery, while 9% had superficial infections. These results led the authors to the conclusion that the scarf procedure should be used with caution in adolescents. Veri et al. [74] analyzed 37 feet that had crescentic osteotomy and distal soft tissue reconstruction. A short-term follow-up was conducted at 1 year, along with a long-term follow-up at 12.2 years (31 feet). HVA and IMA values both deteriorated during the follow-up period. Ninety percent of patients were satisfied with their physical abilities during long-term follow-up, while only 80% were satisfied with the appearance. At the short-term follow-up, superficial infection occurred in 16%, 8% had delayed unions, 5% had varus after surgery, and 11% had recurrence.

To this point we have defined deviations from the normally accepted angles based on a comparison of preoperative and postoperative angles as recurrence. Looking at this issue from another perspective, we can ask, are we in reality even correcting the original deformity? Edmonds et al. [26] looked at postoperative radiographic measurements following distal, proximal, and double osteotomies in 106 juvenile feet (mean age 14.7 years). Their primary aim was to report which of the procedures returned the radiographic measurements of IMA, HVA, and DMAA to within a normal range. For the single distal first metatarsal osteotomy, the IMA was corrected to within normal limits in only 21% of the cases, HVA was within normal limits 42% of the time (however 13% of the time there was overcorrection), and the DMAA was within normal limits 46% of the time (with 4% overcorrected). The single proximal osteotomy had 36% of IMA, HVA, and DMAA within normal limits, with only DMAA having overcorrection in 7% of the cases. Finally the double osteotomy had 54% within normal limits for IMA, HVA within normal limits 40% (7% overcorrected), and DMAA was within normal limits for 56% of the cases (22% overcorrected). From these numbers it was found that the rate of HVA overcorrection was not correlated with the type of osteotomy performed, but there was a significantly higher rate of overcorrection in the double osteotomy when compared to both types of single osteotomies. This study highlights the shortcomings of these popular procedures in returning the radiographic bone segment positions to the normal range. We may in fact not be dealing with recurrence but simply our failure to correct the original deformity. If we consider the fact that the CORA for a bunion is not within this first metatarsal but at a point proximal to the deviated metatarsal, we are in fact creating a new deformity with metatarsal osteotomy. We believe that failure to correct the original deformity is likely the prime reason for poor outcomes. This is discussed in detail in Chap. 6 (Table 7.1).

Studies Reporting Mechanical Axis or Dual Measurements

As discussed above, since in the normal state the anatomic axis and the mechanical axis of the first metatarsal are collinear, using center of joint landmarks both before and after the procedure represents the exact same bias of measurement as the dual measurement technique. Alteration of reference point for the first metatarsal incorrectly reports a normal anatomic position (IMA) of the first metatarsal when in fact a new deformity has been created and the original aIMA deviation persists. The following studies used the system of dual measurements or the center of head and base technique to report on correction. Although we cannot fully critique the data, knowing the effect this convention has on the measured results, we can assume that degree of correction is overestimated and incidence of deformity recurrence is underestimated.

Jeuken et al. [40] compared 36 scarf to 37 chevron osteotomies 14 years after surgery. Patient-reported satisfaction and patient satisfaction with pain reduction ranged between 59% and 73% for each of the groups in all three of these categories based on MOXFQ, SF-36, and VAS scores. Seventy-three percent of feet in the chevron group and 78% of feet in the scarf group had recurrence based on their definition of HVA greater than 15 degrees. The high recurrence rate was determined using the center of head to center of base technique raising the question about the possibility of underestimation of true correction. As could be expected, the satisfaction was not particularly high in this study population despite the authors reporting significant improvement in AOFAS scores after surgery illustrating the potential bias between physician-rated scales and PROMs. Aiyer et al. [2] studied the recurrence of hallux valgus after 587 foot surgeries, comparing patients who have underlying metatarsus adductus (29.5%) (MA) to those who do not. Recurrence was defined as HVA of more than 20 degrees. HVA, IMA, and metatarsus adductus angle (MAA) were all measured, with MAA being considered abnormal if greater than 20 degrees. Patients with MA had greater HVA and IMA pre- and postoperative angles as compared to individuals without MA. There was a 15% recurrence rate in patients without MA, compared to a 29.6% recurrence rate in patients with MA. The rate of recurrence in the patients with MA did not vary based on procedure (Lapidus 28.5%, distal first metatarsal osteotomy 29.4%, proximal first metatarsal osteotomy 28.9%). Interestingly patients who had less severe MA (<31 degrees) were shown to have a higher rate of recurrence than those with more severe MA (82% vs 18%). In a previous study [3], reported metatarsus adductus to be associated with HAV in 30% of the cases reviewed. We have noted that the presence of metatarsus adductus clearly changes the ability to adequately and consistently correct the deformity long term and that this finding needs to be considered in the treatment algorithm. Metatarsus adductus assessment and clinical implications are discussed further in Chap. 5. Groningen et al. [34] analyzed the outcomes of 438 feet that had chevron osteotomies. The average IMA improved from 12.4 to 6.2 degrees after surgery, while the HVA improved from 28.5 to 14.8 degrees. FAOS assessments were completed at an average of 3 years for 250 of these patients, 28.3% had complications with undercorrection of the deformity occurring in 11.6% and hardware complications occurring in 9.1%. Those who had undercorrection had significantly lower FAOS assessment scores than their counterparts who had the original deformity corrected. With the use of dual measurements, we must question the true recurrence rate due to the bias imparted by the measurement technique. Agrawal et al. [1] looked at

