The Journal of Foot & Ankle Surgery 61 (2022) 785−791

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Correlation of Loss of Correction With Postoperative Radiological Factors After Distal Chevron Osteotomy in Dependence of Concomitant Akin Osteotomy

Gerhard Kaufmann, MD[1], Matthias Braito, MD, PhD[2], Moritz Wagner, MD[2], David Putzer, PhD[3], Hanno Ulmer, PhD[4], Dietmar Dammerer, MD, MSc, PhD[5]

[1] *OFZ Innsbruck, Orthopedic and Foot Center, Innsbruck, Austria*
[2] *Department of Orthopedic Surgery, District Hospital St. Johann, St. Johann, Austria*
[3] *Department of Experimental Orthopedics, Medical University of Innsbruck, Innsbruck, Austria*
[4] *Department of Medical Statistics, Informatics and Health Economics, Medical University of Innsbruck, Innsbruck, Austria*
[5] *Senior Author, Department of Orthopedic Surgery, Medical University of Innsbruck, Innsbruck, Austria*

A R T I C L E I N F O

Level of Clinical Evidence: 2

Keywords:
akin
chevron
hallux valgus
outcome
postoperative parameter
radiological

A B S T R A C T

Loss of correction is frequently observed following hallux valgus correction and is associated with recurrence of a hallux valgus deformity. The purpose of this study was to correlate loss of correction and radiological parameters following distal chevron (Group C) and combined chevron/akin (Group AC) osteotomy. A total of 859 feet were included for analysis and grouped according to treatment with a distal chevron osteotomy alone or a combined chevron/akin osteotomy. Radiographs were evaluated preoperatively, postoperatively, after 6 weeks, 3 months and, if available, at long term follow-up with a mean of 34.2 (range 7.5-155.3) months. With the exception of the proximal to distal phalangeal articular angle (PDPAA), preoperative deformity was comparable between both groups. Significant correction of all examined parameters ($p < .001$) was seen. Loss of correction at 6 weeks with minor deterioration until follow-up was also detected, with group AC somewhat better than Group C. A strong correlation with loss of correction was found for the postoperative hallux valgus angle (HVA) ($p < .002$), intermetatarsal angle (IMA) ($p < .001$), distal metatarsal articular angle (DMAA) ($p < .002$), positioning of the sesamoids ($p < .002$) and joint congruity ($p < .035$) in Group C and for the DMAA ($p < .033$) and HVA ($p < .046$) in Group AC. Multiple postoperative radiological parameters correlated with loss of correction following distal chevron osteotomy. In Group AC only postoperative HVA and DMAA determined loss of correction. Correction of the deformity in Group AC showed greater stability.

Although good clinical and radiological results have been published for various surgical techniques (1-4), loss of correction is a generally observed finding following hallux valgus correction, irrespective of the applied surgical technique (5,6). Early loss of correction and in consequence recurrence was associated with the postoperative sesamoid position (7). Some authors consider the type of osteotomy and the grade of deformity to be less important than the quality of the surgical correction (1). Which surgical method yields the best clinical and radiological results is still the subject of controversy (8). Therefore, identification of radiographic factors resulting in loss of correction would be advantageous for future improvement of outcome following hallux surgery.

The site of the osteotomy determines the extent of IMA correction and limits the corrective potential for distal procedures (9). Consequently, the distal chevron osteotomy is used mainly to correct mild to moderate deformities (10). Numerous publications presenting good radiological (11,12) and good clinical outcome following chevron osteotomy have been published and make this method one of the most frequently used surgical methods for hallux valgus correction today (13,14). Hallux valgus is commonly associated with an additional hallux valgus interphalangeus (HVI) deformity. Underestimation of HVI in hallux valgus patients may be a reason for loss of correction following metatarsal osteotomy (15). Nevertheless, to date the role of concomitant akin osteotomy additional to the metatarsal osteotomy in hallux valgus correction remains unclear (16-18). Whereas one group found superiority of the combined chevron and akin osteotomy after 12 months follow-up (17), Shibuya et al found promising correction

Financial Disclosure: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest: The authors declare that they have neither financial nor non-financial competing interests.

Address correspondence to: Kaufmann Gerhard, MD, OFZ Innsbruck, Orthopedic and Foot Center, Innrain 2 / 3.Stock, 6020 Innsbruck, Austria.

E-mail address: gerhard.kaufmann9@chello.at (G. Kaufmann).

