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Classification of hallux valgus deformity–is there a standard?

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Abstract

Introduction Hallux valgus deformity severity is one determent for the surgical procedure for hallux valgus (HV) correction. HV deformities are usually classified into mild/moderate/severe. The aim was to investigate the cut-off criteria used to classify HV deformity.

Materials and Methods The study was based on a previous living systematic review. Four common databases were searched for the last decade. All review-steps were conducted by two reviewers. Data assessed were the individual cut-off values used to classify HV deformity into mild/moderate/severe, and the referenced classification systems.

Results 46 studies were included. 21/18 studies grade deformity based on the intermetatarsal angle (IMA)/ hallux valgus angle (HVA) with great heterogeneity throughout the different cut-off values. The most referenced classification systems were the Coughlin and Mann's and the Robinson classification.

Conclusions The currently used classification systems are heterogenic, and no standard could be defined. The community should define a uniform classification system.

Level of Evidence.

Level I, systematic review of randomized controlled trials and prospective comparative studies.

Keywords Hallux valgus deformity · Classification · Intermetatarsalangle · Hallux valgus angle · Radiological

Introduction

More than 100 different surgical techniques have been published for correction of hallux valgus deformity [1, 2], with the severity of the hallux valgus deformity usually as the main determent for the surgical procedure [3, 4]. The degree of the deformity is commonly rated by the intermetatarsal angle (IMA) and the hallux valgus angle (HVA). Based on the combination of both, IMA and HVA, the deformity is frequently categorized into mild, moderate, or severe [1]. Up to now, the authors considered the classification to be consistently applied throughout the literature.

During the course of a living systematic review [5], initiated for the German hallux valgus guidelines, the authors

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became aware, that various cut-off criteria were used to classify hallux valgus severity. Still, as the degree of deformity is frequently considered as the predominant factor for choosing the surgical procedure, varying classifications will result in differing surgical approaches despite a comparable deformity. This subsequently leads to a considerable selection bias, which limits any comparative analysis of the literature available.

The aim of the current study was to investigate the cut-off criteria used to classify hallux valgus deformity into mild, moderate, or severe.

Materials and methods

Study selection

The study was based on a previous living systematic review [5] and was conducted per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-P) guidelines [6] and the PICOS criteria [7] and a priori registered (Prospero #CRD42021261490). Included were only prospective comparative studies comparing two surgical procedures or the same procedure for different degrees of deformity. Eligible studies must have reported at least one objective outcome parameter. Four common databases (MEDLINE (PubMed), Scopus, Central, and EMBASE) were searched from 01/01/2012 to 01/31/2023. The whole study selection-, level of evidence-, risk of bias-, and data extraction assessment was conducted by two reviewers independently (SE, SFB).

Data assessed

The level of evidence was rated per the recommendations of Wright et al. [8] and the risk of bias was assessed by the Risk of Bias 2 (RoB 2) tool [9] or the Newcastle–Ottawa scale [10], where appropriate. The data assessed were the classification systems cited/used and the stated cut-off values for the IMA and HVA. In case the authors did not state on the actual cut-off values but reported a reference, the cut-off values of the respective reference were used.

Statistics

Based on the final data sheet, the lower- (LB) and upper bounds (UB) for the categories mild (UB only), moderate (LB and UB) and severe (LB only) were analyzed. The analysis performed was descriptive, values are presented as mean ± SD, and were calculated using IBM Statistical Package for the Social Sciences, version 28 (SPSS).

Results

Study selection

The study selection process is outlined in Fig. 1. 46 studies [11–56] were finally eligible for further analysis, including 30 RCTs (RoB2: 2 × high risk, 28 moderate risk) and 16 non-randomized comparative studies (Newcastle–Ottawa-Scale: 6 ± 1 points ≙ moderate risk).

