Current Concepts Review: Hallux Valgus Part II: Operative Treatment

Mark E Easley and Hans-Joerg Trnka

Foot Ankle Int 2007 28: 748
DOI: 10.3113/FAI.2007.0748

FOOT & ANKLE INTERNATIONAL

DOI: 10.3113/FAI.2007.0748

Current Concepts Review: Hallux Valgus Part II: Operative Treatment

Mark E. Easley, M.D.; Hans-Joerg Trnka, M.D.
Durham, NC and Vienna, Austria

INTRODUCTION

This current concepts review complements Part I, presented in the May, 2007 issue of *Foot and Ankle International*. In Part I, the etiology, pathomechanics, degrees of severity, and nonoperative treatment for hallux valgus deformity were reviewed. Part II discusses the various approaches to the operative treatment of hallux valgus.

CONSIDERATIONS IN INTERPRETING RESULTS

Outcome Studies for Hallux Valgus

Results of most hallux valgus corrective procedures typically focus on the physicians' perceptions rather than the patients' perceptions of outcome.[113] Thordarson et al.[113] noted that patients' perceptions of outcome generally are reduced to satisfied, satisfied with reservations, or dissatisfied. Although the American Orthopaedic Foot and Ankle Society (AOFAS) rating system aims to standardize outcomes data collection,[55] it remains a physician-driven tool. Furthermore, its validity has been questioned in the evaluation of the hindfoot,[118] a shortcoming that may also manifest in the forefoot.[9] This is not a shortcoming isolated to the AOFAS rating system. In a recent meta-analysis of outcomes scales in foot and ankle surgery, Button and Pinney[12] concluded that none of the 49 rating scales identified proved to be reliable, valid, or responsive in patients with foot and ankle conditions. The effort by a team of AOFAS members to create such an outcomes tool suggests that the AOFAS clinical rating system lacks adequate assessment of quality of life measures.[114] Recently, SooHoo et al.[110] demonstrated increased responsiveness of foot and ankle specific outcomes tools compared to the SF-36. However, the level of responsiveness for the bodily pain subscale and the physical component summary approached that of the AOFAS outcomes measure and the foot function index after foot and ankle surgery. This thrust to establish valid outcomes measures that include patients' perceptions has been directed at corrective surgery for hallux valgus.

The first of these studies to focus on patients' perceptions of the results of hallux valgus surgery was by Thordarson et al.[116] and used the AAOS Lower Limb Outcomes Data Collection questionnaire and the Foot and Ankle Outcomes Data Collection questionnaire. These validated lower extremity instruments include the Short-Form 36 (SF-36) and demonstrated significant improvement in satisfaction, pain, and function with results derived from 311 patients who had hallux valgus corrective surgery done by members of the AOFAS. Furthermore, to properly determine the effect on outcome of hallux valgus surgery, the AOFAS hallux Metatarsophalangeal-interphalangeal (MTP-IP) joint scoring data should be collected prospectively. Retrospectively collected preoperative data leads to an overestimation of the improvement, i.e., a worse preoperative score than would have been recorded prospectively.[106,118]

Fig. 1: Hans-Joerg Trnka, M.D.

Corresponding Author:
Mark E. Easley, M.D.
Duke Health Center
3116 North Duke Street, Room 243
Durham, NC 27705
E-mail: Easle004@mc.duke.edu

Table 1: Level of evidence and grades of recommendation

Level of Evidence
— Level I: high quality prospective randomized clinical trial
— Level II: prospective comparative study
— Level III: retrospective case control study
— Level IV: case series
— Level V: expert opinion

Grades of Recommendation (given to various treatment options based on Level of Evidence supporting that treatment)
— **Grade A** treatment options are supported by strong evidence (consistent with Level I or II studies)
— **Grade B** treatment options are supported by fair evidence (consistent with Level III or IV studies)
— **Grade C** treatment options are supported by either conflicting or poor quality evidence (Level IV studies)
— **Grade I** when insufficient evidence exists to make a recommendation

More recently, Thordarson et al.[114] evaluated 285 women, with an average age of 49 years who were scheduled for corrective surgery for hallux valgus. Again, the validated AAOS foot-specific outcomes data collection questionnaires were used. Preoperative radiographic data of the hallux valgus angle (HVA) and intermetatarsal angle (IMA) were stratified into degree of deformity. The data were stratified into age groups consistent with those reported for the SF-36, and the results were compared to the SF-36 for the general population. The global foot and ankle score and the shoe comfort score were compared with the general population, and the severity of the preoperative deformity was correlated with the baseline scores. Bodily pain scores were uniformly worse for hallux valgus patients compared to the general population, with significantly lower global foot and ankle and shoe comfort scores, a finding that suggests that the bodily pain score from the SF-36 represents a sensitive measure of the difficulties experienced by patients who require corrective hallux valgus surgery. The preoperative radiographically-determined severity of deformity failed to correlate with any scores measured.

Thordarson et al.[113] subsequently reported these patient-derived outcome measures along with the AOFAS hallux rating system in a comparison of results for three different hallux valgus techniques: modified McBride procedure, distal chevron osteotomy, and Lapidus procedure. For the SF-36 instrument, the bodily pain, physical function, role-physical, and role-emotional scores improved. In the AAOS lower extremity scores, global foot and ankle, shoe comfort, physical health and pain, and patient satisfaction with symptoms scores improved significantly. The AOFAS score also improved significantly. The magnitude of preoperative deformity, postoperative deformity, and magnitude of correction did not significantly influence the amount of improvement in any score, and the type of operation did not influence outcome.

CONSIDERATIONS IN INTERPRETING RADIOGRAPHIC MEASUREMENTS OF HALLUX VALGUS

Intraobserver and interobserver reliability rates are high for measuring the HVA and IMA (< 5 degrees, 95% confidence interval),[26,94,103] but radiographic assessment of the distal metatarsal articular angle (DMAA) remains a diagnostic challenge, with poor intraobserver and interobserver reliability.[17,24,26] In a cadaver study, Vittetoe et al.[127] demonstrated a high intraobserver but poor interobserver reliability for the DMAA measurement, and noted that interpretation depended on rotation of the first metatarsal.[127] Thordarson et al.[113,114] reported that functional outcome failed to correlate with radiographic outcome after corrective surgery for hallux valgus. Because osteotomies distort anatomic landmarks frequently used on preoperative radiographs, Resch et al.[88] also supported evaluating results of hallux valgus on clinical examination rather than radiographic measures. When interpreting the literature, the reader should be aware that the high interobserver and intraobserver reliability rates for HVA and IMA on preoperative measurements often are forfeited in the interpretation of postoperative radiographs.[2,102,103,105] Several authors have noted discrepancies when the same radiographs are interpreted with different techniques for linear and angular measures, particularly in the evaluation of postoperative radiographs following first metatarsal osteotomies.[2,69,102,103,105] When comparing five different techniques, Schneider et al.[103] concluded that the technique described by Miller[76] (center first MT head to center of base of first MT) reduced interobserver and intraobserver interpretation error most effectively.

OVERVIEW OF OPERATIVE TREATMENT

Over 100 different operative treatments have been proposed for hallux valgus. As a general principle, the severity of the deformity dictates treatment options. While mild-to-moderate deformities often can be corrected with a more distal procedure such as a chevron osteotomy, more severe deformities typically are managed with a more proximal procedure such as a proximal metatarsal osteotomy or Lapidus procedure. A first metatarsophalangeal (MTP) joint arthodesis generally is reserved for hallux valgus associated with first MTP joint arthrosis, severe deformities, or salvage of failed previous hallux valgus procedures.

DISTAL PROCEDURES

Simple Bunionectomy

Few recent orthopaedic articles report simple bunionectomy (medial eminence resection with medial capsular plication). In a retrospective review of simple bunionectomy, Kitaoka et al.[56] noted high recurrence and high patient dissatisfaction rates. Given the limited level IV evidence for simple bunionectomy, no specific recommendation (Grade I) can be made for medial eminence resection in hallux valgus correction.

