A commentary by Joshua S. Everhart, MD, MPH, is linked to the online version of this article at jbjs.org.

Unfavorable Outcomes Following Surgical Treatment of Hallux Valgus Deformity

A Systematic Literature Review

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Background: Surgical correction of deformity plays a central role in the treatment of hallux valgus deformity. However, complications or unintended outcomes are frequently noted in clinical series. There has been no rigorous systematic review of studies reporting outcomes of surgical treatment for hallux valgus deformity, to the best of our knowledge.

Methods: We performed a systematic review of studies reporting the outcomes of surgical correction for hallux valgus deformity.

Results: A total of 229 studies met the inclusion criteria. The pooled rates of postoperative patient dissatisfaction and postoperative first metatarsophalangeal pain were 10.6% and 1.5%, respectively. The overall rate of recurrent deformity was 4.9%.

Conclusions: Hallux valgus surgery has been reported to have fairly consistent results and rates of complications or unfavorable outcomes.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Hallux valgus (HV) deformity is one of the most common foot disorders^{1,2}. The pooled prevalence of HV deformity in the reported literature has been estimated to be 23% among those 18 to 65 years of age and 35.7% among those over 65 years of age³. The pathogenesis of HV deformity is complex⁴. Surgical correction of deformity plays a central role in the treatment of HV deformity, and >100 different surgical techniques have been described^{5,6}.

The more commonly reported unintended outcomes from surgical correction of HV include recurrence of HV deformity^{7,8}, persistent pain⁹, secondary metatarsalgia⁷, nerve injury^{7,10}, infection^{10,11}, delayed union or nonunion¹², hallux varus deformity^{7,8,11}, and the need for secondary procedures^{7,9,11}. Dissatisfaction and the need for hardware removal are also frequently noted in clinical series, with rates of up to 47%¹³ and 25%¹⁴, respectively.

While each of these individual surgical outcomes has been highlighted in independent clinical series⁵, to the best of our knowledge no rigorous systematic review of studies reporting the outcomes of surgical treatment of HV deformity has been published. The objectives of our study were to (1) describe the characteristics of studies of surgical HV deformity treatment, (2) determine patient dissatisfaction and pain, (3) determine the rates of postoperative complications by surgery type, and (4) identify correlations between preoperative or intraoperative factors and rates of postoperative complications.

Materials and Methods

Search Method and Strategy

PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines were followed when preparing

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TABLE I Inclusion and Exclusion Criteria for the Systematic Literature Review

Inclusion Criteria	Exclusion Criteria
Reporting of clinical, surgical, and/or radiographic outcomes	Review article
Reporting of surgical complications	Case report
Minimum follow-up ≥ 1 year or median follow-up ≥ 2 years	Surgical technique article
Minimum 10 feet reported on	Cadaveric study
Identification of specific surgical procedure(s) used	Biomechanical/kinematic study
English, German, French, Italian, Norwegian, Russian, Spanish, or Swedish language	Patient-oriented educational article (e.g., “why not to wear high heels”)
	Double publication involving the same patient cohort
	Primarily adolescent-onset HV patient cohort, defined as inclusion of patients < 18 years old or mean patient age < 25 years
	Inclusion of patients with spasticity (stroke, cerebral palsy, etc.)-induced HV
	Inclusion of patients treated for hallux rigidus or metatarsophalangeal osteoarthritis
	Inclusion of patients with rheumatoid or inflammatory arthritis, gout, or hemophilia
	Inclusion of patients who underwent surgery outside the first ray
	Revision of failed HV surgery
	Prosthetic replacement of first metatarsophalangeal joint

this systematic literature review¹⁵. Five major medical databases were searched from inception through July 1, 2016: PubMed, MEDLINE, Embase, CINAHL (Cumulative Index to Nursing and Allied Health), and the Cochrane Central Register of Controlled Trials (CENTRAL). We also searched the “gray” literature (conference proceedings, industry white papers, Google Scholar). A medical library search strategist (M.L.) was consulted to develop a sensitive and comprehensive search strategy (see Appendix Table E-1). Supplemental bibliographic reference searches were also conducted by 2 of the reviewers (A.B. and J.R.H.) to identify potentially relevant studies.

Study Selection and Data Extraction Procedure

The study selection process was conducted independently by 3 reviewers (A.B., J.R.H., and C.L.S.). If a study passed an initial screening on the basis of the title and abstract review, the full text was retrieved and reviewed in detail to determine if the study met inclusion and exclusion criteria (Table I). The decision to include or exclude the study was made on the basis of a group consensus.