Table 7.1 Studies using anatomic axis measurements

Author	Year	N=	Procedure	Recurrence rate	Recurrence definition	Satisfaction change/tool
Shibuya	2016	154	Metatarsal osteotomies with and without Akin	14.30% complications	Needed revision surgery	Not reported
Bock	2015	115	Scarf osteotomy	30%	HVA >20 degrees	VAS improved 6.3–0.4 AOFAS improved 57–95 No PROM
Edmonds	2015	106	Distal, proximal, and double osteotomies	Not defined	Argues that the original deformity was never really corrected	Not reported
Iyer	2015	17	Proximal opening wedge osteotomy	64.70%	Increase of HVA during recovery of >5 degrees	Significant improvement FAOS QoL subscale No PROM
Fakoor	2014	44	Chevron vs. scarf vs. McBride	21% (13% chevron, 27% McBride, 0% scarf)	Any reforming of the deformity occurring 6 months after surgery	Reported difference between VAS and Persian FADI for the three procedures with McBride having the worst outcomes of the groups
Pentikainen	2014	100	Distal chevron	73%	HVA >15 degrees	Not reported
Choi	2013	51	Scarf osteotomies	15.6% total complications, did not report recurrence	Not defined	AOFAS improved 52–88 SF-36 physical component 46–52
Choi	2013	103	Ludloff	15.5%	HVA >20 degrees	AOFAS improved 52.3–89.9 VAS improved 5.8–0.8
Deveci	2013	50	Scarf	10%	HVA >15 degrees	AOFAS improved 50.66–80 VAS 7.52–2.48
George	2009	19	Scarf	36.80%	Symptomatic and deformity had recurred	61%; Nonvalidated survey AOFAS at final follow-up average was 80
Veri	2001	31	Crescentic osteotomy and distal soft tissue reconstruction	11%	Greater than 10 degree increase in HVA	90% physical 80%appearance; SF-36

