Comparison of outcomes of different osteotomy sites for hallux valgus: A systematic review and meta-analysis

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Abstract

Background: Hallux valgus (HV) is a common foot deformity for which several corrective surgical procedures, with different osteotomy sites, have been reported. The purpose of the present study was to systematically review randomized (RCTs) or controlled (CCTs) clinical trials and perform meta-analysis on outcomes of different osteotomy sites of the first metatarsal.

Methods: An extensive literature search was conducted in PubMed and the Cochrane Library from January 1983 to July 2020. Studies were identified using the terms “hallux valgus” and “osteotomy”. We included RCTs or CCTs comparing different locations of osteotomy for the first metatarsal bone (distal vs. mid-shaft, distal vs. proximal, and mid-shaft vs. proximal). The surgical outcomes included postoperative hallux valgus angle (HVA), intermetatarsal angle (IMA), American Orthopaedic Foot and Ankle Society (AOFAS) score, pain visual analog scale (VAS) score, perioperative complications and recurrence of deformity. We enrolled 10 studies with a total of 793 feet in the qualitative synthesis following full-text screening.

Results: A majority of patients included in the enrolled trials showed mild to moderate deformity, with mean HVA <40°. Out of the 10 enrolled studies; six compared distal osteotomies with mid-shaft osteotomies and showed no significant differences in the surgical outcomes between the scarf and chevron groups; three RCTs compared distal osteotomies with proximal osteotomies with conflicting results, one RCT showed the superiority of proximal osteotomy while the other two RCTs showed equivalent outcomes; one study that compared between mid-shaft and proximal osteotomies showed equivalent outcomes between the groups.

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Conclusion: For the management of mild to moderate HV deformity, we found no significant clinical and radiological differences between patients treated with scarf and chevron osteotomies. Further controlled trials comparing different sites of osteotomies for moderate to severe HV deformity are needed.

Keywords
chevron, comparison, hallux valgus, meta-analysis, osteotomy site, scarf

Background
Hallux valgus (HV) is one of the most common foot deformities. When conservative treatment is ineffective for symptomatic patients, they require surgical intervention. More than 100 surgical procedures have been reported for HV correction. For a mild HV deformity, distal osteotomy, such as distal chevron osteotomy, is usually applied.1 When HV deformity is severe, mid-shaft osteotomy such as scarf osteotomy, or proximal osteotomy such as crescentic osteotomy is more likely to be used.1 In addition to open procedures, minimally invasive and percutaneous operative procedures have been proposed in recent years.2–4 However, the gold standard for the surgical repair of HV remains elusive, and the choice of osteotomy seems largely dependent on the operating surgeon’s judgment.1

Several randomized controlled trials (RCTs) have been conducted to compare different procedures in the treatment of HV. Although the majority of RCTs reported no significant differences between the procedures, some conflicting results have been reported.5,6 For example, a study comparing scarf and long chevron osteotomies showed that the American Orthopedic Foot and Ankle Society (AOFAS) scores were higher in the long chevron group.7 On the other hand, percutaneous chevron/Akin osteotomy showed comparable results to open scarf/Akin osteotomy with regard to clinical and radiological outcomes, although the percutaneous group had significantly less pain postoperatively.8 Therefore, it is unclear whether outcomes were affected by differences in the first metatarsal osteotomy site.

The purpose of the present study was to systematically review RCTs, controlled clinical trials (CCTs), and meta-analyses that assessed outcomes of different osteotomy sites of the first metatarsal including a distal, mid-shaft, and proximal metatarsal osteotomy for HV correction and to clarify whether the radiological and clinical results were affected by differences in the first metatarsal osteotomy site.

Methods
The systematic search was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement.9

Data sources and keywords
An extensive literature search was conducted in PubMed and the Cochrane Library using medical subject headings (MeSH) complemented with a free text search. The following search terms were used: [1] HV and [2] osteotomy. Electrical searches with combinations of [1] and [2] were performed.

The purpose of this search was to identify RCTs comparing different surgical techniques. Reference lists from previous reviews1,5,6 were also checked to identify additional articles that met the inclusion criteria. The language was restricted to English and the years of publication were from January 1983 to July 2020.