Data were extracted from studies that met the above-mentioned inclusion/exclusion criteria independently by the 2 reviewers (A.B. and J.R.H.). Data extraction was verified by a third reviewer (C.L.S.). The following data were extracted from each study: author(s), journal of publication, title, publication year, study design (prospective versus retrospective, single-center versus multicenter, observational versus comparative), type of surgical procedure, number of subjects and/or number of feet, sex distribution, subject age, follow-up duration, percentage of subjects and/or feet available at the latest follow-up, and preoperative radiographic parameters (HV angle, intermetatarsal angle). The following data elements regarding

unfavorable outcomes were also extracted from each study: patient dissatisfaction (see Appendix Table E-2), recurrence of HV deformity, postoperative pain (visual analog scale [VAS], ≥ 5), postoperative metatarsalgia, nerve injury, infection, non-union, iatrogenic hallux varus, reoperation, and removal of hardware.

Study Design

A total of 229 studies (reporting on 266 patient cohorts) met the inclusion criteria (see Appendix Table E-3) and are the focus of the present systematic review. The studies were published between 1968 and 2016 (Table II). For multiple studies by the same authors, only 1 study was included unless clear information on the absence of overlap between the cohorts was available.

TABLE II Study Designs for the 266 Included Patient Cohorts

Design	No. (%)
Prospective	63 (23.7%)
Retrospective	203 (76.3%)
Single center	260 (97.7%)
Multicenter	6 (2.3%)
Observational	191 (71.8%)
Comparative	75 (28.2%)
Level of evidence	
I	22 (8.3%)
II	13 (4.9%)
III	55 (20.7%)
IV	176 (66.2%)

TABLE III Criteria Used for the Modified Coleman Methodology Score

Section	Number or Factor	Score
Part A*		
1. Study size: no. of subjects (<i>no.</i>)	>60	10
	41-60	7
	20-40	4
	<20 or not stated	0
2. Mean follow-up (<i>mo</i>)	>24	5
	12-24	2
	<12, not stated, or unclear	0
3. No. of different surgical procedures included in each reported outcome	1 surgical procedure only	10
	More than 1 surgical procedure, but >90% of subjects undergoing the 1 procedure	7
	Not stated, unclear, or <90% of subjects undergoing the 1 procedure	0
4. Type of study	Randomized controlled trial	15
	Prospective cohort study	10
	Retrospective cohort study	0
5. Diagnostic certainty	In all	5
	In ≥80%	3
	In <80%, not stated, or unclear	0
6. Description of surgical procedure	Adequate (technique stated and necessary details of that type of procedure given)	10
	Fair (technique only stated without elaboration)	5
	Inadequate, not stated, or unclear	0
7. Description of postoperative rehabilitation	Well described with >80% of patients complying	5
	Well described with 60-80% of patients complying	3
	Not well described	0
Part B†		
1. Outcome criteria	Outcome measures clearly defined	2
	Timing of outcome assessment clearly stated (e.g., at best outcome after surgery or at the time of follow-up)	2
	Use of outcome criteria that have reported good reliability	3
	Use of outcome with good sensitivity	3
2. Procedure for assessing outcomes	Subjects recruited (results not taken from surgeon's files)	5
	Investigator independent of surgeon	4
	Written assessment	3
3. Description of subject selection process	Selection criteria reported and unbiased	5
	Recruitment rate reported >80%	5
	Eligible subjects not included in the study satisfactorily accounted for or 100% recruitment	5

*Only 1 score to be given for each of the 7 sections. †Scores may be given for each option in each of the 3 sections if applicable.

Study Quality Evaluation

Two reviewers (A.B. and J.R.H.) applied a modified version of the Coleman methodology score (mCMS) to assess the quality of methodology in each study^{16,17}. The 2-part mCMS grades studies on the basis of 10 criteria (Table III). Part A evaluates

the study size, mean follow-up duration, number of different surgical procedures, type of study, diagnostic certainty, and descriptions of the surgical procedure and postoperative rehabilitation. Part B evaluates the outcome criteria, procedure for assessing outcomes, and description of the subject selection

Fig. 1
Flowchart showing identification of the included studies.

process. The maximum score on the mCMS is 100, which indicates that a study largely avoids chance, biases, and confounding factors¹⁸. The CMS is a validated, reliable scoring system¹⁶.

Statistical Methods

The study type (prospective versus retrospective), number of patients, number of feet, patient age and sex, and follow-up duration were summarized across the 9 surgery types. The percentage of female patients was estimated using an inverse-variance weighting method, and patient age and follow-up duration were summarized using a simple weighted average because the majority of studies did not report the variance.

