Foot & Ankle

EOR | VOLUME 1 | AUGUST 2016
DOI: 10.1302/2058-5241.1.000005
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EFORT open reviews

Treatment of hallux valgus deformity

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- Hallux valgus deformity is a very common pathological condition which commonly produces painful disability. It is characterised as a combined deformity with a malpositioning of the first metatarsophalangeal joint caused by a lateral deviation of the great toe and a medial deviation of the first metatarsal bone.
- Taking the patient's history and a thorough physical examination are important steps. Anteroposterior and lateral weight-bearing radiographs of the entire foot are crucial for adequate assessment in the treatment of hallux valgus.
- Non-operative treatment of the hallux valgus cannot correct the deformity. However, insoles and physiotherapy in combination with good footwear can help to control the symptoms.
- There are many operative techniques for hallux valgus correction. The decision on which surgical technique is used depends on the degree of deformity, the extent of degenerative changes of the first metatarsophalangeal joint and the shape and size of the metatarsal bone and phalangeal deviation. The role of stability of the first tarsometatarsal joint is controversial.
- Surgical techniques include the modified McBride procedure, distal metatarsal osteotomies, metatarsal shaft osteotomies, the Akin osteotomy, proximal metatarsal osteotomies, the modified Lapidus fusion and the hallux joint fusion. Recently, minimally invasive percutaneous techniques have gained importance and are currently being evaluated more scientifically.
- Hallux valgus correction is followed by corrective dressings of the great toe post-operatively. Depending on the procedure, partial or full weight-bearing in a post-operative shoe or cast immobilisation is advised. Post-operative radiographs are taken in regular intervals until osseous healing is achieved.

Keywords: hallux valgus; bunion; metatarsus primus varus; osteotomy, treatment

Cite this article: Fraissler L, Konrads C, Hoberg M, Rudert M, Walcher M. Treatment of hallux valgus deformity. *EFORT Open Rev* 2016;1:295-302. DOI: 10.1302/2058-5241.1.000005.

Introduction

The term hallux valgus was first mentioned by Carl Hueter in 1870.[1] The hallux valgus complex is characterised as a combined deformity with a malpositioning in the first metatarsophalangeal (MTP) joint with lateral deviation of the great toe and medial deviation of the first metatarsal bone.[2] It is the most common pathology of the big toe. Coughlin reported in a prospective study with 103 patients a bilateral deformity in 84% of the cases.[3] While there is disagreement regarding the age of onset of hallux valgus, a female predilection is generally acknowledged. In most cases hallux valgus has a multi-factorial origin: genetic predisposition, occupation, type of footwear and pes planus have been identified as predisposing causes of hallux valgus with little if any solid supporting evidence.

Clinical and radiological presentation

Evaluation of the hallux valgus starts with careful history-taking. Typical complaints are pain over the medial eminence, local skin or bursa irritation, medial deviation of the first ray, lateral deviation and pronation of the great toe. Physical examination usually starts with observing the patient's gait. The degree of hallux deformity and the presence of pes planus are evaluated with the patient standing. Range of motion of the ankle, subtalar, transverse tarsal and MTP joints, and first tarsometatarsal (TMT) joint mobility can be evaluated with the patient seated.[4] Limited range of motion in the first MTP joint indicates degenerative changes. The mobility of the first TMT joint is evaluated with the tip of one thumb beneath the second metatarsal head and the tip of the other thumb beneath the plantar aspect of the first. Dorsally directed force on the first metatarsal head then allows evaluation of the degree of instability of the first metatarsal with respect to the second.[5] Klaue defined hypermobility as a motion exceeding between 8 and 10 mm without a firm end-point.[6]

Anteroposterior (AP) and lateral weight-bearing radiographs of the entire foot are recommended for diagnostics and angular measurements to define the extent of the deformity. Additionally, other conditions such as

instabilities, joint degenerations and malalignment of other joints of the foot are assessed.

In weight-bearing AP radiographs, specific angles have been defined to quantify and understand the deformity (Fig. 1).

The hallux valgus angle (HVA) is defined as the angle between the shaft axis of the first metatarsal and the proximal phalanx of the hallux (standard 15° angle).