Study selection
The following inclusion criteria were adopted: (1) English language studies on the curative effect of osteotomy on patients with HV; (2) RCTs or CCTs comparing different locations of osteotomy for the first metatarsal bone (distal vs. mid-shaft, distal vs. proximal, and mid-shaft vs proximal); and (3) surgical outcome data including the post-treatment hallux valgus angle (HVA) and intermetatarsal angle (IMA), AOFAS score, pain visual analog scale (VAS) score, perioperative complications, and recurrence of deformity. We excluded case reports, non-comparative studies, and review articles. We also excluded trials of metatarsophalangeal joint arthrodesis and tarsometatarsal joint arthrodesis (Lapidus procedure).

Data extraction and quality assessment
We extracted the participants’ demographic data and the following outcome measurements from the studies: preoperative and postoperative HVA, IMA, AOFAS scores, pain VAS score, complications, and recurrence rate of deformity. Complications were defined as any report of infection, wound dehiscence, hallux varus deformity, osteonecrosis, or complex regional pain syndrome. With regard to quality assessment of the included studies, the bias risks and the level of evidence were evaluated by three reviewers independently. The bias risks were evaluated
according to Cochrane risk of bias tool ver.2.10. The level of evidence was assessed according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) scale.11

**Data analysis**

All statistical analyses were performed using Review Manager (Version 5.3, The Cochrane Collaboration). Dichotomous data were analyzed by risk ratio (RR), and continuous variables were assessed using weight mean difference (WMD), both with 95% confidence intervals (CI). Considering the problem of multiple testing (HVA, IMA, recurrence of deformity, AOFAS score, pain VAS score, and complications), the Bonferroni correction was applied, and the adjusted p-values <0.007 were considered significant.

For data presented as median and range, the values of means and standard deviations were estimated using Hozo’s method.12 A random-effects ($I^2 > 50\%$) or fixed-effects model ($I^2 < 50\%$) was used depending on the heterogeneity of the studies included in the assessment.

**Results**

**Characteristics of the included studies**

The literature search yielded 2096 potentially relevant studies. Following subsequent abstract screening by eight reviewers (approximately 250 abstracts per a reviewer), 83 studies comparing the results of osteotomies remained. Full-text screening was finally performed by three reviewers independently (83 papers per a reviewer), which resulted in the enrollment of 10 qualitative synthesis studies (Figure 1 and Table 1), six studies that compared distal osteotomies with mid-shaft osteotomies,9,10,13–16 three RCTs that compared distal osteotomies with proximal osteotomies,17–19 and one study that compared mid-shaft osteotomy with proximal osteotomy.20 Table 1 shows the summary of the designs of included studies. With regard to the participant’s
Table 1. Summary of the designs of included studies.