the clinical, functional, and radiological outcomes of the scarf-Akin procedure on 47 adolescent and juvenile feet. Radiological recurrence defined as IMA greater than 9 degrees and an HVA of greater than 15 degrees occurred in 29.8% with 21% needing additional or repeat surgeries. It should be noted that these high recurrence rates were probably underestimated based on center of head radiographic measurement technique and because of a very short radiographic follow-up (6-week post-radiographs used to report results). Despite the high radiographic recurrence, the AOFAS scores at short-term follow-up between the recurrent and nonrecurrent were not significantly different; therefore one has to question the validity of the outcomes scale based on these conflicting findings. Lee et al. [48] compared outcomes of proximal and distal chevron osteotomies in 92 feet in 46 female patients that were undergoing moderate to severe hallux valgus bilaterally, one foot proximal and one foot distal for comparison. The average follow-up was 40.2 months (range 24.1–80.5) at which point 6.5% of the distal group and 4.3% of the proximal group were dissatisfied. Recurrence occurred in 6.5% feet in the proximal group and 2% of feet in the distal group. Again due to measurement technique, the conclusions are biased so we cannot draw accurate conclusions based on comparison to normal. If we analyze the radiographs provided in the study, the aIMA and the TSP are quite abnormal despite the report of these measures being corrected by use of the center of head technique similar to the figures presented in this chapter (Fig. 7.5). Buciuto [9] presented a comparison of the outcomes for the Mitchell osteotomy and the chevron osteotomy. They reported satisfactory correction for both procedures (chevron had better results) based on the dual measurement technique with a loss of hallux valgus correction of 4–6 degrees. Of note they reported a 36% rate of transverse metatarsalgia pain. Recurrence rate was not specifically discussed in their analysis. Evaluation of the pre- and postoperative images provided in the paper clearly shows overestimation of the correction of all measured angles. There are a plethora of additional papers reporting individual author's results with a wide diversity of procedures. Unfortunately the use of dual measurements and the diversity of outcomes scales make systematic analysis impossible and leave us with a lack of solid answers as to the best and most reliable methods to correct HAV. Faber et al. [27] compared the Lapidus procedure with the Hohmann distal closing wedge metatarsal osteotomy in 91 feet specifically to determine if arthrodesis procedures are necessary to control hypermobility. AOFAS scores which were taken preoperatively, 2 years postoperatively, and 10 years post-operation were compared. The AOFAS significantly increased between preoperative and both 2 and 10 years post surgery. However there was a significant decrease in AOFAS scores between 2 years and 10 years. The IMA was significantly worsened in both groups between the 2- and 10-year follow-ups. Both of these factors show the importance of long-term follow-up. The average recurrence rate in both of the groups was 8.8% with underestimation of recurrence likely secondary to measurement technique. Farrar et al. [29] assessed scarf osteotomies of 39 feet in 28 adolescent patients (mean age 14.1 years). Of the 18% that had recurrence, they defined 71% as minimal recurrence that did not desire repeat surgery and 14% as significant symptoms that required revision surgery and 14% whom did not choose to have additional surgery. Okuda et al. [55] reviewed 77 feet treated with a proximal metatarsal osteotomy omitting five cases from the result due to hallux varus at a 14–120 months final postoperative visit. Hallux valgus recurrence defined as an HVA greater than or equal to 20 degrees was found in 13.9%. Seven percent had recurrence occurring at 10 weeks after surgery. Patients who had a preoperative HVA greater than 40 degrees had an increased risk for recurrence. The authors found that patients who had an HVA of less than or equal to 15 degrees and an IMA of less than 10 degrees at 10 weeks after surgery had a decreased risk of recurrence. Kilmartin and O'Kane [45] reviewed scarf and Akin osteotomies in 73 feet at an average of 9 years post surgery. Patients reported stiffness in the first MTP joint in 8%; hallux varus occurred in 4% and recurrence of 4%. The authors considered an

HVA of 20 degrees as "mild." An additional 8% of feet had HVA greater than 15 degrees which has been defined by some authors to be abnormal. Total satisfaction rate was 88% based on their definitions. This again highlights the difficulty in comparing studies due to methodological inconsistencies. Deenik et al. [22] studied HVA in scarf and chevron osteotomies in 136 feet. Subluxation of the MTPJ occurred postoperatively in 35% of patients with preoperative HVA greater than 37 degrees which progressively lead to recurrence. Only 3% of these cases of mild HVA preoperatively lead to recurrence. Patients whose HVA was more than 37 degrees preoperatively were only 65% satisfied after surgery and had significantly more pain than those who had smaller HVAs preoperatively. Coetzee [17] investigated scarf osteotomies in 20 patients at 6 and 12 months post-operation. Preoperative AOFAS was 53, 6 months 54, and 12 months after surgery 62. Fifty-five percent were satisfied at 6 months, while only 53% were satisfied after 1 year. IMA reduced from 16 degrees preoperatively to 13 degrees at 12 months; HVA improved from a mean of 40–34 degrees. Overall satisfaction was 55%, with 45% being dissatisfied in the early postoperative and 47% still unsatisfied at 12 months. Recurrence rate was 25% defined as HVA angle greater than 32 degrees and an IMA of greater than 10 degrees. Seven patients required revision surgery. Fokter et al. [30] studied 105 feet in patients who returned for clinical exam with a mean of 21 years (range 15–24 years) after a modified Mitchell procedure. They found that pain was present either at the first MTPJ or under the lesser metatarsals in 41% of the patients. Clinical return of the hallux valgus deformity was present in 47% of their patients. First and second toe overlap was noted in 18% and rotational deformity of the hallux in 39%. They concluded that the results of the procedure could not withstand the test of time for more than a decade (Table 7.2).