Several authors have suggested angles greater than 15° as pathological values.[7-10] The intermetatarsal angle (IMA) is the angle between the shaft axis of the first and second metatarsal. Values of more than 9° are usually seen as pathological.[7-10] The hallux valgus interphalangeus angle (HVI) is formed between the metaphyseal and diaphyseal axis of the first proximal phalanx and has a 10° upper limit.[7,8,11] The distal metatarsal articular angle (DMAA) is measured between the distal articular surface and the perpendicular line to the longitudinal axis of the first metatarsal. It is considered non-pathological at up to 10° in angle.[11,12] There is some variability in the literature regarding absolute radiographic measurements to define the degree of hallux valgus deformity (mild, moderate, severe), and according to Easley and Trnka, no evidence exists to support absolute radiographic measurements.[13] A classification to describe the position of the sesamoids in relation to the first metatarsal has been introduced by Hardy and Clapham, but is rarely used in clinical practice.[9]

Non-operative treatment

Non-operative management of hallux valgus deformity will not produce deformity correction, but can relieve its symptoms. Non-surgical care should especially be considered in patients with general hypermobility, ligamentous laxity or neuromuscular disorders because of the high recurrence rate,[14] and of course in the presence of absolute contraindications to surgical correction like a relevant peripheral arterial vessel disease, or relative contraindications like diabetes or smoking. A non-symptomatic mild hallux valgus should be checked periodically, both clinically and radiologically to evaluate progression of the deformity. Non-operative treatment includes footwear modification such as accommodating shoes with a wide toe-box, padding over the medial eminence, adjustments to the shoe, night splints or physically therapy and insoles.[13,14] Wu et al reported on the use of botulinum toxin type A in hallux valgus deformity with reduction of pain for up to six months, as well as improved HVA and disability scores.[15] However, non-operative management cannot correct hallux valgus deformity, whereas successful surgery improves functional outcome.

Operative treatment

More than 100 different operative techniques have been described for the correction of hallux valgus.

Fig. 1 Angular measurements. a) intermetatarsal angle (IMA); b) hallux valgus angle (HVA); c) hallux valgus interphalangeus angle (HVI); d) position of the medial sesamoid in relation to the axis of the metatarsal head; e) distal metatarsal articular angle (DMAA).

Overall, the appearance and the degree of the deformity determine surgical treatment strategies. Depending on the degree of the deformity, potential degenerative changes of the first MTP joint, size and the shape of the metatarsal and the joint congruency, a suitable technique is chosen. The role of hypermobility of the first TMT joint is controversial. To avoid confusion, we present our treatment algorithm for hallux valgus deformities (Fig. 2).

Modified McBride procedure

The modified McBride procedure (distal soft-tissue procedure; Fig. 3) is widely used as an adjunct to osseous hallux valgus corrective techniques. The combination of