| Comparison                  | First author | Year | Follow-up (month) | Study type | Osteotomy         | Feet (n) | Gender | Mean age (year) | Pre HVA (degree) | Pre IMA (degree) | Pre AOFAS (point) |
|-----------------------------|--------------|------|-------------------|------------|-------------------|----------|--------|----------------|------------------|------------------|------------------|
| Distal versus Mid-shaft    | Deenik [12]  | 2008 | 30                | RCT        | Chevron           | 70       | NA     | 30.5 ± 6.7     | 13.4 ± 2.4       | NA               | 46               |
|                            |              |      |                   |            | Scarf             | 66       | NA     | 30.0 ± 6.9     | 13.1 ± 2.6       | 47               |                  |
|                            | Giannini [13]| 2013 | 96                | CCT        | SERI              | 20       | NA     | 53 ± 1         | 35.8 ± 3.5       | 16.1 ± 3.9       | 51 ± 10          |
|                            |              |      |                   |            | Scarf             | 20       | NA     | 35.5 ± 4.7     | 16.1 ± 3.8       | 48 ± 9           |                  |
|                            | Mahadevan [14]| 2016 | 12                | RCT        | Modified chevron  | 60       | 75/9   | 50.7 ± 14.1    | 32.3 ± 8.3       | 15.2 ± 3.1       | NA               |
|                            |              |      |                   |            | Scarf             | 49       | NA     | 29.5 ± 7.6     | 14.3 ± 2.9       | NA               |                  |
|                            | Jeuker [15]  | 2016 | 24                | RCT        | Chevron           | 37       | NA     | 56.3 ± 13.9    | 30.7 (15.0, 46.0) | 13.5 (8.0, 19.0) | 48.5 (24.0, 75.0) |
|                            |              |      |                   |            | Scarf             | 36       | NA     | 58.2 ± 14.1    | 29.5 (18.0, 44.0) | 12.6 (8.0, 22.0) | 47.2 (24.0, 78.0) |
|                            | Lee [7]      | 2017 | 6                 | RCT        | PECA              | 25       | 23/2   | 52.6 (20–76)   | 31.4 ± 2.1       | 15.6 ± 1.0       | 61.8             |
|                            |              |      |                   |            | Scarlet/Akin      | 25       | 22/3   | 53.4 (25–75)   | 31.2 ± 4.1       | 15.7 ± 1.4       | 57.3             |
|                            | Elshazy [6]  | 2019 | 12                | RCT        | Long chevron      | 22       | 24/19  | 36 (18–67)     | 32.5 ± 2.81      | 20.4 ± 3.5       | NA               |
|                            |              |      |                   |            | Scarf             | 21       | 24/19  | 34.8 ± 13.4    | 18.5 ± 4.5       | NA               |                  |
| Distal versus Proximal     | Resch [16]   | 1993 | 42                | RCT        | Chevron           | 43       | NA     | 49 (16–78)     | 33 ± 9.0         | 15 ± 3.7         | NA               |
|                            |              |      |                   |            | Proximal closing wedge | 37 | 49 (16–78) | 33 ± 9.0 | 15 ± 3.7 | NA |                  |
|                            | Park [17]    | 2013 | 39                | RCT        | Distal chevron    | 54       | 55/0   | 53 (24–52)     | 39.9 ± 7.6       | 18.0 ± 2.9       | 56.6 ± 11.8      |
|                            |              |      |                   |            | Proximal chevron  | 56       | 55/0   | 54 (33–70)     | 41.0 ± 7.2       | 18.8 ± 3.2       | 54.0 ± 11.9      |
|                            | Lee [18]     | 2015 | 40                | RCT        | Distal chevron    | 46       | 46/0   | 53.8 (30–62)   | 34.3 ± 7.6       | 16.2 ± 2.7       | 55.7 ± 13.6      |
|                            |              |      |                   |            | Proximal chevron  | 46       | 46/0   | 37.0 ± 7.6     | 16.2 ± 2.6       | 55.2 ± 13.3      |                  |
| Mid-shaft versus Proximal  | Şahin [19]   | 2018 | 12                | RCT        | Rotational scarf  | 30       | 23/7   | 40.9 ± 12.6    | 36.1 ± 7.5       | 16.2 ± 2.6       | 36.2 ± 16.1      |
|                            |              |      |                   |            | Proximal crescentic | 30  | 22/5   | 40 ± 14.5    | 38.1 ± 7.1       | 17.3 ± 3.8       | 42 ± 16.2        |

NA: not applicable; Pre: preoperative; SERI: simple, effective, rapid, inexpensive; PECA: percutaneous chevron/Akin; RCT: randomized controlled trials; CCT: controlled clinical trials.
Table 2. Quality assessment of the included studies.

|                          | Participants (studies) | Risk of bias | Inconsistency | Imprecision | Indirectness | Publication bias | Other considerations | Quality of evidence |
|--------------------------|------------------------|--------------|---------------|-------------|--------------|------------------|---------------------|---------------------|
| Correction of deformity  | 371 (5)                | Not serious  | Not serious   | Not serious | Not serious  | None             | High                |                     |
| Recurrence of deformity  | 252 (3)                | Not serious  | Not serious   | Not serious | Not serious  | None             | High                |                     |
| AOFAS score              | 219 (3)                | Not serious  | Not serious   | Not serious | Not serious  | None             | High                |                     |
| Pain VAS                 | 123 (2)                | Not serious  | Not serious   | Serious     | Not serious  | None             | High                | Moderate            |

AOFAS: American Orthopaedic Foot and Ankle Society.

background including age, preoperative HVA, IMA and AOFAS score, no significant differences were observed between two osteotomies in each study.