A chi-square Q test for heterogeneity was used to test for differences across surgery types for average rates of patient dissatisfaction, HV deformity recurrence, reoperation, removal of hardware, nonunion, intraoperative nerve injury, postoperative infection, persisting pain (VAS ≥ 5), and postoperative metatarsalgia. Time-to-event information was ignored for these outcomes because of an absence of consistent reporting. Outcome estimates for each surgery type were transformed and pooled across studies using the inverse-variance weighting method implemented using the metaprop function of the meta

package in R¹⁹. The arcsine transformation was used to handle rare events for which some studies did not contribute any affected patients²⁰. A random-effects model was used in which

TABLE IV Modified Coleman Methodology Score for the Included Cohorts*

Surgery Type	mCMS		
	Part A	Part B	Total
Distal osteotomy	45.7	27.5	73.2
Proximal osteotomy	43.3	29.4	72.9
Shaft osteotomy	48.7	29.9	78.2
Joint hemiresection	40.4	24.5	64.9
Simple bunionectomy	41.7	26.2	67.8
Shaft and Akin osteotomies	44.5	28.3	72.8
Proximal and Akin osteotomies	44.6	27.3	71.9
First TMT arthrodesis	43.4	29.4	72.9
Other	39.2	25.8	65.1

*mCMS = modified Coleman methodology score, and TMT = tarsometatarsal.

TABLE V Descriptive Summary of Cohort Characteristics by Surgery Type

Surgery Type	No. of Patients	No. of Feet	Prospective/ Retrospective	Mean Age (Range)* (yr)	% Female Patients (95% CI)†	Mean Follow-up (Range)‡ (yr)
Distal osteotomy	6,765 (52.6%)	8,809 (54.1%)	35/89	47.1 (11.0-87.0)	73.5 (70.7-76.1)	3.9 (0.5-34.0)
Proximal osteotomy	1,295 (10.1%)	1,548 (9.5%)	7/27	48.0 (13.0-84.0)	77.6 (72.5-82.1)	4.3 (0.8-22.2)
Shaft osteotomy	1,028 (8.0%)	1,154 (7.1%)	10/12	50.9 (11.0-83.0)	79.2 (70.9-85.6)	2.5 (1.0-10.1)
Joint hemiresection	882 (6.9%)	1,136 (7.0%)	1/21	55.7 (16.0-87.0)	72.2 (65.3-78.2)	5.8 (0.5-26.0)
Simple bunionectomy	699 (5.4%)	939 (5.8%)	2/17	45.5 (9.0-76.0)	69.2 (63.2-74.6)	6.0 (1.0-34.0)
Shaft and Akin osteotomies	497 (3.9%)	555 (3.4%)	3/7	52.2 (13.4-78.0)	79.2 (70.4-85.9)	4.1 (1.0-11.7)
Proximal and Akin osteotomies	380 (3.0%)	482 (3.0%)	1/6	50.3 (14.0-83.0)	76.7 (66.1-84.7)	1.9 (1.0-5.0)
First TMT arthrodesis§	271 (2.1%)	309 (1.9%)	2/4	44 (12.0-84.0)	72.6 (61.9-81.2)	3.9 (1.0-12.0)
Other	1,049 (8.2%)	1,341 (8.2%)	2/20	49.4 (12.0-88.0)	72.1 (63.6-79.2)	4.6 (0.5-20.0)
Total	12,866 (100%)	16,273 (100%)	63/203			

*Weighted average, calculated by weighting each reported mean age by the numbers of patients in the cohort. †Percentage of feet that were in female patients, estimated using a random-effects model and inverse-variance weighting. ‡Weighted average, calculated by weighting each reported mean follow-up by the numbers of feet in the cohort. §TMT = tarsometatarsal.

between-study variance was estimated using the DerSimonian-Laird method²¹. A 95% confidence interval (CI) was included with each estimate.

We examined risk of bias across studies by testing for differences in study characteristics including publication year, level of evidence, and total mCMS across surgery types. We compared publication year and level of evidence across surgery types using a chi-square test with Monte Carlo stimulation because of low cell counts and across total mCMS using analysis of variance (ANOVA). Because these characteristics could bias

our results comparing patient outcomes across surgery types, we repeated our analyses controlling for study characteristics by meta-regression implemented using the metareg function of the meta package in R (adjusted p value, p_{adj}). We also tested for heterogeneity of the studies within each surgery type using the chi-square Q test described above and determined the percentage of study variation due to heterogeneity rather than chance (I^2).

We used meta-analysis techniques to pool outcomes within surgery types and to test for outcome differences across surgery types. However, it is important to emphasize that these

TABLE VI Rate of Postoperative Patient Dissatisfaction by Surgery Type

Surgery Type	No. of Studies (N = 139)	No. of Patients (N = 6,414)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I^2	P Value*
Distal osteotomy	65 (46.8%)	3,502 (54.6%)	357	9.5 (7.1-12.2)	80%	<0.001
Proximal osteotomy	21 (15.1%)	736 (11.5%)	82	9.3 (6-13.3)	60%	<0.001
Shaft osteotomy	12 (8.6%)	340 (5.3%)	38	8.9 (3.6-16.3)	80%	<0.001
Joint hemiresection	17 (12.2%)	697 (10.9%)	133	16.1 (10.8-22.3)	80%	<0.001
Simple bunionectomy†	10 (7.2%)	423 (6.6%)	114	23.3 (14.5-33.5)	80%	<0.001
Shaft and Akin osteotomies	3 (2.2%)	106 (1.7%)	7	6.5 (2.6-11.9)	0%	0.91
Proximal and Akin osteotomies	2 (1.4%)	201 (3.1%)	14	6.9 (3.9-10.9)	0%	0.9
First TMT arthrodesis†	2 (1.4%)	120 (1.9%)	12	10 (5.3-16)	0%	1
Other§	7 (5.0%)	289 (4.5%)	22	5.8 (2.5-10.3)	50%	0.1
Total	139	6,414	779	10.6 (8.8-12.5)	80%	<0.001