1067-2516/$ - see front matter © 2021 by the American College of Foot and Ankle Surgeons. All rights reserved.
https://doi.org/10.1053/j.jfas.2021.11.017

immediately after surgery but maintenance of the correction was questionable in their cohort (18). The hallux interphalangeus angle (HIA) is regarded as the most frequently used angle for describing a hallux valgus interphalangeus deformity, but in a recently published study the reliability of PDPAA was higher than of HIA (19). However, recently beneficial effects of an additional akin osteotomy in cases surmounting 8 degrees of preoperative PDPAA could be detected with follow-up periods from 36 to 45 months (20-22). Some authors combine the akin and the chevron osteotomy without exception (17,23,24), whereas others recommend the akin osteotomy depending on the intraoperative situs in hallux valgus surgery (25).

Loss of correction is a frequent finding following hallux correction and may result in hallux valgus recurrence. Recurrence is generally defined as an HVA exceeding 15 degrees (6). A recently published analysis identified preoperative radiological parameters influencing loss of correction (26). The relevance of postoperative radiological parameters associated with loss of correction is still discussed controversial. By means of a bibliographic search in PubMed we could find 3 studies focusing on postoperative radiographic parameters determining outcome (7,27,28). A correlation with outcome was detected for several parameters, but only one study analyzed outcome in a distal chevron cohort (28). Although the initial postoperative radiographs might be without full weightbearing, these films currently remain the only available radiographic tool for assessing outcome after hallux valgus correction.

The purpose of this study was to define postoperative radiological parameters influencing loss of correction following distal chevron osteotomy and combined chevron and akin osteotomy.

Fig. 1. Standing radiograph after 6 weeks AC procedure.

Patients and Methods

Data were collected retrospectively from a consecutive series of patients who underwent bunion surgery at our department between January 2002 and December 2012. The study was approved by the local ethics committee.

Data on all patients who underwent hallux surgery during this period were collected by electronic search using the ICD10-Code (International Classification of Disease, WHO, Geneva, Switzerland) and the MEL-Code (benefit-related coding system in national hospitals, National Ministry of Health). The hospital chart of every identified patient was used to determine the applied surgical method (BM,UH). Exclusively patients with isolated chevron or concomitant akin osteotomy were included in this study. Patients with other surgical corrections than chevron (e.g. scarf, proximal metatarsal osteotomy), previous hallux correction in the medical history or additional surgery on the forefoot (e.g. Weil osteotomy, hammer toe operation) were excluded to prevent secondary effects on particular radiological angles. Patients operated on for reasons other than hallux valgus deformity were also excluded. In keeping with the literature hallux valgus deformity was defined as an HVA exceeding 15 degrees or an IMA exceeding 10° (29,30). Patients under the age of 18 years were also excluded from analysis in order to exclude juvenile hallux deformity. Radiographic evaluation preoperatively, postoperatively, after 6 weeks and after 3 months postoperatively is part of our clinical routine. The most recent radiograph was also sought for every patient (at least 6 months postoperatively), irrespective of the reason why these patients continued follow-up beyond the typical postoperative period. All anteroposterior and lateral radiographs were made in a standardized manner with the patient in a standing position. Fig. 1 shows a radiograph made 6 weeks after combined chevron and akin osteotomy. All radiographs were read by a surgeon in training as a foot and ankle specialist (BM) advised and supervised by a consultant orthopedic surgeon (KG). Both were not involved in patients' care. Radiographs were digitally analyzed using the Icoview software (syngo.share, ITH icoserve healthcare GmbH, Siemens). The following radiographic measurements were used in this study and have been previously described (19): 1) the HVA, defined as the angle between the midshaft axis of the first metatarsal and the proximal phalanx on the standing anteroposterior radiograph; 2) the IMA, an angle between the midshaft longitudinal axis of the first and second metatarsals on the standing anteroposterior radiograph. In the postoperative radiographs the IMA was measured as the angle formed by the lines from center head to center base of the first and second metatarsals, since the metatarsal anatomy has changed after distal chevron; 3) the DMAA. This angle is formed by a line perpendicular to the midshaft axis of the first metatarsal and the joint line of the head of the first metatarsal. By definition, a positive DMAA shows a valgus tilt of the articular surface in relation to the axis of the metatarsal bone; 4) the PDPAA, which is defined as the angle between the proximal and the distal joint lines of the proximal phalangeal bone of the great toe; 5) the position of the tibial sesamoid in relation to the midshaft axis of the first metatarsal (7 part grading system) (26, 31) and 6) the joint congruity of the great toe joint, which was expressed as the angle formed by the joint lines of the metatarsal head and the proximal joint line of the proximal phalanx.