Data analysis

Out of the 46 studies included [11–56], any cut-off value for the IMA / HVA was stated in 21 studies (46%) [12, 14, 16–18, 21–24, 31, 34–36, 39, 42, 44, 45, 50, 52, 54, 55] / 18 studies (39%) [12, 14, 16, 17, 21, 31–36, 42, 44, 45, 47, 50, 54, 55]. Two studies were excluded due to missing cut-off values [41] or inconclusive data [43]. One paper [52] showed a discrepancy between the stated cut-off values and the values given in the associated reference. Subsequently the cut-off values of the cited paper were used. In one study [22] the referenced paper did not present any cut-off values. Therefore, the cut-off values stated in the paper were used.

The most commonly referenced classification systems were the Coughlin and Mann's [57] (n = 5) [11, 12, 14, 17, 36] as well as the Robinson classification [58] (n = 4) [16, 31, 39, 52].

Figure 2 depicts a cumulative analysis of the IMA and HVA values found in the studies included. Overall, a great heterogeneity was observed for the lower-(LB) and upper bound (UB) values applied in the literature, for both the IMA and HVA.

Discussion

The analysis of the classification systems for grading the severity of the hallux valgus deformity used in literature revealed a tremendous heterogeneity for both the IMA and HVA.

To the best knowledge of the authors' until now no study has investigated the different classification systems, i.e. cut-off values, used to rate the severity of a hallux valgus deformity. The current systematic review only included comparative, clinical outcome studies. As the choice of the surgical procedure is traditionally based on the degree of deformity [3, 4], their classification is of high relevance. The current systematic review revealed a considerable heterogeneity per the cut-off criteria for the different grades in the individual studies. For example, an IMA of 14° can be graded as mild, moderate, or severe, depending on the

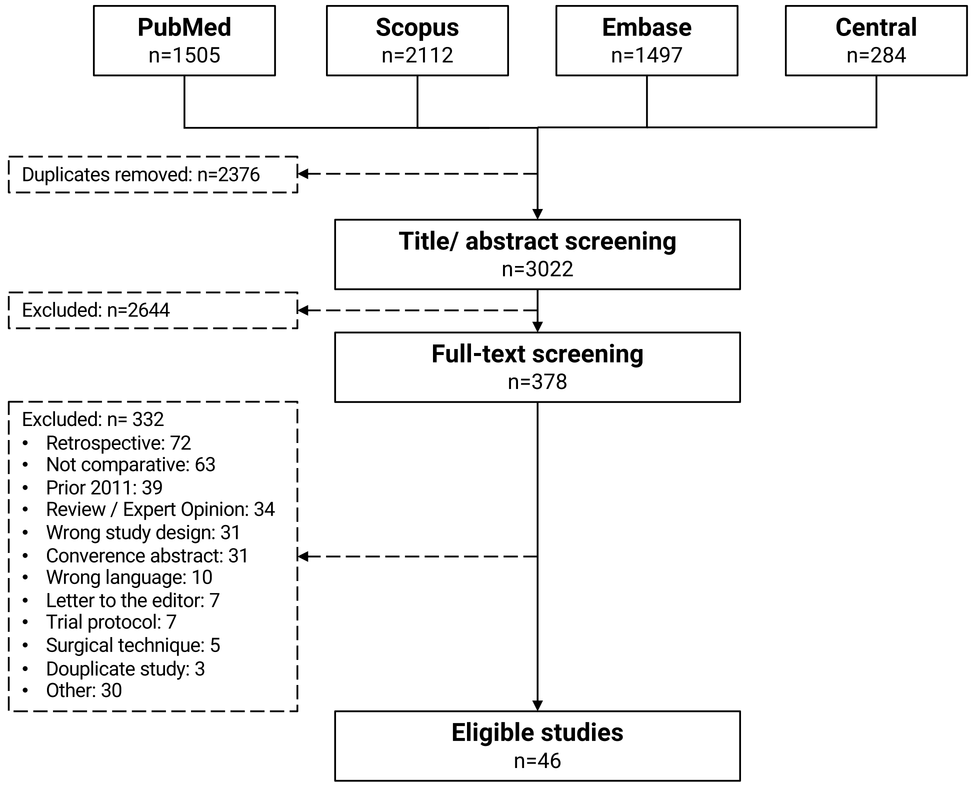
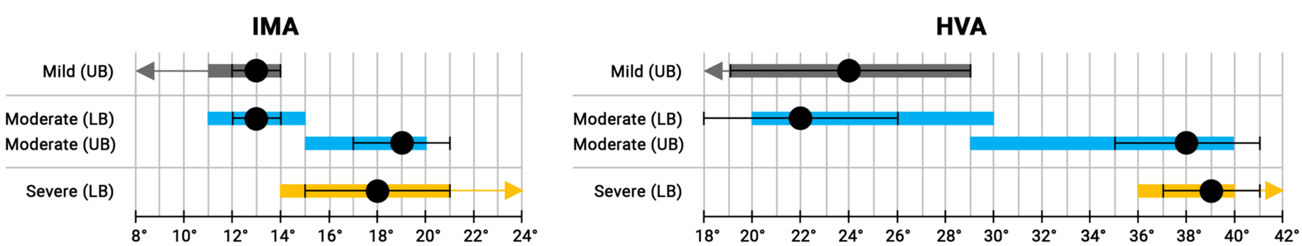