The question that must be considered in future investigations is why do we see recurrence. As noted above we believe that creating a metatarsal osteotomy creates a new deformity and leaves the original problem uncorrected. The fact that there are so many types of procedures that have been recommended and so many modifications seems to indicate we are approaching the problem from the wrong root cause. Others have noted clinical and radiographic factors that seem to be associated with recurrence. Although many of the factors described as associated with recurrence are most likely not causative, they do potentially signal factors to consider to avoid recurrence. Okuda et al. [57] analyzed the shape of the first metatarsal head in patients with hallux valgus deformities. The lateral edge of the lateral first metatarsal head was classified as round, angular, or intermediate. The round type was more prevalent in the presurgical group (78%) when compared to the normal group (1.7%). Following a proximal metatarsal osteotomy, the authors determined that feet which had a positive round sign at 3.4-month follow-up were more likely to have recurrence (defined as an HVA greater than 20 degrees) during the 48-month follow-up. A total of 25% had recurrence of the hallux deformity. The rounded sign of the lateral metatarsal head has been shown to be associated with the presence of frontal plane eversion of the first metatarsal. We discuss the effect that coronal plane rotation has on hallux position, radiographic appearance, and measurements and the potential role it plays in recurrence in Chap. 6. Okuda et al. [56] analyzed the position of the sesamoids after surgery with the possibility of recurrence after proximal osteotomy. They noted an initial improvement of both the IMA and HVA; however, there was a significant increase in HVA and IMA between the 3.1- and 45-month follow-up. They positively associated recurrence with a high preoperative and immediate postoperative tibial sesamoid position. Their final conclusion was that the sesamoids must be completely reduced in order to decrease the probability of recurrence. Again the authors made the association of these findings to frontal plane pronation or eversion. Yasuda et al. [75] discussed a proximal supination osteotomy of 83 feet specifically analyzing the round sign and reduction of the sesamoid position. Of the feet which had recurrence, all of them had a preoperative IMA of 18 degrees or greater and an HVA of 40 degrees or greater and postoperatively had a round sign indicating lack of correction of frontal

Table 7.2 Studies using mechanical axis or dual measurements

Author	Year	N=	Procedure	Recurrence rate	Recurrence definition	Satisfaction and tool	
Jeuken	2016	71	Chevron and scarf osteotomies	73% chevron, 78% scarf	HVA>15 degrees	64–67% scarf	MOXFQ,SF-36,VAS
						59–73% chevron	AOFA S
						79.5 scarf	
						80.1 chevron	
Aiyer	2016	587	Lapidus, distal first metatarsal osteotomy, proximal first metatarsal osteotomy	15% in those without MA, 29.6% in those with MA	HVA >20 degrees	Not reported	
Groningen	2016	438	Chevron	13.5%	Needed reoperations	FAOS at 36 months postoperative:	
				11.6%	Recurrence = HVA greater than 20° with less than 10° of angular correction	83 for pain	
						82 for symptoms	
						88 for ADL	
						74 for sport and rec	
						71 for QoL	
Agrawal	2015	47	Scarf-Akin	29.80%	HVA>15 degrees and an IMA>9 degrees	No PROMs	
				21.3% revision surgery needed		AOFAS scores above 90	
Yasuda	2015	83	Proximal supination osteotomy	4%	HVA >25 degrees	No PROMs	
						AOFAS 53–93.8	
Lee	2015	92	Proximal vs. distal chevron osteotomies	4% (6.5% proximal, 2% distal)	Not defined	91.30% (93.5% proximal, 95.7% distal)	Nonvalidated survey, AOFAS proximal 55.2–91.7
							Distal 55.7–91.8
Fleming	2015	38	Lapidus arthrodesis	5%	Not defined	Not reported	
Faber	2013	91	Lapidus vs. Hohmann distal osteotomy	8.80%	Satisfaction rate about the position of the toe was scored at 3 and/or AOFAS subscore for alignment was 0	80.2% total (78% Hohmann, 83% Lapidus)	Nonvalidated survey
Choi	2013	53	Scarf-Akin	0%	Not defined	No PROMs	
						AOFAS improved 52–88	
Farrar	2012	39	Scarf	18%	Defined by alignment section of AOFAS	93%	Nonvalidated survey, AOFAS post-op 94.2
Okuda	2011	72	Proximal metatarsal osteotomy	13.90%	HVA >20 degrees	Not reported	
Kilmartin	2010	73	Scarf and Akin	4%	HVA >20 degrees	88%	Nonvalidated survey
Okuda	2009	65	Proximal metatarsal osteotomy	25%	HVA >20 degrees	Not reported	