Modified McBride Procedure (Distal Soft-Tissue Procedure)

While an adjunct in most hallux valgus corrective procedures, the McBride distal soft-tissue procedure has been described as an isolated procedure for hallux valgus correction. In 1923, Silver[108] reported the combination of medial eminence resection, lateral capsular release, adductor hallucis tendon release, and medial capsular plication for the treatment of hallux valgus deformity. The modified McBride procedure includes medial capsulotomy (and subsequent plication), division of the ligament between the lateral capsule and fibular sesamoid, adductor hallucis release, lateral capsular fenestration, and a controlled varus stress to the first MTP joint.[46,70,86] A concern about hallux varus with the original McBride procedure[73] prompted the preservation of the fibular sesamoid in the modification.

Few recent orthopaedic articles report isolated modified McBride procedures for the correction of hallux valgus deformity. In a retrospective review, Mann and Pfeffinger[70] noted acceptable patient satisfaction rates and improvement in hallux alignment (Level IV evidence); however, a selection bias to patients with mild and flexible deformities was suggested[67] Johnson et al.[46] retrospectively compared the modified McBride procedure and distal chevron osteotomy, with the two groups matched for age, severity of deformity, and length of followup (Level III evidence). While postoperative satisfaction rates were not significantly different, the distal chevron group exhibited significantly better correction of alignment. Given the limited Level III and IV evidence for the modified McBride procedure, no specific recommendation (Grade I) can be made for its isolated use in hallux valgus correction.

Distal Chevron Osteotomy

The distal chevron osteotomy is a V-shaped osteotomy of the first metatarsal, described by Corless,[23] Johnson et al.,[47] and Austin and Leventen.[5] To narrow the forefoot, the capital fragment is shifted laterally. An anatomical study suggested that the capital fragment can be safely shifted laterally 6.0 mm in men and 5.0 mm in women and still maintain greater than 50% bony apposition of the fragments.[6] The procedure has been performed with or without fixation of the shifted capital fragment.[31,38,69,101,122,123] The symmetric orientation of the distal chevron osteotomy[5] has undergone several modifications to accommodate fixation.[47,69] The combination of a medial closing wedge osteotomy of the first proximal phalanx (Akin) and a distal chevron osteotomy have been described when hallux valgus with metatarsus primus varus is associated with hallux valgus interphalangeus.[77,117] The distal chevron osteotomy also has been combined with a lateral capsular or adductor tendon release, or both.[59,75,91,101,122]

For mild-to-moderate hallux valgus correction, the effectiveness of the distal chevron osteotomy in providing favorable outcomes and patient satisfaction, regardless of fixation method, addition of lateral soft-tissue release, length of followup, or patient age, is supported by numerous retrospective reviews (Level IV Evidence).[13,16,30,31,38,69,75,84,87,101,111,119,122,123] The average preoperative IMA was less than 15 degrees in all studies. DeOrio and Ware[31] reported satisfactory outcomes and patient satisfaction with a low complication rate with bioabsorbable fixation (Level IV evidence). Crosby and Bozarth[30] and Gill et al.[38] noted no significant differences in favorable outcomes or patient satisfaction and minimal complications when comparing of screw, Kirschner wire, and no fixation and Kirschner wires and bioabsorbable fixation, respectively (Level IV evidence).

The addition of a lateral release to a distal chevron osteotomy may improve correction of hallux alignment; however, patient satisfaction is similar in patients who have distal chevron osteotomies with or without lateral release. One Level I evidence investigation by Resch et al.[91] compared distal chevron osteotomy with and without adductor tenotomy. Although the clinical appearance and radiographic alignment were significantly better in the group with adductor release, patient satisfaction was not. Mann and Donatto[69] in a small case series (Level IV evidence) noted satisfactory outcome for distal chevron osteotomy without lateral release, similar to results of Level IV evidence studies of distal chevron osteotomies with lateral release.[16,87,119]

Two recently published Level IV case series of distal chevron osteotomies with lateral release (Schneider et al.[101] and Trnka et al.[122]) noted that the results were maintained with longer followup: Trnka et al.,[122] followup of 2 to 5 years and Schneider et al.,[101] followup of 5.6 to 12.7 years. Furthermore, both studies suggested that results were equal for patients under and over the arbitrarily chosen age of 50 years.

Potential complications of distal chevron osteotomy

Osteonecrosis of the first metatarsal head and recurrence of the deformity due to an increased DMAA are two potential complications of distal chevron osteotomy.

Adding a lateral capsular release to a chevron osteotomy may improve deformity correction,[51,59,87,90,111,123] but this type of release may increase the risk of osteonecrosis of the first metatarsal head[75] (Level IV evidence). A distal chevron osteotomy disrupts the intraosseous blood supply to the metatarsal head, and the medial capsular release

eliminates a substantial portion of the blood supply to the metatarsal head.[59] Retrospective reviews[84,87,101,111,122,123] (Level IV evidence) suggest that a lateral capsular release or adductor tenotomy can be safely combined with a distal chevron osteotomy. Moreover, in a prospective, randomized study (Level I evidence), Resch et al.[90] used scintigraphy to demonstrate that an adductor hallucis tenotomy performed with a distal chevron osteotomy did not lead to an increased circulatory disturbance to the first metatarsal head compared to distal chevron osteotomies performed without a lateral soft-tissue procedure. Kuhn et al.[59] prospectively (Level IV evidence) used an intraoperative laser Doppler probe to demonstrate that the combination of chevron osteotomy, medial capsular release, and lateral release plus adductor tenotomy resulted in a cumulative decrease in blood flow to the metatarsal head of 71%, with the greatest insult being attributed to the medial capsular release (45%). None of the 20 metatarsal heads analyzed in the study by Kuhn et al.[52] developed osteonecrosis. Some investigations note initial radiographic findings suggestive of avascular change in the first metatarsal head, but with further followup these changes resolved in most patients.[69,90,111] Even after chevron osteotomies without lateral release, some subtle findings suggestive of osteonecrosis may be identified, but these rarely have long-term sequelae[69–90] (Level I and IV evidence). Jones et al.[51] proposed that over-penetration of the saw blade through the lateral first metatarsal cortex and the lateral capsule is the technical error potentially leading to osteonecrosis.

In mild hallux valgus deformity, the distal metatarsal articular angle (DMAA) can be decreased by combining the distal chevron osteotomy with and Akin osteotomy[77,101] or by making a biplanar distal chevron osteotomy.[19,80] While the goal of a combination of distal chevron and Akin osteotomies is to improve clinical alignment through extraarticular correction, the biplanar distal chevron osteotomy aims to simultaneously correct hallux valgus and decrease the DMAA. In the biplanar distal chevron procedure, two different osteotomy configurations can be used. With the conventional, symmetric pattern of two osteotomy limbs of equal length, a second oblique wedge resection for each cut allows a reduction in the DMAA in combination with the lateral shift of the metatarsal head.[19] With a short, relatively vertical dorsal limb and horizontal long plantar limb, a second wedge resection dorsally permits redirection of the metatarsal head simultaneous with the lateral shift.[80]

Levels of evidence for distal chevron osteotomy

Given the numerous positive Level IV evidence investigations and one Level I evidence study in the orthopaedic literature, a Grade B treatment recommendation can be made to support the use of a distal chevron osteotomy for correction of mild-to-moderate hallux valgus deformity. One Level I evidence study and multiple Level IV evidence investigations that provide Grade B evidence that hallux alignment and functional outcome may be better after a distal chevron osteotomy with a lateral soft-tissue procedure than without suggest that patient satisfaction is no different in these two groups. Moreover, consistently positive Level IV evidence and a one Level I evidence investigation allow a Grade B recommendation that a lateral capsular or adductor hallucis tendon release can be done with a distal chevron osteotomy without increased risk of first metatarsal head osteonecrosis. Two relatively recent Level IV evidence studies exist for the distal chevron and Akin osteotomies and the biplanar distal chevron osteotomy to correct mild-to-moderate hallux valgus associated with an increased DMAA.[19,77,80,117] While functional outcomes and patient satisfaction for these case series are favorable, only Grade C evidence supports their use in the management of mild-to-moderate hallux valgus with an increased DMAA.