Loss of correction was calculated difference of the described radiological angles between the initial postoperative and the 3 months radiograph, respectively the radiograph at follow-up.

For the analysis of loss of correction in dependence of the application of an additional akin osteotomy, we defined a preoperative cutoff value for PDPAA with 8° in accordance to the recent literature (20-22).

In all patients surgery was performed in a standardized manner a described in the literature (26). A distal soft tissue procedure was applied in all cases. If an akin osteotomy was additionally performed, the dorsomedial incision was lengthened to the proximal phalangeal bone. While protecting the flexor and extensor tendon, a horizontal V-shaped osteotomy was performed including wedge removal. The lateral cortical bone was left intact to preserve a stable hinge. Two drill holes with a diameter of 1.5 mm were made next to the osteotomy site. The osteotomy was closed after threading a No.2 polyglactin 910 suture (Vicryl®, Ethicon, Johnson & Johnson) through the drill holes. After tying the sutures, the skin was closed with nylon No. 3 sutures.

Postoperative management was standardized in both groups. To maintain positioning of the great toe, soft dressings were applied. Patients were mobilized immediately in a custom-made hallux valgus shoe (Ofa GmbH, Bamberg, Germany). The surgical shoe was discarded after 6 weeks. Reduced weightbearing was recommended for 2 weeks, followed by progressive full weightbearing for 4 to 6 weeks.

Statistical Method

Sample characteristics are given as means or medians with standard deviations and frequencies for categorical data. Comparisons between Group C and Group AC with regard to radiological variables were based on Fisher's exact test and the T-test for independent samples or on Mann-Whitney U test when data differed from normal distribution. Shapiro-Wilks test was used to examine if variables were normally distributed. Repeated measurements at particular time points (preoperative, postoperative, 6 weeks, 3 months and long term follow-up) were evaluated descriptively displaying medians and standard deviations and tested for differences between group C and AC using Mann-Whitney U tests. Postoperative radiological parameters correlated with loss of correction (nonparametric Spearman's rank correlation). All statistical analyses (HP) were conducted with SPSS 20.0 (International Business Machines Corporation, Armonk, NY).

Results

In the above-mentioned study period 2661 feet underwent fore-foot surgery at our department. According to our exclusion criteria, a total of 859 feet met the inclusion criteria for analysis. Seventy-three feet underwent an additional akin osteotomy as well. Average age at time of operation was 52.6 years ± 14.1 years. The youngest patient in the

Table 1
Preoperative radiological parameters and demographics

	C cohort	AC cohort	*p* Value
Number of feet (N=859)	N = 786	N = 73	
Age (yr)	52.6 ± 14.1	52.5 ± 15.0	.954
Female (%)	91.1	87.7	.297
Right foot	389	41	.328
HVA (°)	28.3 ± 7.3	28.2 ± 6.8	.910
IMA (°)	13.0 ± 2.6	13.1 ± 2.2	.750
DMAA (°)	12.5 ± 7.4	10.4 ± 6.9	.020
PDPAA (°)	6.7 ± 3.9	10.2 ± 4.6	<.001
Joint congruity (°)	13.1 ± 8.3	13.5 ± 9.2	.697
Sesamoid position (7 part)	5.2 ± 1.3	4.9 ± 1.4	.061

Abbreviations: C, chevron; AC, chevron and akin; yr, years; HVA, Hallux Valgus Angle; IMA, Intermetatarsal Angle; DMAA, Distal Metatarsal Articular Angle; PDPAA, Proximal to Distal Phalangeal Articular Angle.

study was 18.1 years, the oldest 89.1 years of age. Seventy-nine (9.2%) feet were male, 9 (12.3%) of them in the AC cohort and 70 (8.9%) in the C cohort. Table 1 summarizes patient demographics and radiological data. Time for long-term follow-up examination was 34.2 (SD 38.4) months. Mean time in the C cohort was 36.8 (range 7.1-155.3) months, in the AC cohort 31.6 (range 8.1-140.7) months.