(continued)

Table 7.2 (continued)

Author	Year	*N*=	Procedure	Recurrence rate	Recurrence definition	Satisfaction and tool	
Deenik	2008	136	Scarf vs. chevron	9%	Not defined	No PROMs, AOFAS improved average 46 to 87	
Okuda	2007	60	Proximal metatarsal osteotomy	25%	HVA >20 degrees	Not reported	
Coughlin	2007	122	Crescentic osteotomies and distal soft tissue repair	5%	HVA >20 degrees	93%	Nonvalidated survey
Coetzee	2003	20	Scarf	25%	HVA>32 degrees and IMA >10 degrees	62 at 12 months	AOFAS
						55% at 6 mon, 53% at 1 year	Nonvalidated survey
Fokter	1999	105	Modified Mitchell procedures	47%	Not defined	86%	No PROMS
							AOFAS

plane rotation. Instability or hypermobility is another factor that has been associated with recurrence. Although there are many opinions regarding this subject, the true existence of hypermobility especially at the TMTJ is not clear [19]. The concept of first ray stability is discussed in Chap. 2.

It is clear that the recurrence rate for hallux valgus surgery remains unacceptably high. Additionally, the inconsistency and variability of both measurement techniques and lack of PROMs in the analysis of many studies leave us with an incomplete understanding of the true complication rates. We must move toward universal standardization of outcomes measures if we are to understand the true successes and failures of our common techniques. Furthermore, we must examine the most basic components of our philosophy for procedure selection and preoperative radiographic evaluation and apply sound anatomical principles and judgment to improve our understanding of this complex deformity if we wish to improve outcomes.

Hallux Varus

Hallux varus is a troublesome and sometimes disabling iatrogenic complication associated with bunion surgery. McBride [53] was the first to describe to deformity in 1935 citing an overall incidence of 5.1% [52]. The overall reported incidence is between 2% and 17% after hallux valgus correction [59, 62]. The classic description of the deformity is a true triplanar malalignment with transverse plane adduction of the hallux, dorsal contracture of the MTP in the sagittal plane, and in some cases frontal plane rotation of the first metatarsal with medial deviation of the sesamoids relative to the first metatarsal head [25]. Advanced cases may result in flexion of the hallux IP joint and a rigid deformity due to arthritis if left untreated.

While various etiologies exist for hallux varus, including trauma, inflammatory arthritis, and congenital deformity, the most common reason remains surgical overcorrection [6, 7]. Specific causes of hallux varus are excessive medial eminence resection or loss of the anatomic sagittal groove overly tightened medial capsulorrhaphy, aggressive lateral release, osseous overcorrection by osteotomy, or TMT arthrodesis with excessive transposition or attempt to reduce the intermetatarsal angle ([39, 50]). The true McBride procedure with removal of the fibular sesamoid is the most frequently associated procedure with loss of the lateral soft tissue restraints either when performed alone or in combination with an osteotomy [18] (Goldman [33]; Johnson [41]; Leemrijse [50]; Rochwerger [63]; Skalley [69]; Tourne [70]). Weakening the lateral flexor hallucis brevis can result to a mechanical advantage to the medial structures including the medial head of the FHB and the abductor hallucis. Other procedures commonly implicated include the Keller Brandeis (Skalley [69]; Tourne 70) [71] scarf (Killmartin 2011; Leemrijse [50]), and Lapidus [52].

Clinical Presentation and Examination

The classic clinical presentation of hallux varus includes pain, multiplanar deformity, clawing, weakness of push-off during gait, and, in some cases, reduced motion or a rigid deformity. In many cases, the patient does not consider hallux varus a failure, but an oddity or unusual position as long as they can wear shoes. Frequently, a foot and ankle specialist will be the first to clarify that the position is not a normal expected outcome and represents a complication.

The patient is examined while both weight bearing and non-weight bearing. Gait evaluation is important to determine if the deformity is accentuated during the swing or stance phase and whether weight bearing magnifies the positional abnormality. A dynamic deformity is due to imbalance caused by altered function of the stabilizing intrinsic muscles after surgical correction. Static hallux varus is an osseous deformity due to overcorrection of the intermetatarsal angle or excessive resection of the medial bunion prominence and normal associated bone [43, 51].