Fig. 1 PRISMA flow chart



	Mild (UB)	Moderate (LB)	Moderate (UB)	Severe (LB)
Mean [°]	13	13	19	18
SD [°]	1	1	2	3
Min [°]	11	11	15	14
Max [°]	14	15	20	21

	Mild (UB)	Moderate (LB)	Moderate (UB)	Severe (LB)
Mean [°]	24	22	38	39
SD [°]	5	4	3	2
Min [°]	19	20	29	36
Max [°]	29	30	40	40

Fig. 2 Cumulative analysis of the cut-off values for IMA and HVA used in literature.*UB* Upper bound, *LB* Lower bound, *SD* Standard deviation, *Min* Minimum, *Max* Maximum, ° Degrees

Table 1 Outline of different classification systems for hallux valgus deformity

	Guideline Germany (old Ver.) [57]		Guideline Netherland & Robinson 2005 [55]		Coughlin and Mann 2013 [54]		Current study*	
	IMA	HVA	IMA	HVA	IMA	HVA	IMA	HVA
Mild	< 16°	< 31°	< 14°	< 20°	< 11°	< 20°	< 13°	< 25°
Moderate	16°–20°	31°–40°	14°–20°	20°–40°	11°–16°	20°–40°	13°–18°	25–38°
Severe	> 20°	> 40°	> 20°	> 40°	> 16°	> 40°	> 18°	> 38°

IMA: Intermetatarsal angle, *HVA* Hallux valgus angle

*The values were extrapolated from the cumulative analysis in terms of a literature synopsis reference cited. Table 1 provides an overview of different classification systems published and a consensus on the data identified in the current study. The most referenced classification systems were those by Coughlin and Mann [57] and Robinson and Limbers [58]. Coughlin and Mann have just published the 10th volume [59]. Interestingly, their classification apparently has changed over time as well. The Robinson and Limbers classification has also been recommended in the Dutch national guidelines for hallux valgus (Federatie Medisch Specialisten, Richtlijnen Database; VS. July 29th 2021).

In 2022, the American College of Foot and Ankle Surgeons® published a consensus statement on hallux valgus [60]. Overall, the consensus group could not reach a consensus on whether the "procedural selection for hallux valgus should be based on the severity of the deformity". Amongst others, they argued that approaching evidence is pointing at the relevance of frontal plane deformity, i.e. pronatory rotation and hindfoot driven pronation. Therefore, traditional classifications, which are based on the transverse plane deformity, might not sufficiently characterize the deformity, and can therefore not indicate the necessary surgical procedure [61]. Furthermore, minimal invasive procedures have extended the deformity correction potential compared to traditional open osteotomies [4, 62–65]. With the approach of these novel diagnostic and treatment approaches, we might be in the need for novel classification systems. These should then be defined and applied uniformly throughout literature.