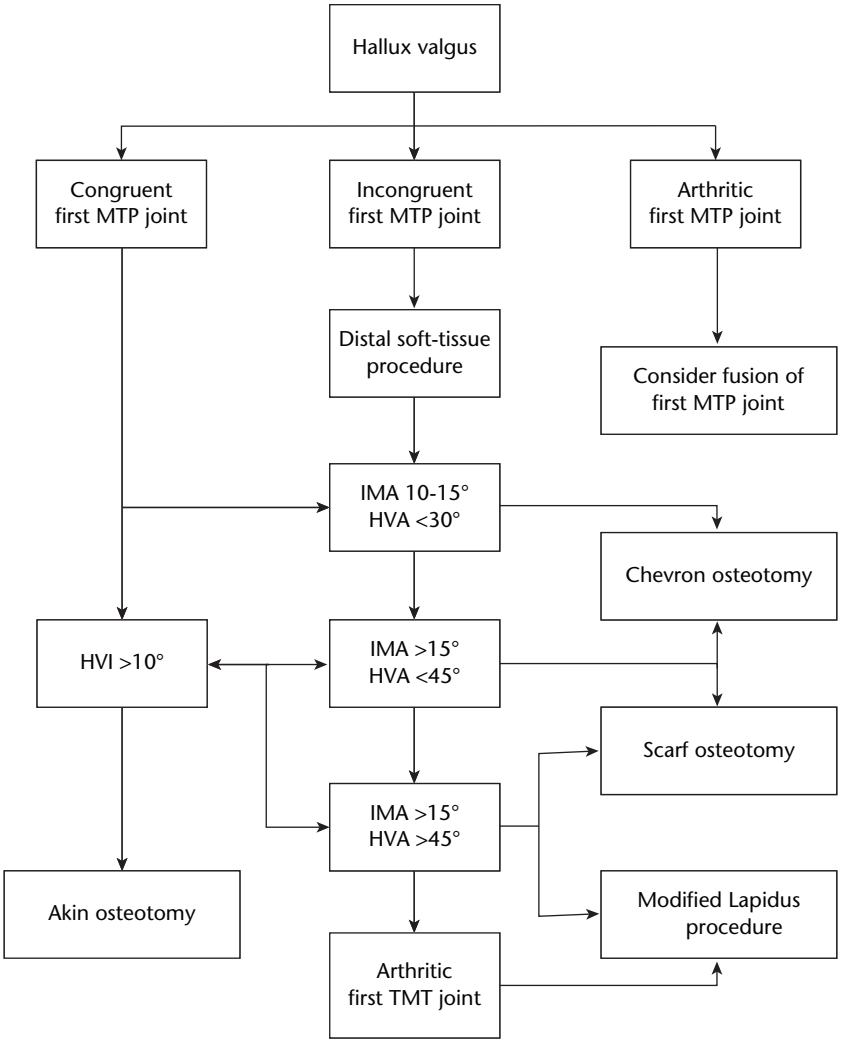

Fig. 2 Operative treatment algorithm.

Fig. 3 Incision for McBride procedure.

the distal soft-tissue procedure and metatarsal osteotomy shows good overall results.[16-19] The modified McBride procedure typically includes a medial capsulotomy and subsequent capsular plication, a release of the adductor hallucis, the lateral capsule, and the sesamoid ligaments and a controlled varus stress to the first MTP joint.[19,20]

There are two surgical approaches for lateral soft-tissue release: the dorsal first web-space approach and the medial transarticular approach through a single medial incision. The dorsal-first web-space approach requires an additional incision, but allows a fairly easy release of the lateral soft-tissue and an excellent visualisation. A minimally-invasive modification of the dorsal approach is also described.[21] There is literature indicating that the release of the lateral soft-tissues through a medial incision tends to be incomplete[22] and that there is a risk of cartilage injury and flexor hallucis brevis injury.[23]

Distal metatarsal osteotomy

Mild to moderate hallux valgus with an IMA of up to 15° can be corrected with a distal osteotomy of the first metatarsal, such as the chevron osteotomy. Originally, the technique was described by Austin and Leventen as a symmetrical V-shaped osteotomy,[24] but there are several modifications. To narrow the forefoot, the metatarsal head is shifted laterally and even though the chevron osteotomy is inherently stable, internal fixation with a screw helps to prevent malunion or nonunion. An abnormal DMAA can be addressed with an additionally medial closing-wedge osteotomy. We prefer a distal first metatarsal osteotomy in the shape of a reversed 'L' (Fig. 4), as described by Helmy et al, in mild-to-moderate hallux valgus deformities which provides reliable clinical and radiological results and has a low risk of nonunion or avascular necrosis.[25]

Overall, the effectiveness of the distal chevron osteotomy is supported by numerous retrospective reviews but avascularity of the head of the metatarsal is a serious complication.[15,16,26,27]

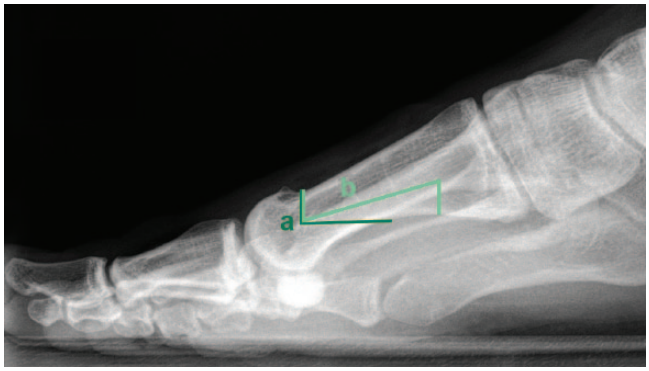

Fig. 4 First metatarsal osteotomies. a) modified chevron osteotomy in shape of a reversed 'L'; b) scarf osteotomy.

Scarf osteotomy

The scarf osteotomy, popularised by Barouk,[28] is a versatile diaphyseal osteotomy of the first metatarsal and is frequently used for correction of moderate to severe hallux valgus deformity, with an increased HVA < 40° and IMA < 20° (Fig. 5).