KELLER RESECTION ARTHROPLASTY

Several Level IV retrospective case series have been published on the Keller resection arthroplasty.[53,92,93,100,104,124,126,129] The Keller resection arthroplasty is the resection of the first proximal phalanx base to correct hallux valgus deformity. In a prospective comparison, Turnbull et al.[124] demonstrated better HVA and IMA correction, hallux MTP joint motion, and metatarsal head relationship with the sesamoid complex for the distal chevron osteotomy compared to the Keller procedure (Level II evidence). While some authors have reported satisfactory results with the Keller resection arthroplasty, these authors noted that acceptable results were achieved because of ancillary procedures. Specifically, Donley et al.[33] noted acceptable postoperative alignment when the resection arthroplasty is combined with a fibular sesamoidectomy (Level IV). Likewise, several authors[7,15,41,100,104] attributed improved outcome applying a "cerclage fibreux" (described by LeLievre and LeLievre[61]) distal soft-tissue procedure or tendon transfer in conjunction with the resection (Level IV). Zembesch et al.,[129] in a retrospective, uncontrolled comparative case series, demonstrated worse results with the Keller procedure than with proximal metatarsal closing wedge osteotomy, with significantly better correction of hallux valgus deformity in the proximal osteotomy group. Both groups had high rates of transfer metatarsalgia (Level IV evidence). Anecdotally, most authors have suggested that the Keller procedure be used only in older patients with limited functional expectations who may be at risk if subjected to corrective surgery. Given that no more than Level IV evidence exists in the orthopaedic literature, only Grade C evidence exists for recommending the Keller procedure in the management of hallux valgus deformity.

PROXIMAL PROCEDURES AND FIRST METATARSOPHALANGEAL JOINT ARTHRODESIS

For a moderate-to-severe hallux valgus deformity associated with metatarsus primus varus, a more powerful deformity correction generally is required. A wide variety of approaches have been described for correction of severe hallux valgus deformity, including various proximal first metatarsal osteotomies, corrective first tarsometatarsal (TMT) joint arthrodesis (Lapidus), or first metatarsophalangeal joint arthrodesis. Typically a distal soft-tissue procedure is performed in conjunction with a proximal osteotomy or a Lapidus procedure.

Proximal First Metatarsal Osteotomies

While crescentic[34,35,68,72,125] and closing wedge osteotomies are done through a dorsal approach, proximal chevron, opening wedge Ludloff, and scarf osteotomies are done from the medial aspect of the proximal first metatarsal.[18,95–97] Several authors have suggested that dorsiflexion malunion is less likely to occur with proximal osteotomies done from the medial aspect of the first metatarsal than from the dorsal aspect.[18,35,95] Most proximal first metatarsal osteotomies require full transection of the first metatarsal; the opening and closing wedge procedures maintain lateral and medial cortical hinges, respectively. For all proximal osteotomies combined with a distal soft-tissue procedure potential complications include recurrence, hallux varus, first MTP joint stiffness, malunion, nonunion, and infection.

Proximal Crescentic Osteotomy

The proximal crescentic osteotomy for correction of hallux valgus associated with metatarsus primus varus has been popularized by Mann.[71] Unique to the proximal crescentic osteotomy is the use of a crescentic saw blade. A commonly cited potential complication of the proximal crescentic osteotomy is dorsiflexion malunion.[31,71,72,130] Recently, Jones et al.[50] described a technique to aid surgeons in properly orienting the crescentic saw blade in the coronal plane to minimize the risk of initial dorsiflexion malpositioning.

Several case series (Level IV evidence) reported satisfactory radiographic correction, high rates of satisfaction, and significant improvement in functional outcomes with the proximal crescentic osteotomy at intermediate-to-long term followup.[34,68,71,72,82,115,125,130] A prospective randomized comparison[35] (Level II evidence) of the proximal crescentic and proximal chevron osteotomies suggested favorable radiographic correction and clinical outcomes for both procedures, with AOFAS outcome scores and radiographic correction of HVA and IMA improving significantly at an average followup of 24 months (proximal crescentic) and 20 months (proximal chevron). Dorsiflexion malunion was observed in 17% of the proximal crescentic cohort. Mann et al.,[71] in one of the original articles describing this procedure, noted dorsiflexion malunions in 28% of cases. The consistently favorable results from several case series and one Level II evidence study determine a Grade B recommendation for the use of the proximal crescentic osteotomy in the surgical management of hallux valgus.

Proximal chevron osteotomy

The proximal chevron osteotomy, first reported by Sammarco et al.,[95] relies not simply on lateral translation of the distal fragment, as with the distal chevron procedure, but concomitantly incorporates an opening wedge principle.[35,95–97] The large contact area is relatively stable, and recommended fixation is with a combination of a screw and a Kirschner wire, two screws, or a plate.[4,35,37,95–97] The procedure has been described using a single[95,97] or two-incision[35,95] technique.

Three case series[95,97] (Level IV evidence) and one prospective, randomized comparative study[35] (Level II evidence) reported favorable radiographic correction, high rates of satisfaction, and significant improvements in the functional outcomes with the proximal chevron osteotomy at intermediate followup. In the Level II investigation comparing the proximal chevron and crescentic osteotomies, healing time was shorter and the tendency for first metatarsal shortening was less for the proximal chevron cohort. Dorsiflexion malunion was observed in 0% and 17% for the proximal chevron and crescentic cohorts, respectively. Taking the limited but favorable Level IV evidence and the positive Level II evidence into consideration, a Grade B recommendation for the use of the proximal chevron osteotomy in the operative management of hallux valgus can be made.

Opening wedge proximal first metatarsal osteotomy

An opening wedge proximal first metatarsal osteotomy was described by Trethowen in 1923 but was largely abandoned because of concerns of stability and nonunion. With improved fixation techniques, including fixed-angle plating, the opening wedge has regained acceptance in some centers. It probably is inaccurate to state that an opening wedge proximal first metatarsal osteotomy lengthens the metatarsal, but it may maintain length, a feature that may be beneficial when the first metatarsal is relatively short compared to the second metatarsal. Healing rarely is problematic despite the gap that is created; minimal periosteal stripping and an intact lateral cortex allow relatively rapid incorporation of local autograft, allograft, or bone graft substitutes.

Despite the attention given this technique in recent years, to our knowledge, no investigations have been published that report the results of hallux valgus correction using an opening wedge proximal first metatarsal osteotomy. Thus, insufficient (Grade I) evidence exits to make a recommendation.

Proximal Oblique ("Ludloff") Osteotomy

The proximal oblique first metatarsal osteotomy was introduced in 1913, by Ludloff but failed to gain acceptance

because the original description did not include fixation.[64] More recently, a modified technique included fixation with two screws.[18] The first screw is placed before the osteotomy is completed, allowing the surgeon to maintain full control of the osteotomy throughout the procedure.[18] Beischer et al.[11] reported the optimal geometric parameters of the modified Ludloff osteotomy in a three-dimensional computer analysis. Specifically, they determined that first metatarsal shortening and rotational malalignment can be controlled if the osteotomy is started dorsally at the first tarsometatarsal joint and extended distally to the plantar first metatarsal, just proximal to the sesamoid complex. They also explained that first metatarsal elevation is avoided by tilting the osteotomy 10 degrees plantarward, thereby directing the distal fragment plantarward during correction.

A few recent orthopaedic clinical series (Level IV evidence) have analyzed the modified Ludloff osteotomy combined with a distal soft-tissue procedure.[18,45,85] At intermediate followup, in prospective case series (Level IV evidence), Hofstaetter et al.,[45] Petroutsas and Trnka,[85] and Chiodo et al.[18] reported significant improvement in the AOFAS Hallux-IP joint score, favorable patient satisfaction, and significant correction of radiographic hallux alignment. Based on the limited clinical series of level IV papers, a Grade B recommendation exists for the modified Ludloff osteotomy and distal soft-tissue procedure in the operative management of moderate to severe hallux valgus deformity.