Conclusion

Overall, the currently used classification systems are heterogenic. Therefore, any inter-study comparison is limited. Moreover, they probably underestimate the multidimensional nature of the deformity. With the approach of novel diagnostic tools, i.e. weightbearing CT, and treatment strategies, i.e. minimal invasive surgery, novel classifications must be developed [66]. But only their standardization throughout literature will allow a sufficient inter-study comparison and therefore generate the highest level of evidence.

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Author contributions The study idea was consented in the whole study group during the course of a living systematic review for the German guidelines for hallux valgus treatment. SFT, ES and BSF were responsible for the study design and conception. BSF and SFT were responsible for the manuscript preparation. SFT and BSF conducted the review and data extraction. The whole study group participated in the data interpretation, paper conception and proof reading.

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Declarations

Conflict of interest All authors have completed the ICMJE uniform disclosure form at http://www.icmje.org/disclosure-of-interest/ and declare: all authors had no financial support for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

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References

1. Coughlin MJ, Jones CP (2007) Hallux valgus: demographics, etiology, and radiographic assessment. Foot Ankle Int 28(7):759–777. https://doi.org/10.3113/FAI.2007.0759
2. de Cesar NC, Ehret A, Walt J, Chinelati RMK, Dibbern K, de Carvalho KAM et al (2023) Early results and complication rate of the LapiCotton procedure in the treatment of medial longitudinal arch collapse: a prospective cohort study. Arch Orthop Trauma Surg 143(5):2283–2295. https://doi.org/10.1007/s00402-022-04399-0
3. Izzo A, Vallefuoco S, Basso MA, Ray R, Smeraglia F, Cozzolino A et al (2023) Role of lateral soft tissue release in percutaneous hallux valgus surgery: a systematic review and meta-analysis of the literature. Arch Orthop Trauma Surg 143(7):3997–4007. https://doi.org/10.1007/s00402-022-04693-x
4. Nunes GA, de Carvalho KAM, Ferreira GF, Filho MVP, Baptista AD, Zambelli R et al (2023) Minimally invasive Chevron Akin (MICA) osteotomy for severe hallux valgus. Arch Orthop Trauma Surg 143(9):5507–5514. https://doi.org/10.1007/s00402-023-04849-3
5. Ettinger S, Spindler FT, Savli M, committee DAFs, Baumbach SF (2023) Correction potential and outcome of various surgical procedures for hallux valgus surgery – a living systematic review and meta-analysis. Arch Orthop Trauma Surg currently under review. not available yet.
6. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Rev Esp Cardiol (Engl Ed) 74(9):790–799. https://doi.org/10.1016/j.rec.2021.07.010
7. da Costa Santos CM, de Mattos Pimenta CA, Nobre MR (2007) The PICO strategy for the research question construction and evidence search. Rev Lat Am Enfermagem 15(3):508–511. https://doi.org/10.1590/s0104-11692007000300023