*Cochran test for heterogeneity of studies within each surgery type. †Surgery type with highest value. ‡TMT = tarsometatarsal. §Surgery type with lowest value.

TABLE VII Rate of Persisting Postoperative Pain (VAS ≥ 5) by Surgery Type

Surgery Type	No. of Studies (N = 120)	No. of Patients (N = 7,303)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I ²	P Value*
Distal osteotomy	58 (48.3%)	3,815 (52.2%)	103	0.8 (0.2-1.7)	80%	<0.001
Proximal osteotomy	10 (8.3%)	336 (4.6%)	12	1.1 (0-4.6)	80%	<0.001
Shaft osteotomy	6 (5.0%)	371 (5.1%)	7	1.3 (0-4.9)	80%	0.001
Joint hemiresection	15 (12.5%)	851 (11.7%)	78	4.6 (0.8-11.3)	90%	<0.001
Simple bunionectomy	11 (9.2%)	551 (7.5%)	24	2.5 (0.2-7.1)	90%	<0.001
Shaft and Akin osteotomies	2 (1.7%)	143 (2.0%)	5	1.5 (0-11.8)	90%	0.028
Proximal and Akin osteotomies	2 (1.7%)	208 (2.8%)	5	1.4 (0-12.3)	90%	0.003
First TMT arthrodesis†	2 (1.7%)	83 (1.1%)	0	0 (0-1.2)	0%	1
Other	14 (11.7%)	945 (12.9%)	56	3 (0.6-7.4)	90%	<0.001
Total	120	7,303	290	1.5 (0.8-2.4)	90%	<0.001

*Cochran test for heterogeneity of studies within each surgery type. †TMT = tarsometatarsal.

analyses were conducted within the context of a systematic review. The studies synthesized here were highly heterogeneous and reported on just 1 to 2 surgery types each, and thus we were unable to perform a traditional meta-analysis that pools effect sizes for comparisons of 2 surgery types. Similarly, we were unable to assess publication bias.

The HV angle and first-second intermetatarsal angle were compared with outcomes (average rates of HV deformity recurrence, patient dissatisfaction, and pain VAS ≥ 5) using a weighted Pearson correlation coefficient, with weights corresponding to study size. Corresponding 95% CIs were estimated using the Fisher z transformation, and p values were calculated using permutation tests. Statistical analyses were conducted in R version 3.3.1, significance was assessed at the 0.05 level, and all tests were 2-tailed.

Results

The study selection process is shown in Figure 1. A total of 16,273 procedures on 12,866 patients from 229 studies were included in the data analysis (see Appendix Table E-3). The mCMS for the included cohorts was comparable in all subgroups, ranging between 64.9 and 73.2 (Table IV). A descriptive summary of the cohort characteristics is shown in Table V.

Postoperative Patient Dissatisfaction and Postoperative Pain

Patient satisfaction was assessed using dichotomous (n = 47; 33.8%), ordinal (n = 89; 64.0%), or interval (n = 3; 2.2%) scales (see Appendix Table E-2). There was a significant difference in the rate of patient dissatisfaction across the 9 different surgery types (p = 0.004; p_{adj} = 0.03) (Table VI). The

TABLE VIII Rate of Postoperative Metatarsalgia by Surgery Type

Surgery Type	No. of Studies (N = 54)	No. of Patients (N = 2,707)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I ²	P Value*
Distal osteotomy	25 (46.3%)	1,201 (44.4%)	166	10.8 (6.5-16)	90%	<0.001
Proximal osteotomy	6 (11.1%)	264 (9.8%)	34	8.2 (2.1-17.8)	80%	<0.001
Shaft osteotomy	3 (5.6%)	118 (4.4%)	0	0 (0-0.8)	0%	1
Joint hemiresection	5 (9.3%)	243 (9.0%)	43	17.4 (12.8-22.6)	10%	0.51
Simple bunionectomy	4 (7.4%)	199 (7.4%)	11	0.8 (0-7.6)	80%	0.009
Shaft and Akin osteotomies	2 (3.7%)	73 (2.7%)	2	2.6 (0.2-7.5)	0%	0.86
Proximal and Akin osteotomies	2 (3.7%)	140 (5.2%)	4	1.2 (0-8.8)	80%	0.13
First TMT arthrodesis†	7 (13.0%)	469 (17.3%)	7	0.6 (0-2.6)	70%	0.006
Other	54	2,707	267	6.3 (4-9.2)	90%	<0.001

*Cochran test for heterogeneity of studies within each surgery type. †TMT = tarsometatarsal.