Examination of the skin for surgical scars or suggestion of prior wound healing complication that could have resulted in residual infection is important. The pattern of lesion formation is an important consideration and may coincide with other areas of pain such as adjacent MTP joint pain or digital deformity due to dynamic changes in gait, altered pressure distribution, or associated deformities. It is important to assess the second MTP joint for stability as with first ray malalignment, there is frequently overload to the second MTP due to pressure transfer. Frequently with long-standing deformity, the lesser toes will begin to adduct at the MTP and can become difficult to reduce requiring surgical procedures to address them whether by osteotomy or MTP capsular release and rebalancing. The range and quality of motion to the first MTP and hallux IP joints are important when examining for potential degenerative changes in long-standing deformity. The ability to reduce the deformity manually and to maintain it in a corrected position is essential in determining whether potential exists for a soft tissue correction alone or whether osseous procedures are indicated. Medial column instability is important to assess as are proximal deformities such as gastrocnemius equinus or a planovalgus foot type that may result in first ray instability.

Classifications

Classifications previously described are not easy to follow and implement ([7], Skalley 69). A classification described by Tourne et al. [70] is broad and excessively simple. Hawkins [36] developed a classification which includes static or dynamic presentations. Static deformities tend to be asymptomatic, and dynamic presentations most commonly involve a multiplanar deformity and are symptomatic [62]. Alternative classifications describe the complexity of the deformity or simply the joint plane of involvement [42]. These classifications are descriptive only and have not been validated to predict prognosis or guide treatment and therefore are of limited utility. Most recently, Akhtar et al. [4] reviewed 402 patients who underwent scarf osteotomy for hallux varus. Four patients developed hallux varus postoperatively, and based on these patients, the authors propose a new classification system based on the anatomic factors that caused the deformity. Three categories are identified: (1) osseous, (2) myoligamentous, and (3) combined. Osseous deformities are treated by osseous reconstruction involving either reverse scarf osteotomy or bone grafting procedures. Myoligamentous causes are treated by nonsurgical management depending on the degree of symptoms and deformity or by tendon transfers. The authors state that for combined deformities, the appropriate response is to "treat the cause" without providing specific recommendations.

The role of nonoperative management is limited [7]. There are reports supporting an attempt at nonoperative care in deformities that are recognized early and remain flexible. Skalley and Myerson reported [69] 22% of patients avoided surgical intervention and improved clinically with combination therapy including taping, shoe modifications, and NSAIDS. Hallux varus can be a well-tolerated deformity when flexible, and deformities ranging between 8 and 15 degrees can be well tolerated with little clinical significance [46, 71]. In many cases, operative intervention is recommended if the deformity presents after 6–12 weeks and is progressive or unresponsive to nonoperative modalities.

Treatment

Early aggressive surgical management is paramount for a successful outcome; however, it is difficult to apply treatment algorithms due to the individual presentation of each deformity. The goal of treatment is realignment and restoration of motion with the end result being joint salvage when possible. However, arthrodesis is the treatment of choice in non-reducible deformities or when degenerative changes dictate. What is clear is that a lateral capsular repair alone is insufficient and that tendon rebalancing alone or in combination with osseous reconstruction is also necessary. There is strong support for MTPJ fusion resulting in a durable and mechanically stable foot which functions near normal in gait [discussed in detail in Chap. 15]. This coupled with the inconsistency of hallux varus deformity understanding and questions regarding the wide variety of approaches, one could make a strong argument for fusion in all cases of symptomatic or progressive hallux varus.

Soft Tissue Reconstruction

The difficulty is often in determining when a soft tissue correction alone is feasible. In general, a flexible deformity with a painless first MTP and no degenerative changes is the optimal presentation for attempt at soft tissue rebalancing (Graisek 2016). In mild deformities which are recognized early, surgical release of the medial capsule combined with tenotomy or release of the abductor hallucis may be sufficient [18]. However, when applying a stepwise approach to the deformity, complete reduction is often impossible and osseous techniques often become necessary. The preoperative informed consent and documentation should allow for broad categories of procedures should they become necessary. A thoughtful structured plan is important; however, the intraoperative course will dictate the final approach.