The osteotomy is characterised by a distal dorsal vertical limb, a long horizontal cut and a proximal vertical limb (Fig. 3). The shape and length of the osteotomy offers good stability and requires fixation with two screws. It allows lateralisation of the head shaft fragment to reduce the IMA, maintains joint congruence and thus motion of the first MTP joint, and permits elevation or plantarisation of the metatarsal head, lengthening or shortening, and transverse plane rotation for correcting an increased DMAA (> 10°). Several authors report significant improvement in functional outcome, correction of IMA and HVA, pedobarographic foot analyses and patient satisfaction after hallux valgus correction with the scarf osteotomy.[29-32]

Fig. 5 Scarf osteotomy with simultaneous Akin osteotomy.

Akin osteotomy

If there is a hallux valgus interphalangeus with an increased HVI > 10°, the Akin osteotomy is commonly performed, usually as an adjunct to other procedures (Fig. 6).

It was first described in 1925 as a proximal phalanx medial closing-wedge osteotomy with minimal fixation.[33] Today, multiple fixation techniques including suture, wire, screw and staple fixation have been reported.[26,32,34] The authors' favoured technique is staple fixation, which is reported as safe and effective with a low risk for complications.[34]

Complications in chevron and scarf osteotomies were found in between 1.1% and 31% of cases, including nonunion, delayed union, recurrence, hallux varus, superficial and deep wound infections, metatarsalgia, plantar keratosis, post-operative first MTP joint arthritis, metatarsal fracture,

Fig. 6 Akin osteotomy as an adjunct to a chevron osteotomy.

Fig. 7 The modified Lapidus procedure: corrective TMT arthrodesis with two crossed screws through the first TMT joint and adjunctive Akin osteotomy.

metatarsal head osteonecrosis, symptomatic hardware and complex regional pain syndrome (CRPS).[16,30,32,36]

Corrective TMT arthrodesis

Moderate to severe hallux valgus deformities with subluxation of the hallux joint, hypermobility of the first TMT joint, or generalised laxity as well as recurrent hallux valgus are the main indications in the literature for a corrective fusion of the first TMT joint, the so-called modified Lapidus procedure (Fig. 7).[36]

Lapidus originally described a fusion between the base of the first and second metatarsal and the first TMT joint to correct metatarsus primus varus in patients with hallux valgus deformity.[26] The modified Lapidus procedure typically consists of an isolated fusion of the first TMT joint with a lateral and plantar closing-wedge osteotomy of the medial cuneiform. Different types of fixation of the first TMT joint are described in the literature: screw fixation with different screw positions, two crossed screws through the first TMT joint in most of the studies, staple fixation, external fixation, as well as dorso-medial, medial and plantar locking plate fixation with or without a lag screw. In a meta-analysis of 29 studies with 1470 feet, Willegger et al reported an overall complication rate of 16.05% for the modified Lapidus procedure.[37] Most common major complications were nonunion (4.01%), delayed union (1.49%) and recurrence (2.24%). There was a high heterogeneity between the studies, therefore they found no significant differences for any complication concerning the method of fixation or post-operative mobilisation.

The concept of hypermobility of the first ray in the first TMT joint is still in discussion. Coughlin and Jones reported

treatment of moderate to severe subluxed hallux valgus deformities with a proximal crescentic osteotomy of the first metatarsal in combination with distal soft-tissue realignment.[3] Interestingly enough, they found that first ray hypermobility routinely and spontaneously reduced to a normal level without the need for an arthrodesis of the first TMT joint in the post-operative follow-up. They came to the conclusion that the stability of the first ray is a function of the alignment of the first ray and not an intrinsic characteristic of the first TMT joint. We therefore treat only massive deformities or patients with arthritic changes in the TMT with a modified Lapidus arthrodesis in our institution. Nonetheless, it has to be noted that we need more high-quality prospective comparative studies to conclusively answer the question of the role of first TMT joint instability.