We detected significant improvement of all parameters in both cohorts, with the exception of PDPAA ($p < .001$). This angle improved solely in Group AC as a consequence of the phalangeal osteotomy performed in this group. Improvement was also found at all time points evaluated. Loss of correction was found in both groups as well, being better in Group AC with significantly lower loss of correction ($p < .001$).

Mean HVA improved significantly in Group C from 27.5° (SD 7.3) to 9.2° (SD 5.7) ($p < .001$) and from 27.2° (SD 6.8) to 5.0° (SD 4.5) in Group AC ($p < .001$) (Fig. 2, Table 2). Over the whole time period of follow-up, a loss of HVA correction of 4.5 (SD 6.5) in Group C and 3.0° (SD 5.9) in Group AC (Fig. 2, Table 2) was detected. Mean IMA improved significantly ($p < .001$) from 13.0° (SD 2.6) to 4.5° (SD 2.4) in Group C and from 13.2° (SD 2.2) to 3.9° (SD 2.4) in Group AC (Fig. 3, Table 2). Loss of IMA correction until long-term follow-up amounted to 1.6° (SD 2.6) in Group C and 0.7° (SD 2.1) in Group AC. With regard to these findings, mean HVA correction from preoperative to follow-up amounted to 14.6°, mean IMA correction to 7.0° in Group C, whereas in Group AC mean HVA correction was 19.6°, mean IMA correction 8.5°. Although loss of correction was detectable at long-term follow-up, improvement of both IMA and HVA ($p < .001$) remained significant.

DMAA also improved significantly ($p < .001$) from 12.5° (SD 7.4) to 7.2° (SD 4.9) and remained stable at 7.5° (SD 6.7) until long term follow-up, implying a stable significant correction of 5.0° ($p < .001$) in Group C (Table 2). A similar finding could be made for Group AC, namely correction from 10.4° (SD 6.9) to 6.1° (SD 3.7) postoperatively and 6.1° (SD 7.8) at long-term follow-up (Table 2). Correction of DMAA in this group also showed significant improvement ($p < .001$), namely 4.3°.

It is clear that significant correction of the PDPAA from preoperative to postoperative and throughout follow-up was detected only in Group AC (Table 2).

Analysis of sesamoid position revealed significant correction from pre- to postoperative and until long term follow-up being better in Group AC (Table 2). For both cohorts only minor deterioration was detected throughout follow-up. A similar finding was made for joint congruity in both cohorts (Table 2). Initial correction was comparable in both cohorts, nevertheless minor loss of correction was detectable in both groups, with somewhat greater loss in Group AC.

Taken together, significant comparable correction of all measured radiological parameters was detected in both groups. HVA and IMA correction was better in Group AC.

We analyzed the recurrence rate in our study cohort and found 42 documented cases of recurrence in Group C and 2 in Group AC.

For the analysis of loss of correction we analyzed the change of all assessed parameters from the postoperative radiograph to the radiographs at 3 months and at long-term follow-up. In consequence loss of correction represents the calculated difference between postoperative and 3 months and between postoperative and follow-up. Loss of