TABLE IX Rate of Postoperative HV Recurrence by Surgery Type

Surgery Type	No. of Studies (N = 133)	No. of Patients (N = 9,698)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I ²	P Value*
Distal osteotomy	60 (45.1%)	5,247 (54.1%)	286	4.1 (2.7-5.7)	90%	<0.001
Proximal osteotomy	20 (15.0%)	1,051 (10.8%)	123	9.3 (4.6-15.5)	90%	<0.001
Shaft osteotomy	14 (10.5%)	861 (8.9%)	49	5.6 (2.1-10.6)	90%	<0.001
Joint hemiresection	6 (4.5%)	367 (3.8%)	20	4.8 (1.8-9.1)	60%	0.035
Simple bunionectomy	9 (6.8%)	546 (5.6%)	40	5.9 (2.5-10.5)	70%	<0.001
Shaft and Akin osteotomies	5 (3.8%)	267 (2.8%)	12	4.3 (2.2-7.1)	0%	0.83
Proximal and Akin osteotomies	3 (2.3%)	309 (3.2%)	15	4.8 (2.7-7.4)	0%	0.79
First TMT arthrodesis†	5 (3.8%)	261 (2.7%)	8	1.7 (0.1-5.1)	60%	0.1
Other	11 (8.3%)	789 (8.1%)	68	4.3 (1.2-9.3)	90%	<0.001
Total	133	9,698	621	4.9 (3.8-6.1)	90%	<0.001

*Cochran test for heterogeneity of studies within each surgery type. †TMT = tarsometatarsal.

dissatisfaction rate was the highest in patients who underwent a simple bunionectomy or joint hemiresection.

The rate of persisting postoperative pain was comparable in the 9 different surgery types ($p = 0.26$; $p_{adj} = 0.54$) (Table VII). There was a significant difference in the prevalence of postoperative metatarsalgia ($p < 0.001$; $p_{adj} = 0.01$) (Table VIII). The rate of postoperative metatarsalgia was the highest in patients who underwent joint hemiresection.

Recurrence of HV Deformity and Intraoperative Nerve Injury

The rate of recurrent HV deformity was comparable across all surgery types ($p = 0.43$; $p_{adj} = 0.32$), averaging 4.9% (Table IX).

The rate of intraoperative nerve injury was comparable across all surgery types ($p = 0.38$; $p_{adj} = 0.45$), averaging 3% (Table X).

Infection and Osseous Nonunion

There was a significant difference in reported postoperative infection rate across the 9 different surgery types ($p = 0.02$;

$p_{adj} = 0.14$) (Table XI). Patients who underwent a first tarsometatarsal arthrodesis (Lapidus procedure) had the highest reported rate of postoperative infection, and patients who had a metatarsal shaft osteotomy had the lowest reported rate.

There was a significant difference in the postoperative rate of osseous nonunion across the 9 different surgery types ($p = 0.012$; $p_{adj} < 0.001$) (Table XII). The rate of postoperative nonunion was the highest in patients who underwent first tarsometatarsal arthrodesis.

Need for Secondary Surgery and Postoperative Hallux Varus Deformity

The rate of reoperation was comparable across all surgery types ($p = 0.005$; $p_{adj} = 0.18$) (Table XIII), as was the need for hardware removal ($p < 0.001$; $p_{adj} = 0.08$) (Table XIV).

There was a significant difference in the rate of hallux varus deformity across the 9 different surgery types ($p = 0.025$; $p_{adj} = 0.012$) (Table XV). The reported rate of postoperative

TABLE X Rate of Intraoperative Nerve Injury by Surgery Type

Surgery Type	No. of Studies (N = 69)	No. of Patients (N = 3,930)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I ²	P Value*
Distal osteotomy	40 (58.0%)	2,460 (62.6%)	102	3.3 (2.2-4.5)	60%	<0.001
Proximal osteotomy	9 (13.0%)	459 (10.8%)	11	1.4 (0.1-4.2)	70%	0.002
Shaft osteotomy	4 (5.8%)	120 (3.1%)	2	0.5 (0-4)	50%	0.16
Joint hemiresection	4 (5.8%)	171 (4.4%)	4	1.8 (0.1-5.7)	50%	0.2
Simple bunionectomy	6 (8.7%)	264 (6.7%)	26	7.5 (0.3-22.7)	90%	<0.001
Proximal and Akin osteotomies	2 (2.9%)	239 (6.1%)	5	2.1 (0.7-4.3)	0%	0.88
First TMT arthrodesis†	4 (5.8%)	217 (5.5%)	15	5 (0.4-14.1)	80%	0.002
Other	69	3,930	165	3 (2-4.1)	70%	<0.001

*Cochran test for heterogeneity of studies within each surgery type. †TMT = tarsometatarsal.