MTP joint arthrodesis

Fusion of the first MTP joint was first described by Clutton in 1894.[38] It is recommended in the literature as the treatment for numerous conditions including severe hallux valgus, osteoarthritis, rheumatoid arthritis and as a salvage procedure (Fig. 8).[39,40] It offers reliable symptom relief.[39,41-43]

There are two ways to prepare the joint: flat-on-flat and ball-and-socket.[44] The flat-on-flat preparation uses flat cuts on the corresponding surfaces of the MTP joint while the ball-on-socket preparation uses a conical reamer system (Fig. 9). Fixation can be performed with wires, staples, screws, low-profile plates or a combination of these.[42,43,45] Mahadevan et al investigated the influence of joint preparation and fixation technique.[41] They compared flat-on-flat *versus* ball-on-socket arthrodesis using fixation with either crossed compression screws or a combined dorsal plate and oblique compression screw. Joint surface preparation and fixation did not statistically influence the outcome in first MTP joint arthrodesis, but there was a trend towards higher union rates with low velocity bone surface preparation.

First MTP joint arthroplasty

First MTP joint arthroplasty shows acceptable results in short-term follow-up[46,47] but an overall unacceptably high revision rate of between 16% and 26%.[48-50] Dawson-Bowling et al even showed a loosening rate of 52% at up to 8 years (Fig. 10).[49]

We therefore prefer MTP joint fusion as the treatment of end-stage arthritic hallux joints using the ball-on-socket preparation technique, and fixation with two crossed screws for primary fusions. In cases of failed fusion or very weak bone, we use dorsal plate fixation with an additional lag screw and (if necessary) autologous bone graft.

Minimally invasive techniques

In the last decade there has been growing interest in minimally invasive, percutaneous surgery in the treatment of hallux valgus. Different techniques are gaining popularity because of the theoretical advantages of faster recovery and less soft-tissue trauma. The subcapital osteotomy technique by Bösch, Wanke and Legenstein is reported as the origin of percutaneous techniques of hallux valgus surgery.[51] Further procedures are the SERI technique by Giannini et al ('simple, effective, rapid, inexpensive') with Kirschner wire fixation of the osteotomy and the minimally invasive chevron and Akin technique by Redfern, Vernois and Legré with rigid internal fixation.[52,53] While recent review articles based mostly on case series without comparison or control groups

Fig. 8 First MTP joint arthrodesis showing surfaces drilled with a fine Kirschner wire after achieving a 'ball-and-socket' situation.

Fig. 9 Positioning of first MTP joint in slight dorsiflexion to allow walking.

Fig. 10 Loosening of first MTP joint arthroplasty.

concluded that there was not enough evidence to favour MIS over traditional open techniques, Brogan et al showed, in a prospective cohort study with a total of 45 consecutive feet in 35 patients with symptomatic hallux valgus who underwent a third-generation MIS correction, a significant improvement both clinically and radiologically and a very low complication rate.[54] For further evaluation, more comparative long-term studies are needed.

Post-operative care

Our post-operative protocol consists of full weight-bearing mobilisation in a post-operative shoe for six weeks with a corrective dressing after distal or diaphyseal metatarsal osteotomies. In patients with a modified Lapidus fusion, we advise four to six weeks of non-weight-bearing mobilisation in a walker or a cast.

The post-operative results are routinely documented with AP and lateral radiographs and repeated at regular intervals every six weeks until osseous healing is achieved.

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CONFLICT OF INTEREST
None declared.

FUNDING
No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES

1. **Hueter C.** *Klinik der Gelenkkrankheiten mit Einschluss der Orthopaedie*. Leipzig: Vogel, 1870.
2. **Durman DC.** Metatarsus primus varus and hallux valgus. *AMA Arch Surg* 1957;74:128-35.
3. **Coughlin MJ, Jones CP.** Hallux valgus and first ray mobility. A prospective study. *J Bone Joint Surg [Am]* 2007;89-A:1887-98.
4. **Grebing BR, Coughlin MJ.** The effect of ankle position on the exam for first ray mobility. *Foot Ankle Int* 2004;25:467-75.
5. **Voellmicke KV, Deland JT.** Manual examination technique to assess dorsal instability of the first ray. *Foot Ankle Int* 2002;23:1040-1.
6. **Klaue K.** Hallux valgus and hypermobility of the first ray—causal treatment using tarso-metatarsal reorientation arthrodesis. *Ther Umsch* 1991;48:817-23.
7. **Mann RA.** Bunion surgery: decision making. *Orthopedics* 1990;13:951-7.
8. **Saltzman CL, Brandser EA, Berbaum KS, et al.** Reliability of standard foot radiographic measurements. *Foot Ankle Int*. 1994;15:661-5.
9. **Hardy RH, Clapham JCR.** Observations on hallux valgus. *J Bone Joint Surg* 1951;33-B:376-91.
10. **Steel MW, Johnson KA, DeWitz MA, Ilstrup DM.** Radiographic measurements of the normal adult foot. *Foot Ankle Int* 1980;1:151-8.
11. **Coughlin M, Freund E, Roger A.** Mann Award: The reliability of angular measurements in hallux valgus deformities. *Foot Ankle Int* 2001;22:369-79.
12. **Richardson EG, Graves SC, McClure JT, Boone RT.** First metatarsal head-shaft angle: a method of determination. *Foot Ankle Int* 1993;14:181-5.