8. Wright JG, Swiontkowski MF, Heckman JD (2003) Introducing levels of evidence to the journal. J Bone Joint Surg Am 85(1):1–3. https://doi.org/10.2106/00004623-200301000-00001
9. Sterne JAC, Savovic J, Page MJ, Elbers RG, Blencowe NS, Boutron I et al (2019) RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ 366:l4898. https://doi.org/10.1136/bmj.l4898
10. Wells GA, Wells G, Shea B, Shea B, O'Connell D, Peterson J, et al., editors. The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomised Studies in Meta-Analyses2014.
11. Avcu B, Akalin Y, Cevik N, Öztürk A, Sahin N, Öztas S et al (2017) Scarf osteotomy or Mau osteotomy for correction of moderate to severe hallux valgus deformity: a prospective randomized study. Eur Res J. https://doi.org/10.18621/eurj.302186
12. Biz C, Fosser M, Dalmau-Pastor M, Corradin M, Roda MG, Aldegheri R et al (2016) Functional and radiographic outcomes of hallux valgus correction by mini-invasive surgery with Reverdin-Isham and Akin percutaneous osteotomies: a longitudinal prospective study with a 48-month follow-up. J Orthop Surg Res 11(1):157. https://doi.org/10.1186/s13018-016-0491-x
13. Boychenko AV, Solomin LN, Belokrylova MS, Tyulkin EO, Davidov DV, Krutko DM (2019) Hallux valgus correction with rotational scarf combined with adductor hallucis tendon transposition. J Foot Ankle Surg 58(1):34–37. https://doi.org/10.1053/j.jfas.2018.07.012
14. Buciuto R (2014) Prospective randomized study of chevron osteotomy versus Mitchell's osteotomy in hallux valgus. Foot Ankle Int 35(12):1268–1276. https://doi.org/10.1177/1071100714550647
15. Choi JY, Kim BH, Suh JS (2021) A prospective study to compare the operative outcomes of minimally invasive proximal and distal chevron metatarsal osteotomy for moderate-to-severe hallux valgus deformity. Int Orthop 45(11):2933–2943. https://doi.org/10.1007/s00264-021-05106-1
16. Di Giorgio L, Sodano L, Touloupakis G, De Meo D, Marcellini L (2016) Reverdin-Isham osteotomy versus Endolog system for correction of moderate hallux valgus deformity: a randomized controlled trial. Clin Ter 167(6):e150–e154. https://doi.org/10.7417/CT.2016.1960
17. Dragosloveanu S, Popov VM, Cotor DC, Dragosloveanu C, Stoica CI (2022) Percutaneous chevron osteotomy: a prospective randomized controlled trial. Medicina (Kaunas). https://doi.org/10.3390/medicina58030359
18. Elshazly O, Abdel Rahman AF, Fahmy H, Sobhy MH, Abdelhadi W (2019) Scarf versus long chevron osteotomies for the treatment of hallux valgus: a prospective randomized controlled study. Foot Ankle Surg 25(4):469–477. https://doi.org/10.1016/j.fas.2018.02.017
19. Faber FW, Mulder PG, Verhaar JA (2004) 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 Am. https://doi.org/10.2106/00004623-200403000-00005
20. Faber FW, van Kampen PM, Bloembergen MW (2013) Long-term results of the Hohmann and Lapidus procedure for the correction of hallux valgus: a prospective, randomised trial with eight- to 11-year follow-up involving 101 feet. Bone Joint J. https://doi.org/10.1302/0301-620X.95B9.31560
21. Frigg A, Zaugg S, Maquieira G, Pellegrino A (2019) Stiffness and range of motion after minimally invasive chevron-akin and open scarf-akin procedures. Foot Ankle Int 40(5):515–525. https://doi.org/10.1177/1071100718818577
22. Giannini S, Cavallo M, Faldini C, Luciani D, Vannini F (2013) The SERI distal metatarsal osteotomy and Scarf osteotomy provide similar correction of hallux valgus. Clin Orthop Relat Res 471(7):2305–2311. https://doi.org/10.1007/s11999-013-2912-z