Multiple soft tissue reconstructive options have been described in the literature and are largely based on surgeon opinion. The current lack of strong outcomes studies leaves the surgeon with an abundance of confusion and concern as to which approach to take as we noted previously. Hawkins [36] first described a dynamic transfer of the abductor hallucis by releasing the tendon distally from the medial base of the proximal phalanx and the insertional fibers to the tibial sesamoid. The tendon was then passed from medial to lateral plantar to the metatarsal and deep transverse intermetatarsal ligament. The tendon was next passed through a drill hole from lateral to medial in the proximal phalanx and fixated with a biotenodesis screw [36].

Leemrijse et al. [50] described a reverse transfer of the abductor hallucis tendon which resulted in good outcomes but was limited to seven patients who met inclusion criteria. The American Orthopaedic Foot and Ankle Society (AOFAS) hallux metatarsophalangeal-interphalangeal (MTP-IP) score increased from 61 to 88.

EHL transfer was first described by Johnson and Spiegel [41]. The authors released the EHL tendon distally which was then passed from proximal plantar to dorsal distal under the deep transverse intermetatarsal ligament and repaired to the proximal phalanx after being appropriately tensioned. Since the entire EHL tendon is utilized, the authors recommend arthrodesis of the IP joint of the hallux to avoid deformity. Average follow-up was 37.5 months, and 10 out of 14 patients reported excellent results. As an adjunct to this technique, Gradisek and Weil [35] recommend attempt to repair the conjoined adductor tendon. Johnson et al. [42] later modified the EHL transfer by using a split EHL technique where the lateral half was transferred. IP joint arthrodesis was not included; however mild weakness of MTP extension was noted.

Lau and Myerson [47] also described a split EHL transfer, where the lateral half of the EHL was released proximally and attached to the first metatarsal distally after being passed under the DTIL. The authors did not feel that tensioning the tenodesis resulted in alteration of the first MTP joint mechanics. Goldman et al. [33] reported complete satisfaction in eight out of nine patients who underwent transfer of the entire EHL tendon (in five patients) or split EHL tendon (in four patients) with or without hallux IP joint arthrodesis. Diebold and Delagoutte [24] reported recurrent hallux varus in 2 out of 13 patients who underwent the technique described by Johnson with EHL transfer combined with hallux IPJ fusion. Valtin [72] described transfer of the first dorsal interosseous muscle.

One must question the feasibility of transfer under the deep transverse intermetatarsal ligament (DTIL) as it is often excessively scarred within the first interspace. The standard lateral release involves sectioning the DTIL during approach to the conjoined tendon of the adductor hallucis and metatarsal sesamoid ligament. While it is possible to restore the anatomy, dissection and transfer under the remnants of the ligament may be tedious.

Myerson and Komenda [54] described a static transfer involving an EHB tenodesis. The technique involves distal release of the EHB tendon which is then passed from distal to proximal deep to the DTIL. Next, the tendon is passed from lateral to medial through a first metatarsal osseous tunnel and secured with suture or a biotenodesis device. Excellent correction was maintained in all patients at an average of 27 months after surgery. A decrease in dorsiflexion (average 10 degrees) was noted; however no other complications were reported. A variation of the EHB tenodesis was described by Juliano and Campbell [43] which involved distal mobilization of the tendon and lateral to medial transfer via an osseous tunnel in the proximal phalanx. Six patients were included in the study, and all achieved an excellent outcome with AOFAS scores improving from 61 preoperatively to 85 postoperatively. Tourne et al. [70] described a technique of lateral ligament reconstruction using synthetic graft material reporting "excellent outcome" in all patients. Giza et al. (2014) expressed concern regarding potential for infection and high cost associated with synthetic graft application. Tourne and Saragaglia (1995) describe a simple technique of suture reconstruction of the lateral collateral ligament in five cases reporting excellent outcome in all cases at an average follow-up of 4 years. Pappas and Anderson reported correction of hallux varus deformity using a suture endobutton-type device to realign the hallux where it is tensioned to the necessary level for correction which is determined intraoperatively. Crawford and Patel et al. [21] reported potential complications with the technique which include breakage, hematoma, limited joint range of motion, frontal plane deformity, loss of correction, or fracture of the proximal phalangeal base.

Gerbert et al. [32] and Hsu et al. [37] also published isolated case reports that exist using endobutton suture devices with good outcomes reported.