13. Easley ME, Trnka HJ. Current concepts review: hallux valgus part 1: pathomechanics, clinical assessment, and nonoperative management. *Foot Ankle Int* 2007;28:654-9.

14. Coughlin M, Saltzman C, Anderson R. *Mann's Surgery of the Foot and Ankle*. Ninth ed. Philadelphia: Saunders, 2014.

15. Wu KPH, Chen CK, Lin SC, et al. Botulinum toxin type A injections for patients with painful hallux valgus: a double-blind, randomized controlled study. *Clin Neurol Neurosurg* 2015;129 Suppl :S58-62.

16. Deenik A, van Mameren H, de Visser E, et al. Equivalent correction in scarf and chevron osteotomy in moderate and severe hallux valgus: a randomized controlled trial. *Foot Ankle Int* 2008;29:1209-15.

17. Trnka HJ, Hofstaetter S. The chevron osteotomy for correction of hallux valgus. *Interact Surg* 2007;2:52-61.

18. Coetzee JC, Wickum D. The Lapidus procedure: a prospective cohort outcome study. *Foot Ankle Int* 2004;25:526-31.

19. Mann RA, Pfeffinger L. Hallux valgus repair. DuVries modified McBride procedure. *Clin Orthop Relat Res* 1991;272:213-18.

20. Pfeffinger LL. The modified McBride procedure. *Orthopedics* 1990;13:979-84.

21. Park YB, Lee KB, Kim SK, Seon JK, Lee JY. Comparison of distal soft-tissue procedures combined with a distal chevron osteotomy for moderate to severe hallux valgus: first web-space versus transarticular approach. *J Bone Joint Surg Am* 2013;95-A:e158.

22. Lee WC, Kim YM. Correction of hallux valgus using lateral soft-tissue release and proximal chevron osteotomy through a medial incision. *J Bone Joint Surg [Am]* 2007;89-A Suppl 3:82-9.

23. Stamatis ED, Huber MH, Myerson MS. Transarticular distal soft-tissue release with an arthroscopic blade for hallux valgus correction. *Foot Ankle Int* 2004;25:13-18.

24. 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 Relat Res* 1981;157:25-30.

25. Helmy N, Vienne P, Von Campe A, Espinosa N. Treatment of hallux valgus deformity: preliminary results with a modified distal metatarsal osteotomy. *Acta Orthop Belg* 2009;75:661-70.

26. Easley ME, Trnka HJ. Current concepts review: hallux valgus part II: operative treatment. *Foot Ankle Int* 2007;28:748-58.

27. Lee HJ, Chung JW, Chu IT, Kim YC. Comparison of distal chevron osteotomy with and without lateral soft tissue release for the treatment of hallux valgus. *Foot Ankle Int* 2010;31:291-5.

28. Barouk LS. Scarf osteotomy for hallux valgus correction. Local anatomy, surgical technique, and combination with other forefoot procedures. *Foot Ankle Clin* 2000;5:525-58.

29. Aminian A, Kelikian A, Moen T. Scarf osteotomy for hallux valgus deformity: an intermediate followup of clinical and radiographic outcomes. *Foot Ankle Int* 2006;27:883-6.

30. Jones S, Al Hussainy H, Ali F, Betts RP, Flowers MJ. Scarf osteotomy for hallux valgus. A prospective clinical and pedobarographic study. *J Bone Joint Surg [Br]* 2004;86-B:830-6.

31. Maher AJ, Kilmartin TE. Scarf osteotomy for correction of Tailor's bunion: mid- to long-term followup. *Foot Ankle Int* 2010;31:676-82.

32. Larholt J, Kilmartin TE. Rotational scarf and akin osteotomy for correction of hallux valgus associated with metatarsus adductus. *Foot Ankle Int* 2010;31:220-8.