TABLE XI Rate of Postoperative Infection by Surgery Type

Surgery Type	No. of Studies (N = 164)	No. of Patients (N = 10,577)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I ²	P Value*
Distal osteotomy	83 (50.6%)	6,408 (60.6%)	188	2.5 (1.9-3.2)	60%	<0.001
Proximal osteotomy	21 (12.8%)	958 (9.1%)	30	2.2 (1.3-3.7)	50%	0.004
Shaft osteotomy†	13 (7.9%)	677 (6.4%)	13	1.5 (0.6-2.8)	30%	0.21
Joint hemiresection	10 (6.1%)	530 (5.0%)	16	2.2 (0.6-4.8)	60%	0.007
Simple bunionectomy	8 (4.9%)	295 (2.8%)	27	8.4 (4.9-12.8)	40%	0.21
Shaft and Akin osteotomies	6 (3.7%)	380 (3.6%)	12	2.7 (0.8-5.8)	50%	0.1
Proximal and Akin osteotomies	5 (3.0%)	329 (3.1%)	10	2.9 (1.3-4.9)	0%	0.78
First TMT arthrodesis‡§	3 (1.8%)	179 (1.7%)	16	11.4 (0.3-35)	90%	<0.001
Other	15 (9.1%)	821 (7.8%)	27	2.3 (0.7-4.9)	70%	<0.001
Total	164	10,577	339	2.6 (2.1-3.2)	60%	<0.001

*Cochran test for heterogeneity of studies within each surgery type. †Surgery type with lowest value. ‡Surgery type with highest value. §TMT = tarsometatarsal.

hallux varus deformity was the highest in patients who underwent a proximal osteotomy.

Correlation Between Radiographic Parameters and Postoperative Outcomes

The preoperative HV angle was positively correlated with the postoperative rate of HV deformity recurrence ($r = 0.3$, 95% CI = 0.11 to 0.47, $p = 0.002$) (Table XVI). The preoperative first-second intermetatarsal angle was negatively correlated with the postoperative rate of patient dissatisfaction ($r = -0.26$, 95% CI = -0.42 to -0.09 , $p = 0.002$) (Table XVI). The latter result is interpreted as indicating that patients with lower preoperative first-second intermetatarsal angles were more dissatisfied than patients with higher angles.

Discussion

We performed a systematic literature review of studies addressing clinical outcomes in adult patients who underwent primary surgical treatment for HV deformity. Five major medical databases were searched from inception through July 1, 2016, and all articles written in English, Spanish, French, German, Italian, Norwegian, Russian, and Swedish were considered for inclusion. Using strict inclusion and exclusion criteria, we identified papers focused on the outcomes of primary treatment of adult HV without known systemic etiology, without contamination by other surgical treatments, and with sufficient follow-up time and information to be able to make meaningful observations. In identifying those essential articles, we reduced the 5,584 papers identified in the database search

TABLE XII Rate of Postoperative Osseous Nonunion by Surgery Type

Surgery Type	No. of Studies (N = 101)	No. of Patients (N = 7,526)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I ²	P Value*
Distal osteotomy	61 (60.4%)	5,489 (72.9%)	7	0.01 (0-0.06)	0%	1
Proximal osteotomy	14 (13.9%)	646 (8.6%)	2	0.03 (0-0.32)	0%	0.93
Shaft osteotomy†	6 (5.9%)	338 (4.5%)	0	0 (0-0.28)	0%	1
Joint hemiresection†	2 (2.0%)	75 (1.0%)	0	0 (0-1.28)	0%	1
Shaft and Akin osteotomies	2 (2.0%)	71 (0.9%)	1	1.21 (0-13.14)	70%	0.19
Proximal and Akin osteotomies	2 (2.0%)	156 (2.1%)	2	0.69 (0-6.09)	80%	0.11
First TMT arthrodesis‡§	5 (5.0%)	261 (3.5%)	13	3.77 (1.14-7.83)	50%	0.18
Other	9 (8.9%)	490 (6.5%)	1	0.05 (0-0.43)	0%	0.96
Total	101	7,526	26	0.04 (0.01-0.1)	0%	0.7

*Cochran test for heterogeneity of studies within each surgery type. †Surgery type with lowest value. ‡Surgery type with highest value. §TMT = tarsometatarsal.