23. Glazebrook M, Copithorne P, Boyd G, Daniels T, Lalonde KA, Francis P et al (2014) Proximal opening wedge osteotomy with wedge-plate fixation compared with proximal chevron osteotomy for the treatment of hallux valgus: a prospective, randomized study. J Bone Joint Surg Am 96(19):1585–1592. https://doi.org/10.2106/JBJS.M.00231
24. Gutteck N, Wohlrab D, Zeh A, Radetzki F, Delank KS, Lebek S (2013) Comparative study of Lapidus bunionectomy using different osteosynthesis methods. Foot Ankle Surg 19(4):218–221. https://doi.org/10.1016/j.fas.2013.05.002
25. Hofstaetter SG, Schuh R, Trieb K, Trnka HJ (2012) Modified chevron osteotomy with lateral release and screw fixation for treatment of severe hallux deformity. Z Orthop Unfall 150(6):594–600. https://doi.org/10.1055/s-0032-1327933
26. Jeuken RM, Schotanus MG, Kort NP, Deenik A, Jong B, Hendrickx RP (2016) Long-term follow-up of a randomized controlled trial comparing scarf to chevron osteotomy in hallux valgus correction. Foot Ankle Int 37(7):687–695. https://doi.org/10.1177/1071100716639574
27. Jowett CRJ, Bedi HS (2017) Preliminary results and learning curve of the minimally invasive chevron akin operation for hallux valgus. J Foot Ankle Surg 56(3):445–452. https://doi.org/10.1053/j.jfas.2017.01.002
28. Kaufmann G, Dammerer D, Heyenbrock F, Braito M, Moertlbauer L, Liebensteiner M (2019) Minimally invasive versus open chevron osteotomy for hallux valgus correction: a randomized controlled trial. Int Orthop 43(2):343–350. https://doi.org/10.1007/s00264-018-4006-8
29. Kaufmann G, Mortlbauer L, Hofer-Picout P, Dammerer D, Ban M, Liebensteiner M (2020) Five-year follow-up of minimally invasive distal metatarsal chevron osteotomy in comparison with the open technique: a randomized controlled trial. J Bone Joint Surg Am 102(10):873–879. https://doi.org/10.2106/JBJS.19.00981
30. Kaufmann G, Weiskopf D, Liebensteiner M, Ulmer H, Braito M, Endstrasser F et al (2021) Midterm results following minimally invasive distal chevron osteotomy: comparison with the minimally invasive reverdin-isham osteotomy by means of meta-analysis. In Vivo. https://doi.org/10.21873/invivo.12490
31. Kiyak G, Esemenli T (2019) Should we use intermetatarsal angle as primary determinant to define the limits of distal chevron osteotomy? J Foot Ankle Surg 58(5):880–885. https://doi.org/10.1053/j.jfas.2018.12.031
32. Klemola T, Leppilahti J, Laine V, Pentikainen I, Ojala R, Ohtonen P et al (2017) Effect of first tarsometatarsal joint derotational arthrodesis on first ray dynamic stability compared to distal chevron osteotomy. Foot Ankle Int 38(8):847–854. https://doi.org/10.1177/1071100717706153
33. Lamo-Espinosa JM, Flórez B, Villas C, Pons-Villanueva J, Bondía JM, Aquerreta JD et al (2015) The relationship between the sesamoid complex and the first metatarsal after hallux valgus surgery without lateral soft-tissue release: a prospective study. J Foot Ankle Surg 54(6):1111–1115. https://doi.org/10.1053/j.jfas.2015.07.022
34. Lechler P, Feldmann C, Köck FX, Schaumburger J, Grifka J, Handel M (2012) Clinical outcome after chevron-akin double osteotomy versus isolated chevron procedure: a prospective matched group analysis. Arch Orthop Trauma Surg 132(1):9–13. https://doi.org/10.1007/s00402-011-1385-3
35. Lee KB, Cho NY, Park HW, Seon JK, Lee SH (2015) A comparison of proximal and distal Chevron osteotomy, both with lateral soft-tissue release, for moderate to severe hallux valgus in patients undergoing simultaneous bilateral correction: a prospective randomised controlled trial. Bone Joint J. https://doi.org/10.1302/0301-620X.97B2.34449
36. Lee M, Walsh J, Smith MM, Ling J, Wines A, Lam P (2017) Hallux valgus correction comparing percutaneous chevron/