**Proximal versus distal or mid-shaft osteotomies**

Three RCTs with 282 patients evaluated clinical and radiological outcomes of proximal osteotomies compared with distal osteotomies and reported conflicting results. One study reported that proximal closing wedge osteotomy was superior to distal chevron osteotomy in correcting HVA and IMA, while the other two studies reported equivalent radiological correction when distal and proximal chevron osteotomies were performed. Due to study design differences, we did not perform a meta-analysis.

We found only one RCT that compared mid-shaft osteotomy (rotational scarf) with proximal (chevron) osteotomy. The clinical and radiological outcomes were similar between the two groups.

**Meta-analysis for distal versus mid-shaft osteotomies**

Among the six studies that compared distal with mid-shaft osteotomies, five had similar designs which compared chevrons with scarf osteotomies, and were enrolled for meta-analysis. Preoperative HVA, IMA, and AOFAS scores in both groups were similar (Table 1). Results of quality assessments of included studies are shown in Table 2. According to the GRADE scale, the quality of the included studies was mostly high.

Five studies that assessed deformity correction were eligible for inclusion in the current study. Statistical pooling was possible for 411 feet. For the assessment of postoperative HVA and IMA, there were no significant differences between the groups (HVA; WMD = −1.42, 95% CI: −2.89 to 0.06, Z = 1.89, p = 0.06, and IMA; WMD = −0.64, 95% CI: −1.41 to 0.12, Z = 1.65, p = 0.10) (Figure 2(a) and (b)).

Three studies that assessed deformity recurrence were eligible for the current study. Statistical pooling was possible for 252 feet. No significant differences were detected between the groups (RR = 0.93, 95% CI: 0.72 to 1.20, Z = 0.57, p = 0.57) (Figure 2(c)).

Data on AOFAS scores were available in three studies, and statistical pooling was possible for 259 feet. There were no significant differences in the AOFAS scores between the chevron and scarf groups (WMD = 4.30, 95% CI: −0.17 to 8.76, Z = 1.89, p = 0.06) (Figure 2(d)). Data regarding the pain VAS score were available in two studies, and statistical pooling was possible for 123 feet. We did not detect any significant differences in the pain VAS score between the groups (WMD = 0.60, 95% CI: 0.25 to 1.47, Z = 1.12, p = 0.26) (Figure 2(f)).

**Discussion**

Although several RCTs have been conducted to compare different procedures for HV deformity, it is unclear whether the clinical outcomes are affected by the location of osteotomy in the first metatarsal. In this systematic review, we reviewed 10 RCTs that compared different metatarsal osteotomies for HV deformity, with a total of 793 feet. Previously, a few systematic reviews and meta-analyses were conducted to compare specific osteotomies for HV deformity, such as chevron versus scarf osteotomy or proximal versus distal osteotomy. To the best of our knowledge, the present systematic review is the first to provide an overview of controlled trials that specifically compare features of three (distal, mid-shaft, and proximal) first metatarsal osteotomy sites.

The authors found six trials that compared distal osteotomies with mid-shaft osteotomies. Among these trials, five RCTs comparing scarf with chevron osteotomies were enrolled for meta-analysis, indicating that these two procedures were widely used and accepted treatments. Scarf osteotomy is a mid-shaft osteotomy, and the method is widely used to correct moderate to severe HV deformities. According to previous studies, scarf osteotomy provides a...
predictable and strong correction for IMA; however, it is a technically demanding procedure, and troughing of the first metatarsal may be disadvantageous. Chevron osteotomy is a distal V-shaped osteotomy that is widely used for mild to moderate HV deformities. The Chevron procedure has several advantages including stability of osteotomy, rapid healing, and minimal shortening; however, osteonecrosis is known as a possible disadvantage of the method. A previous study comparing chevron and scarf osteotomy showed that both procedures present similar results with regard to radiological and clinical evaluation findings. On the other hand, the modified Chevron osteotomy has been reported to be superior to scarf osteotomy with regard to radiological correction of IMA. In the present meta-analysis, we observed no significant differences in postoperative HV A, IMA, recurrence of deformity, AOFAS score, and pain VAS score at the final follow-up, and perioperative complication.