TABLE XIII Rate of Reoperation Other Than Hardware Removal by Surgery Type

Surgery Type	No. of Studies (N = 92)	No. of Patients (N = 6,040)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I ²	P Value*
Distal osteotomy	37 (40.2%)	3,137 (51.9%)	107	1.3 (0.5-2.4)	80%	<0.001
Proximal osteotomy	15 (16.3%)	649 (10.7%)	24	2.4 (1.4-5)	50%	0.014
Shaft osteotomy	9 (9.8%)	515 (8.5%)	16	2.2 (0.2-6.3)	80%	<0.001
Joint hemiresection	4 (4.3%)	229 (3.8%)	6	2 (0.1-6.1)	60%	0.08
Simple bunionectomy	7 (7.6%)	393 (6.5%)	28	5.5 (1.4-12.2)	80%	<0.001
Shaft and Akin osteotomies	4 (4.3%)	217 (3.6%)	2	0.4 (0-2.3)	40%	0.31
Proximal and Akin osteotomies	3 (3.3%)	273 (4.5%)	15	5 (0.2-15.5)	90%	<0.001
First TMT arthrodesis†	5 (5.4%)	261 (4.3%)	18	6.6 (3.9-9.9)	0%	0.65
Other	8 (8.7%)	366 (6.1%)	9	2.1 (0.9-3.8)	0%	0.7
Total	92	6,040	225	2.1 (1.4-3)	70%	<0.001

*Cochran test for heterogeneity of studies within each surgery type. †TMT = tarsometatarsal.

process to 229 key articles included in the analysis. The total mCMS among the major classes of procedure were between 64 and 74, which suggests moderate overall methodological quality of the sources.

Based on the major overall findings reported at a mean follow-up of 4 years for the total of 16,273 surgeries, we found an average rate of recurrent deformity of 4.9% (95% CI, 3.8% to 6.1%), metatarsalgia of 6.3% (95% CI, 4% to 9.2%), dissatisfaction of 10.6% (95% CI, 8.8% to 12.5%), and first metatarsophalangeal pain of 1.5% (95% CI, 0.8% to 2.4%). Although the rate of hardware removal was relatively high for some procedures (16% for combined shaft and Akin osteotomy procedures), the need for other secondary surgery was relatively low, averaging 2.1% (95% CI, 1.4% to 3%). The observed results should be interpreted carefully, especially with regard to the patient dissatisfaction rate.

First, different scales and tools were used to assess patient dissatisfaction rates, including dichotomous, ordinal, and interval scales (see Appendix Table E-2). Second, pooling satisfaction scores for the purpose of review may not yield a reproducible or valid outcome as the majority of instruments generally used to assess satisfaction have demonstrated low evidence with respect to reliability or validity²². The average infection rate in analyzed studies was 2.6% (95% CI, 2.1% to 3.2%). However, this finding should be carefully interpreted as different definitions for infection were used, without standardized definitions for “wound infections” versus “wound complications.”²³

We were surprised to see that the simple bunionectomy procedure yielded higher relative rates of patient dissatisfaction, perioperative infection, and development of hallux varus. We hypothesize 2 plausible explanations for these

TABLE XIV Rate of Hardware Removal by Surgery Type

Surgery Type	No. of Studies (N = 44)	No. of Patients (N = 2,793)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I ²	P Value*
Distal osteotomy	12 (27.3%)	955 (34.2%)	24	1.9 (0.3-4.9)	80%	<0.001
Proximal osteotomy	15 (34.1%)	708 (25.3%)	43	3.4 (0.7-7.9)	90%	<0.001
Shaft osteotomy	10 (22.7%)	654 (23.4%)	18	2.3 (1.4-2)	40%	0.1
Shaft and Akin osteotomies	2 (4.5%)	143 (5.1%)	23	16 (10.5-22.4)	0%	0.66
Proximal and Akin osteotomies	1 (2.3%)	70 (2.5%)	5	7.1 (2.3-14.3)	—	—
First TMT arthrodesis†	2 (4.5%)	154 (5.5%)	10	6.4 (3.1-10.8)	0%	0.68
Other	2 (4.5%)	109 (3.9%)	23	21.1 (14-29.2)	0%	0.88
Total	44	2,793	146	3.8 (2.2-5.9)	80%	<0.001

*Cochran test for heterogeneity of studies within each surgery type. †TMT = tarsometatarsal.

TABLE XV Rate of Postoperative Hallux Varus Deformity by Surgery Type

Surgery Type	No. of Studies (N = 117)	No. of Patients (N = 7,904)	Total No. of Patients Affected	% of Patients Affected (95% CI)	I ²	P Value*
Distal osteotomy†	45 (38.5%)	3,711 (47.0%)	45	0.7 (0.3-1.3)	70%	<0.001
Proximal osteotomy	24 (20.5%)	1,173 (14.8%)	66	4.1 (2.2-6.7)	70%	<0.001
Shaft osteotomy	10 (8.5%)	574 (7.3%)	17	1.8 (0.4-4.3)	70%	0.003
Joint hemiresection	5 (4.3%)	269 (3.4%)	10	2.9 (0.4-7.7)	70%	0.022
Simple bunionectomy‡	11 (9.4%)	615 (7.8%)	32	3.3 (1.2-6.4)	70%	0.001
Shaft and Akin osteotomies	5 (4.3%)	376 (4.8%)	8	1.8 (0.3-4.7)	60%	0.08
Proximal and Akin osteotomies	4 (3.4%)	356 (4.5%)	17	3.2 (0.6-8.4)	80%	0.016
First TMT arthrodesis§	2 (1.7%)	82 (1.0%)	2	2.9 (1.2-5.5)	0%	0.73
Other	11 (9.4%)	748 (9.5%)	19	1.2 (0.2-3)	70%	0.001
Total	117	7,904	216	1.83 (1.26-2.51)	80%	<0.001