33. Akin O. The treatment of hallux valgus: a new operative procedure and its results. *Med Sentin* 1925;33:678-9.

34. Neumann JA, Reay KD, Bradley KE, Parekh SG. Staple fixation for Akin proximal phalangeal osteotomy in the treatment of hallux valgus interphalangeus. *Foot Ankle Int* 2015;36:457-64.

35. Choi JH, Zide JR, Coleman SC, Brodsky JW. Prospective study of the treatment of adult primary hallux valgus with scarf osteotomy and soft tissue realignment. *Foot Ankle Int* 2013;34:684-90.

36. Coughlin MJ. Hallux valgus. *J Bone Joint Surg [Am]* 1997;78-A:932-66.

37. Willegger M, Holinka J, Ristl R, et al. Correction power and complications of first tarsometatarsal joint arthrodesis for hallux valgus deformity. *Int Orthop* 2014;39:467-76.

38. Clutton H. The treatment of hallux valgus. *St Thomas Rep* 1894;22:1-12.

39. Coughlin MJ, Grebing BR, Jones CP. Arthrodesis of the first metatarsophalangeal joint for idiopathic hallux valgus: intermediate results. *Foot Ankle Int* 2005;26:783-92.

40. Grimes JS, Coughlin MJ. First metatarsophalangeal joint arthrodesis as a treatment for failed hallux valgus surgery. *Foot Ankle Int* 2006;27:887-93.

41. Mahadevan D, Korim MT, Ghosh A, et al. First metatarsophalangeal joint arthrodesis – Do joint configuration and preparation technique matter? *Foot Ankle Surg* 2014;21:103-7.

42. Wassink S, van den Oever M. Arthrodesis of the first metatarsophalangeal joint using a single screw: retrospective analysis of 109 feet. *J Foot Ankle Surg* 2009;48:653-61.

43. Ellington JK, Jones CP, Cohen BE, et al. Review of 107 hallux MTP joint arthrodesis using dome-shaped reamers and a stainless-steel dorsal plate. *Foot Ankle Int* 2010;31:385-90.

44. Roukis TS. Nonunion after arthrodesis of the first metatarsal-phalangeal joint: a systematic review. *J Foot Ankle Surg* 2011;50:710-13.

45. Hunt KJ, Ellington JK, Anderson RB, et al. Locked versus nonlocked plate fixation for hallux MTP arthrodesis. *Foot Ankle Int* 2011;32:704-9.

46. Erkocak OF, Senaran H, Altan E, Aydin BK, Acar M. Short-term functional outcomes of first metatarsophalangeal total joint replacement for hallux rigidus. *Foot Ankle Int* 2013;34:1569-79.

47. Pulavarti RS, McVie JL, Tulloch CJ. First metatarsophalangeal joint replacement using the bio-action great toe implant: intermediate results. *Foot Ankle Int* 2005;26:1033-7.

48. Nagy MT, Walker CR, Sirikonda SP. Second-generation ceramic first metatarsophalangeal joint replacement for hallux rigidus. *Foot Ankle Int* 2014;35:690-8.

49. Dawson-Bowling S, Adimonye A, Cohen A, et al. MOJE ceramic metatarsophalangeal arthroplasty: disappointing clinical results at two to eight years. *Foot Ankle Int* 2012;33:560-4.

50. Titchener AG, Duncan NS, Rajan R. Outcome following first metatarsophalangeal joint replacement using TOEFIT-PLUS™: a mid term alert. *Foot Ankle Surg* 2015;21:119-24.

51. Bösch P, Wanke S, Legenstein R. Hallux valgus correction by the method of Bösch: a new technique with a seven-to-ten-year follow-up. *Foot Ankle Clin* 2000;5:485-98, v-vi.

52. Giannini S, Faldini C, Nanni M, et al. A minimally invasive technique for surgical treatment of hallux valgus: simple, effective, rapid, inexpensive (SERI). *Int Orthop* 2013;37:1805-13.

53. Redfern D, Vernois J, Legré BP. Percutaneous surgery of the forefoot. *Clin Podiatr Med Surg* 2015;32:291-332.

54. Brogan K, Voller T, Gee C, Borbely T, Palmer S. Third-generation minimally invasive correction of hallux valgus: technique and early outcomes. *Int Orthop* 2014;38:2115-21.