Closing Wedge Proximal First Metatarsal Osteotomy

A proximal closing wedge osteotomy perpendicular to the first metatarsal longitudinal axis is not universally accepted by orthopaedic foot and ankle surgeons because of concerns about complications, including shortening and dorsiflexion malunion.[89,120,129] Perhaps with an oblique orientation these risks are diminished, but to date only presented material is available, without peer-reviewed published data in the orthopaedic literature. The proximal closing wedge first metatarsal osteotomy is done through a dorsal approach, with the base of the resected segment directed laterally. Despite a medial hinge being maintained, most published series acknowledge a risk of dorsiflexion malunion. Given the propensity for the osteotomy to shorten, it theoretically is particularly applicable to patients with relatively long first metatarsals.

Several retrospective case series (Level IV evidence) of proximal first metatarsal closing wedge osteotomies and distal soft-tissue procedures with intermediate-to-long-term followup have been reported in the orthopaedic literature.[40,89,120,129] Trnka et al.[120] published long-term retrospective results (followup range 10 to 22 years) of basal metatarsal closing wedge osteotomies. Despite good-to-excellent results in 85% of patients who returned for followup, a considerable number of complications occurred, including dorsiflexion malunion, first metatarsal shortening (mean 5 mm), transfer metatarsalgia, and hallux varus. In an uncontrolled comparative study (Level IV evidence) the same authors reported that a subset of the same patients compared favorably to group of similar patients undergoing Keller resection arthroplasties.[129] While the incidence of transfer metatarsalgia was equal in the two groups, the basal closing wedge osteotomy had significantly better AOFAS Hallux-IP joint scores and radiographic outcomes. Again, the frequency of dorsiflexion malunion and hallux varus was high. In an intermediate followup case series, Resch et al.[89] cited a long average time to healing of the osteotomy and a 20% incidence of dorsiflexion malunion associated with transfer metatarsalgia.

Granberry and Hickey[40] reported a retrospective uncontrolled comparative study (Level III evidence) of proximal first metatarsal closing wedge and Akin osteotomies with or without a distal soft-tissue procedure. While the same combination of osteotomies was done in the two groups, only one group had release of the lateral joint capsule from the sesamoid and transfer of the adductor tendon into the first metatarsal neck. The significantly better radiographic correction of hallux valgus in those with a distal soft-tissue procedure was accompanied by significantly less first MTP joint motion. Several dorsiflexion malunions were observed in the entire group of patients. With the level III and IV evidence, a Grade B recommendation can be made for the closing wedge proximal first metatarsal osteotomy in the correction of hallux valgus, with the observation that dorsiflexion malunion and considerable shortening of the first metatarsal are frequent.

Scarf Osteotomy

Overview

The scarf osteotomy is not a proximal first metatarsal osteotomy but is commonly used outside of the United States for moderate to severe hallux valgus deformity.[8,29,52,58,63] The osteotomy's configuration with (1) a distal dorsal limb (virtually identical to that of a traditional distal chevron osteotomy), (2) a long transverse cut, and (3) a proximal limb (similar to the distal extension of the Ludloff osteotomy) confers adequate stability and permits fixation with two screws. It is designed primarily as an osteotomy that laterally translates the distal fragment, but with slight modification of the bone cuts, rotation also can be imparted to the distal fragment to further correct the IMA increased DMAA. A potential complication unique to the scarf osteotomy is "troughing" (an impaction of the two osteotomy fragments, resulting in loss of metatarsal height).

Several prospective and retrospective case series (Level IV evidence) have reported favorable radiographic correction, high rates of patient satisfaction, and significant improvements in the functional outcomes and pedobaric foot pressure analyses with the scarf osteotomy.[3,8,29,32,52,58,63,83,109] Aminian et al.,[3] in their retrospective review, noted no transfer metatarsalgia pattern in foot pressure analysis. Prospectively, Lorei et al.[63] observed a redistribution from

the lateral forefoot to the first ray following scarf osteotomies in their case series using pedobarographic analysis.(Level IV evidence) Jones et al.,[52] prospectively, and Crevoisier et al.,[29] retrospectively, reported favorable outcomes and radiographic correction using a combination of scarf and Akin osteotomies. (Level IV evidence)

In contrast, Coetzee et al.[20] reported poor AOFAS outcome scores with an alarming complication rate in a prospective case series of scarf osteotomies (Level IV evidence). Complications included "troughing" (35%), rotational malunion (30%), metatarsal fracture (10%), and early recurrence of deformity (25%). While many authors have acknowledged the complexity of this osteotomy, several have provided technique tips and experience to accelerate the learning curve in mastering the procedure.[8,32,66,99,109,128] Despite one Level IV evidence case series condemning the procedure, the favorable results from numerous case series support a Grade B recommendation for the use of the scarf osteotomy in the treatment of primary hallux valgus.

Biomechanical Testing of Proximal First Metatarsal Osteotomies

A multitude of biomechanical studies have evaluated the initial stability of various metatarsal osteotomies not only to determine which osteotomies permit early MTP joint exercises but which also may allow early postoperative weightbearing.[1,14,49,54,62,74,81,107,121] Shereff et al.[107] suggested that the distal chevron osteotomy possessed greater inherent stability than a proximal osteotomy. Acevedo et al.[1] demonstrated that there was no statistical difference in fatigue endurance between the proximal chevron and Ludloff osteotomies in a cadaver model; in a sawbone model, the proximal chevron was significantly more stable in fatigue endurance testing than the crescentic and scarf osteotomies, but not the Ludloff osteotomy. Trnka et al.[121] determined that the Ludloff and scarf osteotomies exhibited greater load to failure when compared to the proximal crescentic and proximal chevron osteotomies.

McCluskey et al.[74] noted that a proximal chevron osteotomy stabilized with screw fixation tolerated a greater load to failure than the same osteotomy with Kirschner wire fixation and the proximal crescentic osteotomy stabilized with screws. Their findings are supported by Lian et al.[62] who noted that screw fixation for proximal chevron, crescentic, and long oblique osteotomies of the first metatarsal has superior load to failure characteristics than Kirschner wire or staple fixation.

Jung et al.[54] added that supplemental axial Kirschner wire fixation significantly enhanced the initial stability of the crescentic and Ludloff osteotomies. In a saw bones model, Jones et al.[49] reported that plate fixation provided a stronger construct than traditional screw fixation. Plate fixation is being applied to proximal first metatarsal osteotomies with greater frequency,[14,49] particularly in opening and closing wedge techniques; biomechanical data for plate fixation for these procedures had not yet been published.

FIRST TMT JOINT ARTHRODESIS (MODIFIED LAPIDUS PROCEDURE)

Lapidus[60] originally described an arthrodesis between the bases of the first and second metatarsals and the first intercuneiform joint to correct metatarsus primus varus in patients with hallux valgus. Currently, the modified Lapidus procedure incorporates an isolated arthrodesis of the first TMT joint with a lateral and plantar based closing wedge osteotomy of the medial cuneiform. This procedure has been indicated for the correction of metatarsus primus varus in patients with moderate to severe hallux valgus and hypermobility of the first ray. First ray hypermobility has been controversial and often questioned.[28,36,39,42]

Several retrospective case series (Level IV evidence) have collectively reported excellent radiographic correction, high rates of satisfaction, and significant improvements in the functional outcomes with the modified Lapidus procedure.[10,22,48,57,98,112] Faber et al.,[36] in a prospective, randomized study comparing the Hohmann procedure (distal first metatarsal osteotomy) to the Lapidus procedure in 101 feet (Level I evidence), found no significant differences in clinical outcomes, radiographic correction, or patient satisfaction. Feet with preoperatively identified hypermobility had equally favorable outcomes with either procedure when compared to feet without hypermobility. A prospective study (Level II evidence) evaluated the efficacy of the modified Lapidus procedure in the treatment of recurrent hallux valgus. Significant decreases in the pain score, and intermetatarsal and hallux valgus angles and increases in the AOFAS clinical ratings score were associated with an 81% satisfaction rate at 2 years after surgery.[21]

Early reports identified nonunion rates of 10% to 12% with the modified Lapidus procedure.[78,79,98] However, a more recent large clinical series reported a 4% nonunion rate and a 2% revision rate in feet treated with the Lapidus procedure. The authors reported that five of the eight patients with nonunions had previous bunion surgery and two patients smoked. Another study reported no nonunions with the use of the modified Lapidus procedure for the primary correction of hallux valgus. The uniformly successful results from numerous case series, supported by one Level I evidence study justify a Grade B recommendation for the use of the modified Lapidus procedure in the treatment of primary hallux valgus. Although the results of Coetzee et al.[21] suggest that the modified Lapidus procedure also is an effective salvage procedure for recurrent hallux valgus, this evidence from a single Level II study is insufficient (Grade I) to make a recommendation.