akin (PECA) and open scarf/akin osteotomies. Foot Ankle Int 38(8):838–846. https://doi.org/10.1177/1071100717704941
37. Ling SKK, Wu YM, Li C, Lui TH, Yung PS (2020) Randomised control trial on the optimal duration of non-weight-bearing walking after hallux valgus surgery. J Orthop Translat 23:61–66. https://doi.org/10.1016/j.jot.2020.04.009
38. Loh B, Chen JY, Yew AK, Chong HC, Yeo MG, Tao P et al (2015) Prevalence of metatarsus adductus in symptomatic hallux valgus and its influence on functional outcome. Foot Ankle Int 36(11):1316–1321. https://doi.org/10.1177/1071100715595618
39. Mahadevan D, Lines S, Hepple S, Winson I, Harries W (2016) Extended plantar limb (modified) chevron osteotomy versus scarf osteotomy for hallux valgus correction: A randomised controlled trial. Foot Ankle Surg 22(2):109–113. https://doi.org/10.1016/j.fas.2015.05.012
40. Matricali GA, Vermeersch G, Busschots E, Fieuws S, Deschamps K (2014) Prospective randomized comparative study on V-Y and pants-over-vest capsulorraphy in chevron and scarf osteotomy. Acta Orthop Belg 80(2):280–7. not available.
41. Milczarek M, Nowak K, Tomasik B, Milczarek J, Laganowski P, Domzalski M (2021) Additional akin proximal phalanx procedure has a limited effect on the outcome of scarf osteotomy for hallux valgus surgery. J Am Podiatr Med Assoc. https://doi.org/10.7547/20-071
42. Mosca M, Russo A, Caravelli S, Massimi S, Vocale E, Grassi A et al (2021) Piezoelectric tools versus traditional oscillating saw for distal linear osteotomy in hallux valgus correction: Triple-blinded, randomized controlled study. Foot Ankle Surg. https://doi.org/10.1016/j.fas.2021.03.024
43. Palmanovich E, Ohana N, David S, Small I, Hetsroni I, Amar E et al (2021) Distal chevron osteotomy vs the simple, effective, rapid, inexpensive technique (SERI) for mild to moderate isolated hallux valgus: a randomized controlled study. Indian J Orthop 55(Suppl 1):110–118. https://doi.org/10.1007/s43465-020-00209-0
44. Park HW, Lee KB, Chung JY, Kim MS (2013) Comparison of outcomes between proximal and distal chevron osteotomy, both with supplementary lateral soft-tissue release, for severe hallux valgus deformity: a prospective randomised controlled trial. Bone Joint J. https://doi.org/10.1302/0301-620X.95B4.30464
45. Park YB, Lee KB, Kim SK, Seon JK, Lee JY (2013) 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 95(21):e158. https://doi.org/10.2106/JBJS.L.01017
46. Patel S, Garg P, Fazal MA, Shahid MS, Park DH, Ray PS (2019) A comparison of two designs of postoperative shoe on function, satisfaction, and back pain after hallux valgus surgery. Foot Ankle Spec 12(3):228–232. https://doi.org/10.1177/1938640018782608
47. Pentikainen I, Ojala R, Ohtonen P, Piippo J, Leppilahti J (2014) Preoperative radiological factors correlated to long-term recurrence of hallux valgus following distal chevron osteotomy. Foot Ankle Int 35(12):1262–1267. https://doi.org/10.1177/1071100714548703
48. Pentikainen I, Piippo J, Ohtonen P, Junila J, Leppilahti J (2015) Role of fixation and postoperative regimens in the long-term outcomes of distal chevron osteotomy: a randomized controlled two-by-two factorial trial of 100 patients. J Foot Ankle Surg 54(3):356–360. https://doi.org/10.1053/j.jfas.2014.08.001
49. Puchner SE, Trnka HJ, Willegger M, Staats K, Holinka J, Windhager R et al (2018) Comparison of plantar pressure distribution and functional outcome after scarf and austin osteotomy. Orthop Surg 10(3):255–263. https://doi.org/10.1111/os.12400
50. Radwan YA, Mansour AM (2012) Percutaneous distal metatarsal osteotomy versus distal chevron osteotomy for correction of mild-to-moderate hallux valgus deformity. Arch Orthop Trauma Surg 132(11):1539–1546. https://doi.org/10.1007/s00402-012-1585-5