Plovanich et al. [60] performed a systematic review including a total of eight studies which concluded that tendon transfer resulted in satisfactory outcomes for flexible hallux varus deformity; however the rate of postoperative complications was 16%. The studies that met inclusion criteria were almost exclusively level IV retrospective studies and one level V study. The authors indicated that sustainable correction of hallux varus deformity is possible with tendon transfer and release of soft tissue contractures. Despite the presence of an abundance of opinions regarding soft tissue repair of hallux varus, we still have no clear and consistent scientific information to guide our recommendations.

Osseous Correction

Overcorrection of the intermetatarsal angle or hallux abductus angle via osteotomies is a frequent cause of hallux varus. Overcorrecting the hallux abductus angle via aggressive or unnecessary Akin osteotomy can result in a medializing force applied by the flexor hallucis longus tendon. This can be corrected via a reverse Akin osteotomy [7]. In most cases, simply utilizing an osteotomy alone will be insufficient for correction, and a combination of osseous and soft tissue balancing procedures is necessary (Fig. 7.6). Lee et al. [49] reported a technique tip using a reverse

Fig. 7.6 (**a**) Preoperative AP radiograph of a 50-year-old female patient with moderate hallux abducto valgus deformity. (**b**) Initial postoperative AP radiograph 10 days status post modified chevron bunionectomy with lateral release. (**c**) Eight-week post-op AP radiograph demonstrating negative hallux abductus angle with medial deviation of the tibial sesamoid. (**d**) Six-week postoperative clinical view demonstrating mild hallux varus deformity. (**e**) Revision with sequential soft tissue release of MTP joint. Image demonstrates dorsal and medial capsulotomy first MTP joint. (**f**) First MTP joint complete with soft tissue release including dorsal, medial, and plantar medial capsulotomy. (**g**) Despite complete soft tissue release, clinical hallux varus deformity remains. (**h**) Reverse chevron osteotomy completed with medial shift of the capital fragment. (**i**) Reverse chevron complete with medial displacement of the capital fragment. (**j**) Fixation of the reverse chevron osteotomy with a 3.0 mm cannulated cancellous bone screw. (**k**) Twelve-week postoperative radiograph of revision via complete sequential soft tissue release and reverse chevron osteotomy. Congruent joint is noted; however fibular sesamoid is laterally deviated. (**l**) Three-month postoperative clinical appearance with rectus-appearing joint

chevron osteotomy where the osteotomy is recreated and the capital fragment is translated medially to reduce the negative relative correction to the intermetatarsal 1–2 angle. Rochwerger et al. [63] described the use of a medial bone graft to restore more appropriate anatomy when an excessive medial bone resection has occurred. This was thought to improve function of the tibial sesamoid. They reported no recurrences with good motion in seven cases at an average follow-up of 8.6 years. Kannegieter and Kilmartin [44] described a reverse scarf procedure with a proximal opening wedge of the proximal phalanx reporting excellent patient satisfaction in five cases. Choi et al. [14] reported a reverse biplanar chevron incorporating a lateral-based wedge in the osteotomy for angular correction. Patient satisfaction was high with only 1 patient out of 19 reporting dissatisfaction; however there were two recurrences.

Arthrodesis is a definitive procedure for management of hallux varus. The procedure is reproducible and results in a high degree of patient satisfaction with symptomatic nonunion rate of 1.8% [64]. The selection of fusion is based on the degree of pain, presence of degenerative changes, time, and reducibility. Time can be a variable indication as some patients may have moderate to significant degenerative changes despite a short period of deformity ([18, 70], Skalley [69]).

In conclusion, nonoperative care has a small role in the management of an iatrogenic hallux varus deformity. The ultimate solution is best determined by intraoperative assessment, as these findings do not always match the clinical and radiographic parameters. Isolated soft tissue release of medial contractures is insufficient and leads to a high degree of patient dissatisfaction. While many variations of tendon transfer have been reported with good results, the cohort size in these studies is generally small, and it is difficult to draw meaningful conclusions as to their long-term efficacy. Osseous correction by reversing the deforming force restores the deformity to some degree and, while reliable, may result in patient dissatisfaction. In general, combining osseous reconstruction with tendon transfer will lead to a high degree of patient satisfaction. When the deformity is long-standing, non-reducible, or demonstrates limited painful range of motion with degenerative changes, a first MTP arthrodesis offers the most definitive solution and results in significant improvement in objective outcome scores. Taking into consideration the diversity of opinions and level of evidence regarding repair of hallux varus and the contrasting good results with fusion across a wide patient population, we conclude that arthrodesis represents a strong choice for repair.

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