DOUBLE/TRIPLE OSTEOTOMIES FOR HALLUX VALGUS CORRECTION

A large IMA in combination with an increased DMAA cannot be corrected with a proximal osteotomy alone;

reducing the IMA will effectively increase the DMAA. In hallux valgus with a large IMA and increased DMAA, a double osteotomy, with a proximal first metatarsal osteotomy or medial opening wedge osteotomy of the first cuneiform (Cotton procedure) to correct the increased IMA and a distal medial closing wedge osteotomy of the first MT (Reverdin osteotomy) to reduce the DMAA, may be considered. With severe deformity, an opening wedge medial cuneiform osteotomy (Cotton procedure) can be added to a proximal first MT osteotomy and Reverdin to further correct the IMA, creating a triple osteotomy.[25] When associated with hallux valgus interphalangeus, an Akin osteotomy also should be added as none of the aforementioned osteotomies directly corrects angulation in the hallux proximal phalanx.[25] One Level IV evidence investigation suggested favorable outcomes in a limited number of patients undergoing multiple osteotomies for a more comprehensive hallux valgus correction.[25] Several case series (Level IV evidence) have reported favorable outcomes with Akin osteotomies added to distal chevron osteotomies[77,117] and more proximal osteotomies.[29,52] The limited published Level IV evidence available for double and triple osteotomies is insufficient (Grade I) to make a recommendation for their use in the management of hallux valgus deformity.

FIRST MTP JOINT ARTHRODESIS

Arthrodesis of the first MTP joint generally is reserved for patients with severe hallux valgus deformity, or patients in whom hallux valgus is associated with arthrosis of the joint, failed prior surgical correction, or a neuromuscular disorder; it also is used as part of the reconstruction of a rheumatoid forefoot. Coughlin et al.[27] (Level IV evidence) reported significant decreases in pain after fusion for moderate to severe hallux valgus. There were no dissatisfied patients and most patients were able to wear conventional or comfort shoewear at an average of 8 years after surgery. However, radiographic progression of arthritis was evident at the interphalangeal joint in seven of the 21 feet in their series.[27] Grimes and Coughlin[43] reported satisfactory outcomes at an average followup of 8 years in a retrospective case series of first MTP joint arthrodeses performed for failed hallux valgus procedures. When fusion was compared to resection of the first MTP joint for reconstruction of the rheumatoid forefoot (Level II evidence), no differences were detected other than a significant increase in the duration of the procedure for the group undergoing arthrodesis.[44] Salvage of a failed Keller procedure with fusion was associated with a higher rate of satisfaction and AOFAS clinical rating score and avoided the onset of postoperative valgus or cock-up deformity when compared to isolated soft-tissue release (Level III evidence).[65] A case series (Level IV evidence) evaluating the results of arthrodesis for hallux valgus in children with cerebral palsy reported high rates of fusion and satisfaction with the procedure. Together, these investigations favor a Grade B recommendation for the use of arthodesis in the management of a wide spectrum of hallux valgus deformities.

SUMMARY POINTS

1. A distal chevron osteotomy appears to be a predictable treatment for mild and some moderate hallux valgus deformities.
2. The addition of a limited lateral capsular release or adductor hallucis tenotomy or both to a distal chevron osteotomy does not seem to increase the risk of first metatarsal osteonecrosis.
3. Multiple proximal first metatarsal procedures, when combined with a distal soft-tissue procedure, appear to provide satisfactory treatment for moderate-to-severe hallux valgus deformity (hallux valgus associated with metatarsus primus varus). These include proximal crescentic, proximal chevron, proximal oblique (Ludloff), proximal closing wedge, and scarf osteotomies and the Lapidus procedure.
4. First metatarsophalangeal joint arthrodesis appears to offer satisfactory outcome in patients with severe hallux valgus.

REFERENCES

1. **Acevedo, JI; Sammarco, VJ; Boucher, HR; et al.:** Mechanical comparison of cyclic loading in five different first metatarsal shaft osteotomies. Foot Ankle Int. **23**:711–716, 2002.
2. **Allen, DM; Nunley JA, 2nd:** Measurement of the first/second intermetatarsal angle following proximal oblique metatarsal osteotomy. Foot Ankle Int. **23**:64–67, 2002.
3. **Aminian, A; Kelikian, A; Moen, T:** Scarf osteotomy for hallux valgus deformity: an intermediate followup of clinical and radiographic outcomes. Foot Ankle Int. **27**:883–886, 2006.
4. **Anderson, RB; Davis, WH:** Internal fixation of the proximal chevron osteotomy. Foot Ankle Int. **18**:371–372, 1997.
5. **Austin, DW; Leventen, EO:** A new osteotomy for hallux valgus: a horizontally directed "V" displacement osteotomy of the metatarsal head for hallux valgus and primus varus. Clin. Orthop. **157**:25–30, 1981.
6. **Badwey, TM; Dutkowsky, JP; Graves, SC; Richardson, EG:** An anatomical basis for the degree of displacement of the distal chevron osteotomy in the treatment of hallux valgus. Foot Ankle Int. **18**:213–215, 1997.
7. **Bardelli, M; Gusso, MI; Allegra, M:** [Hallux valgus treated by the Keller-Lelievre-Viladot technic: indications and results]. Arch. Putti Chir. Organi. Mov. **33**:201–211, 1983.
8. **Barouk, LS:** Scarf osteotomy for hallux valgus correction. Local anatomy, surgical technique, and combination with other forefoot procedures. Foot Ankle Clin. **5**:525–558, 2000.
9. **Baumhauer, JF; Nawoczenski, DA; DiGiovanni, BF; Wilding, GE:** Reliability and validity of the American Orthopaedic Foot and Ankle Society clinical rating scale: a pilot study for the hallux and lesser toes. Foot Ankle Int. **27**:1014–1019, 2006.
10. **Bednarz, PA; Manoli, A 2nd:** Modified Lapidus procedure for the treatment of hypermobile hallux valgus. Foot Ankle Int. **21**:816–821, 2000.