*Cochran test for heterogeneity of studies within each surgery type. †Surgery type with lowest value. ‡Surgery type with highest value.
§TMT = tarsometatarsal.

findings. First, most of these procedures were combined with a lateral soft-tissue release. The combination of an aggressive medial eminence resection with a substantial soft-tissue release and tight medial collateral ligament closure can increase the potential for postoperative problems, including the development of hallux varus. Second, the case-weighted average year of publication for these procedures was 1989. The procedures were performed an average of 6 years prior to publication, well before internal fixation was widely used in treating HV, and most likely involved patients with large deformities needing substantial dissection and bone resection to obtain a satisfactory intraoperative reduction. Today, with other approaches being more commonly used, the patients in those earlier series might very well not be considered for a “simple” bunionectomy.

Similarly, joint hemiresection to treat HV is no longer commonly reported. The case-weighted average year of publication for the included articles on hemiresection of the first metatarsophalangeal joint for the treatment of HV was 1996,

with an average follow-up of 6 years. On average, these procedures were performed during or before 1990. The ultimate dissatisfaction with this procedure and “simple” bunionectomy may be a key reason that other general types of procedures have been reported more frequently in the past 2 decades. Both procedures, simple bunionectomy and joint hemiresection, are associated with a higher-than-average failure rate and are mostly of historical interest, as they fail to acknowledge the complex mechanics of the foot and of HV deformity.

The use of internal fixation is associated with secondary procedures for hardware removal. As expected, the more hardware that is used, the higher the rate of removal. Adding an Akin procedure to a shaft osteotomy procedure is associated with a higher rate of undergoing a subsequent procedure to remove hardware. However, the decision to remove hardware depends on the preferences of the patient and the surgeon; this review does not have the ability to fully elucidate the factors behind these decisions, which could be unrelated to the amount of hardware used.

TABLE XVI Weighted Correlation Between Preoperative Radiographic Parameters and Postoperative Outcomes*

Preop. Variable	Postop. Outcome	Pearson Correlation Coefficient (95% CI)†	P Value‡
HVA	HVA vs. HV deformity recurrence	0.3 (0.11 to 0.47)	0.002
HVA	Postop. patient dissatisfaction	0.01 (−0.16 to 0.18)	0.95
HVA	Postop. persisting pain (VAS ≥ 5)	0.06 (−0.14 to 0.25)	0.59
IMA	HV deformity recurrence	0.11 (−0.09 to 0.3)	0.28
IMA	Postop. patient dissatisfaction	−0.26 (−0.42 to −0.09)	0.002
IMA	Postop. persisting pain (VAS ≥ 5)	−0.05 (−0.24 to 0.14)	0.63

*HVA = hallux valgus angle, and IMA = first-second intermetatarsal angle. †Weighted by size of study. ‡From permutation test.

This study was clearly limited by the quality of the source literature, which is dominated by single-surgeon retrospective case series, and by the long period of time covered, with different data-quality standards. The aggregation of data cannot control for the technical skill of the surgeon, the degree of deformity, or the complexity of the cases treated. As a result, conclusions should be interpreted with caution to reflect this uncertainty. This study is further limited by language, as there undoubtedly were valuable reports in languages that we were unable to critically review. Overall, we found that HV surgery has been reported to have fairly consistent results and rates of complications or unfavorable outcomes. We were further limited by the grouping of procedures (e.g., distal or proximal metatarsal osteotomies) as clearly there are technical differences in how these are performed, and those differences may substantially affect outcomes. Similarly, grouping together series of cases with somewhat different approaches (for example, open and limited-incision distal first metatarsal osteotomies) is an additional limitation of the study. Although we found evidence of recent enthusiasm for less-invasive procedures for HV, we did not identify enough case series with sufficient follow-up for inclusion as a separate type of surgery. Future work should focus on the value of organizing and conducting prospective multicenter studies from which higher-quality data can be abstracted.

Appendix

eA Tables describing the search strategy, the types of tools used for measuring satisfaction, and the characteristics of the included studies, as well as a supplementary reference list containing the included studies, are available with the online version of this article as a data supplement at [jbjs.org \(http://links.lww.com/JBJS/E890\)](http://links.lww.com/JBJS/E890). ■

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