51. Sahin N, Cansabuncu G, Cevik N, Turker O, Ozkaya G, Ozkan Y (2018) A randomized comparison of the proximal crescentic osteotomy and rotational scarf osteotomy in the treatment of hallux valgus. Acta Orthop Traumatol Turc 52(4):261–266. https://doi.org/10.1016/j.aott.2018.02.008
52. Saxena A, St Louis M (2013) Medial locking plate versus screw fixation for fixation of the Ludloff osteotomy. J Foot Ankle Surg 52(2):153–157. https://doi.org/10.1053/j.jfas.2012.11.005
53. Torrent J, Baduell A, Vega J, Malagelada F, Luna R, Rabat E (2021) Open vs minimally invasive scarf osteotomy for hallux valgus correction: a randomized controlled trial. Foot Ankle Int 42(8):982–993. https://doi.org/10.1177/10711007211003565
54. Uygur E, Ozkan NK, Akan K, Cift H (2016) A comparison of chevron and lindgren-turan osteotomy techniques in hallux valgus surgery: a prospective randomized controlled study. Acta Orthop Traumatol Turc 50(3):255–261. https://doi.org/10.3944/AOTT.2016.14.0272
55. Wester JU, Hamborg-Petersen E, Herold N, Hansen PB, Froekjaer J (2016) Open wedge metatarsal osteotomy versus crescentic osteotomy to correct severe hallux valgus deformity–A prospective comparative study. Foot Ankle Surg 22(1):26–31. https://doi.org/10.1016/j.fas.2015.04.006
56. Windhagen H, Radtke K, Weizbauer A, Diekmann J, Noll Y, Kreimeyer U et al (2013) Biodegradable magnesium-based screw clinically equivalent to titanium screw in hallux valgus surgery: short term results of the first prospective, randomized, controlled clinical pilot study. BioMed Central. https://doi.org/10.1186/1475-925X-12-62
57. Coughlin MJ, Saltzman CL, Mann RA (2013) Mann's surgery of the foot and ankle Philadelphia. Mosby
58. Robinson AH, Limbers JP (2005) Modern concepts in the treatment of hallux valgus. J Bone Joint Surg Br 87(8):1038–1045. https://doi.org/10.1302/0301-620X.87B8.16467
59. Coughlin MJ, Haskell A (2024) Coughlin and Mann's surgery of the foot an ankle Philadelphia. Elsevier Philadelphia, PA
60. Meyr AJ, Doyle MD, King CM, Kwaadu KY, Nasser EM, Ramdass R et al (2022) The american college of foot and ankle surgeons(R) clinical consensus statement: hallux valgus. J Foot Ankle Surg 61(2):369–383. https://doi.org/10.1053/j.jfas.2021.08.011
61. Santrock RD, Smith B (2018) Hallux valgus deformity and treatment: a three-dimensional approach: modified technique for lapidus procedure. Foot Ankle Clin 23(2):281–295. https://doi.org/10.1016/j.fcl.2018.02.001
62. Ferreira GF, Nunes GA, Banca V, Michaelis LF, Lewis TL, Ray R et al (2024) Minimally invasive hallux valgus surgery using 3D printed patient specific instrumentation. Arch Orthop Trauma Surg. https://doi.org/10.1007/s00402-024-05383-6
63. Palmanovich E, Ohana N, Tavdi A, Atzmon R, Feldman V, Brin YS et al (2023) A modified minimally invasive osteotomy for hallux valgus enables reduction of malpositioned sesamoid bones. Arch Orthop Trauma Surg 143(10):6105–6112. https://doi.org/10.1007/s00402-023-04868-0
64. Bernasconi A, Rizzo M, Izzo A, Vallefuoco S, Russo AP, Rossi V et al (2023) Bosch osteotomy for hallux valgus correction: results at a mean 10-year follow-up. Arch Orthop Trauma Surg 143(3):1293–1300. https://doi.org/10.1007/s00402-021-04259-3
65. Harrasser N, Hinterwimmer F, Baumbach SF, Pfahl K, Glowalla C, Walther M et al (2023) The distal metatarsal screw is not always necessary in third-generation MICA: a case-control study. Arch Orthop Trauma Surg 143(8):4633–4639. https://doi.org/10.1007/s00402-022-04740-7

66. Lee HY, Mansur NS, Lalevee M, Maly C, Iehl CJ, Hembree WC et al (2023) Does metatarsus primus elevatus really exist in hallux rigidus? A weightbearing CT case-control study. Arch Orthop Trauma Surg 143(2):755–761. https://doi.org/10.1007/s00402-021-04168-5