11. **Beischer, AD; Ammon, P; Corniou, A; Myerson, M:** Three-dimensional computer analysis of the modified Ludloff osteotomy. Foot Ankle Int. **26**:627–632, 2005.
12. **Button, G; Pinney, S:** A meta-analysis of outcome rating scales in foot and ankle surgery: is there a valid, reliable, and responsive system? Foot Ankle Int. **26**:521–525, 2004.
13. **Caminear, DS; Pavlovich, R Jr; Pietrzak, WS:** Fixation of the chevron osteotomy with an absorbable copolymer pin for treatment of hallux valgus deformity. J. Foot Ankle Surg. **44**:203–210, 2005.
14. **Campbell, JT; Schon, LC; Parks, BG; Wang, Y; Berger, BI:** Mechanical comparison of biplanar proximal closing wedge osteotomy with plantar plate fixation versus crescentic osteotomy with screw fixation for the correction of metatarsus primus varus. Foot Ankle Int. **19**:293–299, 1998.
15. **Capasso, G; Testa, V; Maffulli, N; Barletta, L:** Molded arthroplasty and transfer of the extensor hallucis brevis tendon. A modification of the Keller-Lelievre operation. Clin. Orthop. **308**:43–49, 1994.
16. **Chen, YJ; Hsu, RW; Shih, HN; Huang, TJ; Hsu, KY:** Distal chevron osteotomy with intra-articular lateral soft-tissue release for treatment of moderate to severe hallux valgus deformity. J. Formos. Med. Assoc. **95**:776–781, 1996.
17. **Chi, TD; Davitt, J; Younger, A; Holt, S; Sangeorzan, BJ:** Intra- and inter-observer reliability of the distal meatarsal articular angle in adult hallux valgus. Foot Ankle Int. **23**:722–726, 2006.
18. **Chiodo, CP; Schon, LC; Myerson, MS:** Clinical results with the Ludloff osteotomy for correction of adult hallux valgus. Foot Ankle Int. **25**:532–536, 2004.
19. **Chou, LB; Mann, RA; Casillas, MM:** Biplanar chevron osteotomy. Foot Ankle Int. **19**:579–584, 1998.
20. **Coetzee, JC:** Scarf osteotomy for hallux valgus repair: the dark side. Foot Ankle Int. **24**:29–33, 2003.
21. **Coetzee, JC; Resig, SG; Kuskowski, M; and Saleh, KJ:** The Lapidus procedure as salvage after failed surgical treatment of hallux valgus: a prospective cohort study. J. Bone Joint Surg. **85-A**:60–65, 2003.
22. **Coetzee, JC; Wickum, D:** The Lapidus procedure: a prospective cohort outcome study. Foot Ankle Int. **25**:526–531, 2004.
23. **Corless, JR:** A modification of the Mitchell procedure. J. Bone Joint Surg. **55**:138, 1976.
24. **Coughlin MJ:** Hallux vlagus in men: effect of the distal metatarsal articular angle on hallux valgus correction. Foot Ankle Int. **18**:463–470, 1997.
25. **Coughlin, MJ; Carlson, RE:** Treatment of hallux valgus with an increased distal metatarsal articular angle: evaluation of double and triple first ray osteotomies. Foot Ankle Int. **20**:762–770, 1999.
26. **Coughlin, MJ; Freund, E:** Roger A. Mann Award. The reliability of angular measurements in hallux valgus deformities. Foot Ankle Int. **22**:369–379, 2001.
27. **Coughlin, MJ; Grebing, BR; and Jones, CP:** Arthrodesis of the first metatarsophalangeal joint for idiopathic hallux valgus: intermediate results. Foot Ankle Int. **26**:783–792, 2005.
28. **Coughlin, MJ; Shurnas, PS:** Hallux valgus in men. Part II: First ray mobility after bunionectomy and factors associated with hallux valgus deformity. Foot Ankle Int. **24**:73–78, 2003.
29. **Crevoisier, X; Mouhsine, E; Ortolano, V; Udin, B; Dutoit, M:** The scarf osteotomy for the treatment of hallux valgus deformity: a review of 84 cases. Foot Ankle Int. **22**:970–976, 2001.
30. **Crosby, LA; Bozarth, GR:** Fixation comparison for chevron osteotomies. Foot Ankle Int. **19**:41–43, 1998.
31. **Deorio, JK; Ware, AW:** Single absorbable polydioxanone pin fixation for distal chevron bunion osteotomies. Foot Ankle Int. **22**:832–835, 2001.
32. **Dereymaeker, G:** Scarf osteotomy for correction of hallux valgus. Surgical technique and results as compared to distal chevron osteotomy. Foot Ankle Clin. **5**:513–524, 2000.
33. **Donley, BG; Vaughn, RA; Stephenson, KA; Richardson, EG:** Keller resection arthroplasty for treatment of hallux valgus deformity: increased correction with fibular sesamoidectomy. Foot Ankle Int. **23**:699–703, 2002.
34. **Dreeben, S; Mann, RA:** Advanced hallux valgus deformity: long-term results utilizing the distal soft tissue procedure and proximal metatarsal osteotomy. Foot Ankle Int. **17**:142–144, 1996.
35. **Easley, ME; Kiebzak, GM; Davis, WH; Anderson, RB:** Prospective, randomized comparison of proximal crescentic and proximal chevron osteotomies for correction of hallux valgus deformity. Foot Ankle Int. **17**:307–316, 1996.
36. **Faber, FW; Mulder, PG; Verhaar, JA:** Role of first ray hypermobility in the outcome of the Hohmann and the Lapidus procedure. A prospective, randomized trial involving one hundred and one feet. J. Bone Joint Surg. **86-A**:486–495, 2004.
37. **Gallentine JW; DeOrio MJ:** Bunion surgery using locking-plate fixation of proximal metatarsal chevron osteotomies. Foot Ankle Int. **28**:361–368, 2007.
38. **Gill, LH; Martin, DF; Coumas, JM; Kiebzak, GM:** Fixation with bioabsorbable pins in chevron bunionectomy. J. Bone Joint Surg. **79-A**:1510–1518, 1997.
39. **Glasoe, WM; Coughlin, MJ:** A critical analysis of Dudley Morton's concept of disordered foot function. J. Foot Ankle Surg. **45**:147–155, 2006.
40. **Granberry, WM; Hickey, CH:** Hallux valgus correction with metatarsal osteotomy: effect of a lateral distal soft tissue procedure. Foot Ankle Int. 16:132–138, 1995.
41. **Grandi, A; Neri, M:** [Critical review of cases operated for hallux valgus using the Keller-Lelievre-Viladot method]. Chir. Organi. Mov. **71**:115–117, 1986.
42. **Grebing, BR; Coughlin, MJ:** Evaluation of Morton's theory of second metatarsal hypertrophy. J. Bone Joint Surg. **86-A**:1375–1386, 2004.
43. **Grimes, JS; Coughlin, MJ:** First metatarsophalangeal joint arthrodesis as a treatment for failed hallux valgus surgery. Foot Ankle Int. **27**:887–893, 2006.
44. **Grondal, L; Hedstrom, M; Stark, A:** Arthrodesis compared to Mayo resection of the first metatarsophalangeal joint in total rheumatoid forefoot reconstruction. Foot Ankle Int. **26**:135–139, 2005.
45. **Hofstaetter, SG; Gruber, F; Ritschl, P; Trnka, HJ:** [The modified Ludloff osteotomy for correction of severe metatarsus primus varus with hallux valgus deformity]. Z. Orthop. Ihre Grenzgeb. **144**:141–147, 2006.
46. **Johnson, JE; Clanton, TO; Baxter, DE; Gottlieb, MS:** Comparison of Chevron osteotomy and modified McBride bunionectomy for correction of mild to moderate hallux valgus deformity. Foot Ankle **12**:61–68, 1991.
47. **Johnson, KA; Cofield, RH; Morrey, BF:** Chevron osteotomy for hallux valgus. Clin. Orthop. **142**:44–47, 1979.
48. **Johnson, K. A., and Kile, T. A.:** Hallux valgus due to cuneiform-metatarsal instability. J South Orthop Assoc, **3(4)**:273-82, 1994.
49. **Jones, C; Coughlin, M; Petersen, W; Herbot, M; Paletta, J:** Mechanical comparison of two types of fixation for proximal first metatarsal crescentic osteotomy. Foot Ankle Int. **26**:371–374, 2005.
50. **Jones, C; Coughlin, M; Villadot, R; Golano, P:** Proximal crescentic metatarsal osteotomy: the effect of saw blade orientation on first ray elevation. Foot Ankle Int. **26**:152–157, 2005.
51. **Jones, KJ; Feiwell, LA; Freedman, EL; Cracchiolo, A 3rd:** The effect of chevron osteotomy with lateral capsular release on the blood supply to the first metatarsal head. J. Bone Joint Surg. **77-A**:197–204, 1995.
52. **Jones, S; Al Hussainy, HA; Ali, F; Betts, RP; Flowers, MJ:** Scarf osteotomy for hallux valgus. A prospective clinical and pedobarographic study. J. Bone Joint Surg. **86-B**:830–836, 2004.
53. **Jordan, HH; Brodsky, AE:** Keller operation for hallux valgus and hallux rigidus. Arch. Surg. **62**:586–596, 1951.
54. **Jung, HG; Guyton, GP; Parks, BG; et al.:** Supplementary axial Kirschner wire fixation for crescentic and Ludloff proximal