**Figure 2.** Forest plots showing the (a) hallux valgus angle, (b) intermetatarsal angle, (c) recurrence of deformity, (d) American orthopedic foot and ankle society score, and (e) pain visual analog scale score at the final follow-up, and (f) perioperative complication.
score, pain VAS score, and complications between scarf and chevron osteotomies. In line with a previously reported meta-analysis including three RCTs and one CCT, the results of the current study suggest that the clinical outcomes of these two osteotomies were equivalent, at least for mild to moderate HV deformities.

The authors identified three RCTs that compared distal and proximal osteotomies. A study that compared proximal closing wedge and distal chevron osteotomies showed that proximal osteotomy resulted in a greater degree of HVA and IMA correction; however, patient satisfaction was similar between the groups. Other studies comparing proximal and distal chevron osteotomies showed equivalent clinical outcomes between the groups, although there was a tendency that the amount of correction was greater with the proximal procedure. In the present study, we did not perform a meta-analysis of the three trials because of significant differences in their study designs. Tsikopoulos et al. conducted a meta-analysis that compared any type of distal osteotomy with any type of proximal osteotomy and reported no significant differences in the clinical and radiological outcomes between the groups. However, half of the trials included in the study were determined to have unclear risk of bias via quality assessment, and the authors suggested that their results should be interpreted with caution. Thus, it remains unclear whether clinical and radiological outcomes of distal osteotomies are equivalent to those of proximal osteotomies.

The authors found only one RCT that compared mid-shaft (rotational scarf) osteotomy (n = 30) with proximal crescentic osteotomy (n = 30). They stated that the clinical and radiological outcomes were similar between the two groups. However, an average 2.6-mm shortening in the first metatarsal was observed in the group with proximal crescentic osteotomy, and no shortening was seen in the group with scarf osteotomy. Additional trials with similar study designs are required to conclude whether outcomes are equivalent between these two procedures.

The majority of patients included in the aforementioned trials showed mild to moderate deformity, and the mean HVA was <40° in most of the groups (Table 1). We found only one RCT that included patients with moderate to severe HV deformity, which compared distal and proximal chevron osteotomies, reporting similar clinical and radiological outcomes. The lack of RCTs in patients with severe HV deformities may reflect the fact that proximal metatarsal osteotomies have been popular for treating more severe HV deformities.

Some limitations of the present study should be mentioned. First, the lack of a long-term follow-up study limited the strength of the current study. The longest follow-up period of the enrolled studies was 2.6 years, which may underestimate the recurrence of deformity. Second, evaluation for pain VAS was lacking in some of the enrolled studies. Although affected by the types of anesthesia, the degree of postoperative pain has been reported to be different among the surgical procedures. Third, there have been no controlled studies including patients with severe HV deformity, which have historically been corrected by proximally orientated osteotomies or arthrodesis. Further controlled trials comparing different sites of osteotomies for moderate to severe HV deformity are needed.

Conclusions

We observed no significant differences in postoperative HVA, IMA, recurrence of deformity, AOFAS score, pain VAS score, and complications between scarf and chevron osteotomies in the meta-analysis. The results of the present study suggest that the clinical outcomes of these two osteotomies were equivalent, at least for mild to moderate HV deformities. Three RCTs comparing distal osteotomies with proximal osteotomies demonstrated conflicting results. It remains unclear whether the surgical outcomes of distal osteotomies are equivalent to those of proximal osteotomies. We found only one RCT that compared mid-shaft osteotomy with proximal crescentic osteotomy, demonstrating equivalent outcomes between the groups. Additional trials with similar study designs are required to conclude whether outcomes are equivalent between these two procedures. In addition, further controlled trials comparing different sites of osteotomies for moderate to severe HV deformity are needed.

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Authors’ contributions

JF, HT, TN, MH, MK, MK, DN, and KW collected the data, applied the eligibility criteria in full-texts stage, extracted the data from the included studies, and assessed the included studies for quality. JF and RO conducted the meta-analysis. All authors contributed to drafting the manuscript of this work. All authors have read and approved the final manuscript.

Declaration of conflicting interests

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**Availability of data and materials**

The datasets used during the current study are available at Harvard Dataverse (https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/NHGZ9T).

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