metatarsal osteotomies: a biomechanical study. Foot Ankle Int. **26**:620–626, 2005.
55. **Kitaoka, HB; Alexander, IJ; Adelaar, RS:** Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. **15**:349–353, 1994.
56. **Kitaoka, HB; Franco, MG; Weaver, AL; Ilstrup, DM:** Simple bunionectomy with medial capsulorrhaphy. Foot Ankle **12**:86–91, 1991.
57. **Kopp, FJ; Patel, MM; Levine, DS; Deland, JT:** The modified Lapidus procedure for hallux valgus: a clinical and radiographic analysis. Foot Ankle Int. **26**:913–917, 2005.
58. **Kristen, KH; Berger, C; Stelzig, S; et al.:** The SCARF osteotomy for the correction of hallux valgus deformities. Foot Ankle Int. **23**:221–229, 2002.
59. **Kuhn, MA; Lippert, FG 3rd; Phipps, MJ; Williams, C:** Blood flow to the metatarsal head after chevron bunionectomy. Foot Ankle Int. **26**:526–529, 2005.
60. **Lapidus, PW:** Operative correction of the metatarsus varus primus in hallux valgus. Surg. Gynecol. Obstet. **58**:183–191, 1934.
61. **LeLievre, J; LeLievre, J-F:** [Technique chirurgicale de l'avant pied]. LeLievre J (ed.) In *Pathologie due Pied,* Edited by LeLievre, J, Paris, Masson et Cie, pp. 809-812, 1967.
62. **Lian, GJ; Markolf, K; Cracchiolo, A 3rd:** Strength of fixation constructs for basilar osteotomies of the first metatarsal. Foot Ankle **13**:509–514, 1992.
63. **Lorei, TJ; Kinast, C; Klarner, H; Rosenbaum, D:** Pedographic, clinical, and functional outcome after scarf osteotomy. Clin. Orthop. 2006.
64. **Ludloff, K:** Die Beseitigung des Hallux Valgus durch die schraege planta-dorsale Osteotomie des Metatarsus. I. Arch. Klin. Chir. **110**:364–387, 1918.
65. **Machacek, F Jr; Easley, ME; Gruber, F; Ritschl, P; Trnka, HJ:** Salvage of a failed Keller resection arthroplasty. J. Bone Joint Surg. **86-A**:1131–1138, 2004.
66. **Madhav, R; Singh, D:** Re: Scarf osteotomy for hallux valgus repair: the dark side, Coetzee, JC, Foot Ankle Int. **24**:29–33, 2003. Foot Ankle Int, **24**:572; author reply 572, 2003.
67. **Mann, R; Coughlin, MJ:** Adult hallux valgus. In Coughlin, M; Mann, RA, *Surgery of the Foot and Ankle*, Philadelphia, Mosby, pp. 150-269, 1999.
68. **Mann, RA:** Distal soft tissue procedure and proximal metatarsal osteotomy for correction of hallux valgus deformity. Orthopedics **13**:1013–1018, 1990.
69. **Mann, RA; Donatto, KC:** The chevron osteotomy: a clinical and radiographic analysis. Foot Ankle Int. **18**:255–261, 1997.
70. **Mann, RA; Pfeffinger, L:** Hallux valgus repair. DuVries modified McBride procedure. Clin. Orthop. **272**:213–218, 1991.
71. **Mann, RA; Rudicel, S; Graves, SC:** Repair of hallux valgus with a distal soft-tissue procedure and proximal metatarsal osteotomy. A long-term follow-up. J. Bone Joint Surg. **74-A**:124–129, 1992.
72. **Markbreiter, LA; Thompson, FM:** Proximal metatarsal osteotomy in hallux valgus correction: a comparison of crescentic and chevron procedures. Foot Ankle Int. **18**:71–76, 1997.
73. **McBride, ED:** The conservative operation for bunions. J. Bone Joint Surg. **10**:735, 1928.
74. **McCluskey, LC; Johnson, JE; Wynarsky, GT; Harris, GF:** Comparison of stability of proximal crescentic metatarsal osteotomy and proximal horizontal "V" osteotomy. Foot Ankle Int. **15**:263–270, 1994.
75. **Meier, PJ; Kenzora, JE:** The risks and benefits of distal first metatarsal osteotomies. Foot Ankle **6**:7–17, 1985.
76. **Miller, JW:** Distal first metatarsal displacement osteotomy. Its place in the schema of bunion surgery. J. Bone Joint Surg. **56-A**:923–931, 1974.
77. **Mitchell, LA; Baxter, DE:** A Chevron-Akin double osteotomy for correction of hallux valgus. Foot Ankle **12**:7–14, 1991.
78. **Myerson, M:** Metatarsocuneiform arthrodesis for treatment of hallux valgus and metatarsus primus varus. Orthopedics **13**:1025–1031, 1990.
79. **Myerson, M; Allon, S; McGarvey, W:** Metatarsocuneiform arthrodesis for management of hallux valgus and metatarsus primus varus. Foot Ankle **13**:107–115, 1992.
80. **Nery, C; Barroco, R; Ressio, C:** Biplanar chevron osteotomy. Foot Ankle Int. **23**:792–798, 2002.
81. **Newman, AS; Negrine, JP; Zecovic, M; Stanford, P; Walsh, WR:** A biomechanical comparison of the Z step-cut and basilar crescentic osteotomies of the first metatarsal. Foot Ankle Int **21**:584–587, 2000.
82. **Okuda, R; Kinoshita, M; Morikawa, J; Jotoku, T; Abe, M:** Surgical treatment for hallux valgus with painful plantar callosities. Foot Ankle Int. **22**:203–208, 2001.
83. **Perugia, D; Basile, A; Gensini, A; Stopponi, M; Simeonibus, AU:** The scarf osteotomy for severe hallux valgus. Int. Orthop. **27**:103–106, 2003.
84. **Peterson, DA; Zilberfarb, JL; Greene, MA; Colgrove, RC:** Avascular necrosis of the first metatarsal head: incidence in distal osteotomy combined with lateral soft tissue release. Foot Ankle Int. **15**:59–63, 1994.
85. **Petroutsas, J; Trnka, HJ:** The Ludloff osteotomy for correction of hallux valgus. Op. Orthop. Traumatol. **17**:102–117, 2005.
86. **Pfeffinger, LL:** The modified McBride procedure. Orthopedics 13:979-84, 1990.
87. **Pochatko, DJ; Schlehr, FJ; Murphey, MD; Hamilton, JJ:** Distal chevron osteotomy with lateral release for treatment of hallux valgus deformity. Foot Ankle Int. **15**:457–461, 1994.
88. **Resch, S; Ryd, L; Stenstrom, A; Johnsson, K; Reynisson, K:** Measuring hallux valgus: a comparison of conventional radiography and clinical parameters with regard to measurement accuracy. Foot Ankle Int. **16**:267–270, 1995.
89. **Resch, S; Stenstrom, A; Egund, N:** Proximal closing wedge osteotomy and adductor tenotomy for treatment of hallux valgus. Foot Ankle**9**:272–280, 1989.
90. **Resch, S; Stenstrom, A; Gustafson, T:** Circulatory disturbance of the first metatarsal head after Chevron osteotomy as shown by bone scintigraphy. Foot Ankle **13**:137–142, 1992.
91. **Resch, S; Stenstrom, A; Reynisson, K; Jonsson, K:** Chevron osteotomy for hallux valgus not improved by additional adductor tenotomy. A prospective, randomized study of 84 patients. Acta Orthop. Scand. **65**:541–544, 1994.
92. **Richardson, EG:** Keller resection arthroplasty. Orthopedics **13**: 1049–1053, 1990.
93. **Rogers WA:** Hallux valgus, weak foot, and the Keller operations: an end-result study. Surg. Clin. North Am. **27**:1295–1302, 1947.
94. **Saltzman, CL, Brandser, EA; Berbaum, KS; et al.:** Reliabiltiy of standard foot radiographic measurements. Foot Ankle Int. **15**:661–665, 1994.
95. **Sammarco, GJ; Brainard, BJ; Sammarco, VJ:** Bunion correction using proximal Chevron osteotomy. Foot Ankle **14**:8–14, 1993.
96. **Sammarco, GJ; Conti, SF:** Proximal Chevron metatarsal osteotomy: single incision technique. Foot Ankle **14**:44–47, 1993.
97. **Sammarco, GJ; Russo-Alesi, FG:** Bunion correction using proximal chevron osteotomy: a single-incision technique. Foot Ankle Int. **19**:430–437, 1998.
98. **Sangeorzan, BJ; Hansen, ST Jr:** Modified Lapidus procedure for hallux valgus. Foot Ankle **9**:262–266, 1989.
99. **Saragas, NP:** Technique tip: preventing "troughing" with the scarf osteotomy. Foot Ankle Int. **26**:779–780, 2005.
100. **Sarda, G; Bertini, G; Celenza, M; Guagnini, M; De Tullio, V:** [Review of 64 cases of hallux valgus surgically treated with the Keller-Leviere technique]. Minerva Med **81**(7–8 Suppl):121–122, 1990.
101. **Schneider, W; Aigner, N; Pinggera, O; Knahr, K:** Chevron osteotomy in hallux valgus. Ten-year results of 112 cases. J. Bone Joint Surg. **86-B**:1016–1020, 2004.

102. **Schneider, W; Csepan, R; Kasparek, M; Pinggera, O; Knahr, K:** Intra-and interobserver repeatability of radiogrpahic measurements in hallux surgery: improvement and validation of a method. Acta Orthop. Scand. **73**:670–673, 2002
103. **Schneider, W; Csepan, R; Knar, K:** Reproducibility of the radiographic metatarsophalangeal angle in hallux surgery. J. Bone Joint Surg. **85-A**:494–499, 2003.
104. **Schneider, W; Knahr, K:** Keller procedure and chevron osteotomy in hallux valgus: five-year results of different surgical philosophies in comparable collectives. Foot Ankle Int. **23**:321–329, 2002.
105. **Schneider, W; Knahr, K:** Metarsophalangeal and intermetatarsal angle: different values and interpretation of postoperative results dependent on the technique of measurement. Foot Ankle Int. **19**:532–536, 1998.
106. **Schneider, W; Knahr, K:** Poor agreement beteen prospective and retrospective assessment of hallux surgery using the AOFAS Hallux Scale. Foot Ankle Int. **26**:1062–1066, 2005.
107. **Shereff, MJ; Sobel, MA; Kummer, FJ:** The stability of fixation of first metatarsal osteotomies. Foot Ankle **11**:208–211, 1991.
108. **Silver, D:** The operative treatment of hallux valgus. J. Bone Joint Surg. 5:225, 1923.
109. **Smith, AM; Alwan, T; Davies, MS:** Perioperative complications of the Scarf osteotomy. Foot Ankle Int. **24**:222–227, 2003.
110. **SooHoo, NF; Vyas, R; Samimi, D:** Responsiveness of the foot function index, AOFAS clinical rating systems, and SF-36 after foot and ankle surgery. Foot Ankle Int. **27**:930–934, 2006.
111. **Thomas, RL; Espinosa, FJ; Richardson, EG:** Radiographic changes in the first metatarsal head after distal chevron osteotomy combined with lateral release through a plantar approach. Foot Ankle Int. **15**:285–292, 1994.
112. **Thompson, IM; Bohay, DR; Anderson, JG:** Fusion rate of first tarsometatarsal arthrodesis in the modified Lapidus procedure and flatfoot reconstruction. Foot Ankle Int. **26**:698–703, 2005.
113. **Thordarson, D; Ebramzadeh, E; Moorthy, M; Lee, J; Rduicel, S:** Correlation of hallux valgus surgical outcome with AOFAS forefoot score and radiological parameters, Foot Ankle Int. **26**:698–703, 2005
114. **Thordarson, DB; Ebramzadeh, E; Rudicel, SA; Baxter, A:** Age-adjusted baseline data for women with hallux valgus undergoing corrective surgery. J. Bone Joint Surg. **87-A**:66–75, 2005.
115. **Thordarson, DB; Leventen, EO:** Hallux valgus correction with proximal metatarsal osteotomy: two-year follow-up. Foot Ankle **13**:321–326, 1992.
116. **Thordardson, DB; Rudicel, SA; Ebramzadeh, E; Gill, LH:** Outcome study of hallux valgus surgery—an AOFAS multi-center study. Foot Ankle Int. **22:956–959, 2001.**
117. **Tollison, ME; Baxter, DE:** Combination chevron plus Akin osteotomy for hallux valgus: should age be a limiting factor? Foot Ankle Int. **18**:477–481, 1997.
118. **Toolan, BC; Wright Quinones, VJ; Cunningham BJ, Brage, ME:** An evaluation of the use of retrospectively acquired preoperative AOFAS clinical rating scores to assess surgical outcome after elective foot and ankle surgery. Foot Ankle Int. **22**:775–778, 2001.
119. **Trnka, HJ; Hofmann, S; Salzer, M; Ritschl, P:** Clinical and radiological results after Austin bunionectomy for treatment of hallux valgus. Arch. Orthop. Trauma Surg. **115**:171–175, 1996.
120. **Trnka, HJ; Muhlbauer, M; Zembsch, A; et al.:** Basal closing wedge osteotomy for correction of hallux valgus and metatarsus primus varus: 10- to 22-year follow-up. Foot Ankle Int. **20**:171–177, 1999.
121. **Trnka, HJ; Parks, BG; Ivanic, G; et al.:** Six first metatarsal shaft osteotomies: mechanical and immobilization comparisons. Clin. Orthop. **381**:256–265, 2000.
122. **Trnka, HJ; Zembsch, A; Easley, ME; et al.:** The chevron osteotomy for correction of hallux valgus. Comparison of findings after two and five years of followup. J. Bone Joint Surg. **82-A**:1373–1378, 2000.
123. **Trnka, HJ; Zembsch, A; Wiesauer, H; et al.:** Modified Austin procedure for correction of hallux valgus. Foot Ankle Int. **18**:119–127, 1997.
124. **Turnbull, T; Grange, W:** A comparison of Keller's arthroplasty and distal metatarsal osteotomy in the treatment of adult hallux valgus. J. Bone Joint Surg. **68-B**:132–137, 1986.
125. **Veri, JP; Pirani, SP; Claridge, R:** Crescentic proximal metatarsal osteotomy for moderate to severe hallux valgus: a mean 12.2 year follow-up study. Foot Ankle Int. **22**:817–822, 2001.
126. **Viladot, R; Rochera, R; Alvarez, F; Pasarin, A:** [Resection arthroplasty in the treatment of hallux valgus]. Orthopade **25**:324–331, 1996.
127. **Vittetoe, DA; Saltzman, CL; Krieg, JC; Brown, TD:** Validity and reliability of the first distal metatarsal articular angle. Foot Ankle Int. **15**:541–547, 1994.
108. **Weil, LS:** Scarf osteotomy for correction of hallux valgus. Historical perspective, surgical technique, and results. Foot Ankle Clin **5**:559–580, 2000.
109. **Zembsch, A; Trnka, HJ; Ritschl, P:** Correction of hallux valgus. Metatarsal osteotomy versus excision arthroplasty. Clin. Orthop. **376**:183–194, 2000.
110. **Zettl, R; Trnka, HJ; Easley, M; Salzer, M; Ritschl, P:** Moderate to severe hallux valgus deformity: correction with proximal crescentic osteotomy and distal soft-tissue release. Arch. Orthop. Trauma Surg. **120**:397–402, 2000.