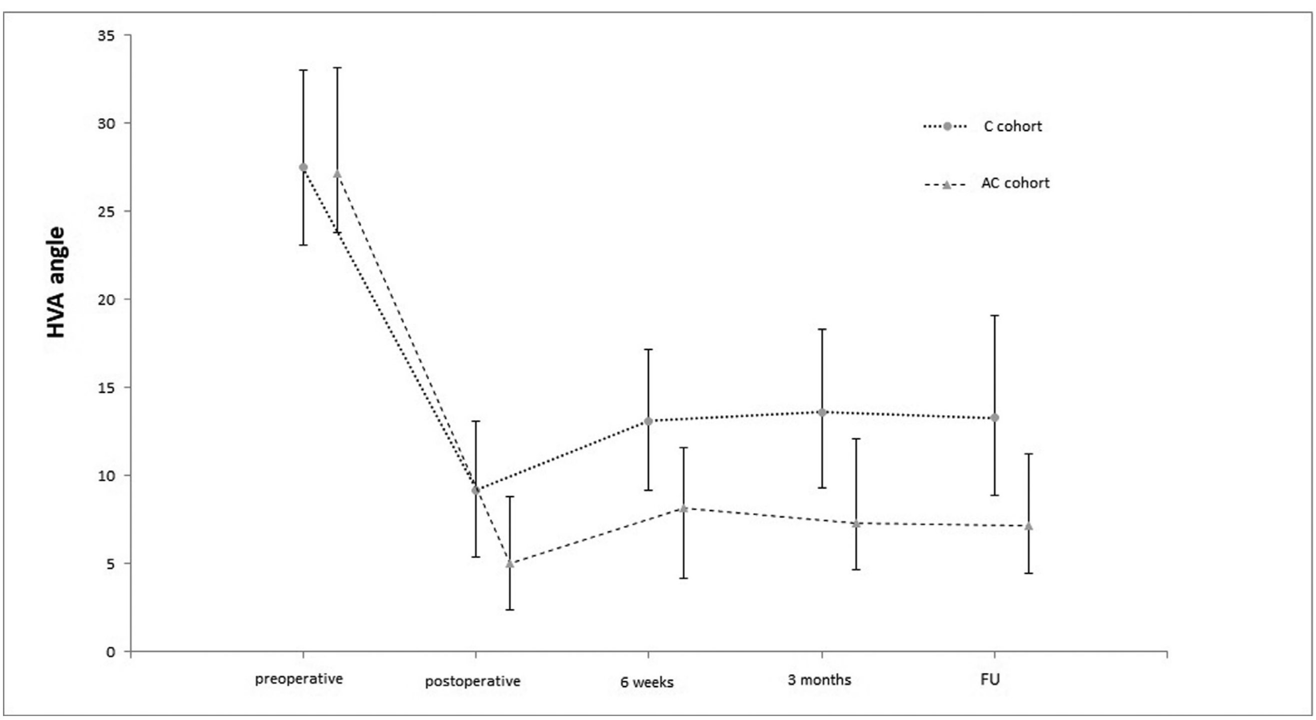

Fig. 2. Chronological sequence of HVA throughout follow-up in both cohorts. The values represent medians, with bars representing 25th to 75th percentiles.

Table 2
Chronological sequence of several radiological parameters (medians plus standard deviations)

	Radiological Parameter	Pre-Op	Post-Op	6 Weeks	3 Months	Long-Term FU
C	HVA	27.5 ± 7.3	9.2 ± 5.7	13.1 ± 6.0	13.6 ± 6.7	13.3 ± 7.8
AC		27.2 ± 6.8	5.0 ± 4.5	8.1 ± 5.9	7.3 ± 5.7	7.1 ± 6.3
C	IMA	13.0 ± 2.6	4.5 ± 2.4	5.8 ± 2.8	6.3 ± 3.0	5.9 ± 2.8
AC		13.2 ± 2.2	3.9 ± 2.4	5.6 ± 2.9	5.8 ± 3.1	3.6 ± 2.9
C	DMAA	12.5 ± 7.4	7.2 ± 4.9	6.7 ± 6.8	7.5 ± 5.6	7.4 ± 6.7
AC		10.4 ± 7.4	6.1 ± 3.9	4.9 ± 7.7	6.9 ± 5.3	6.1 ± 7.8
C	PDPAA	6.7 ± 3.9	7.7 ± 3.8	7.7 ± 4.3	7.6 ± 3.9	7.0 ± 4.0
AC	($p < .001$)	10.2 ± 4.6	5.5 ± 2.9	4.3 ± 3.2	6.0 ± 3.8	4.4 ± 2.3
C	sesamoids	5.2 ± 1.3	1.5 ± 0.8	2.3 ± 0.9	2.2 ± 1.2	2.7 ± 1.0
AC		4.9 ± 1.4	1.4 ± 0.6	2.1 ± 1.1	1.9 ± 1.0	2.1 ± 1.0
C	congruity	13.1 ± 8.3	5.3 ± 5.0	6.2 ± 6.2	5.7 ± 5.5	6.5 ± 7.0
AC		13.5 ± 9.2	5.4 ± 5.0	8.4 ± 7.6	7.1 ± 6.6	9.6 ± 6.0

Abbreviations: C, chevron; AC, chevron and akin; HVA, Hallux Valgus Angle; IMA, Intermetatarsal Angle; DMAA, Distal Metatarsal Articular Angle; PDPAA, Proximal to Distal Phalangeal Articular Angle; long-term FU, long-term follow-up.
Median (°) with standard deviations (°)
Significant differences ($p < .001$) between C and AC were found at all time-points for PDPAA and at long-term follow-up ($p < .003$) only for sesamoid position and joint congruity between C and AC groups.

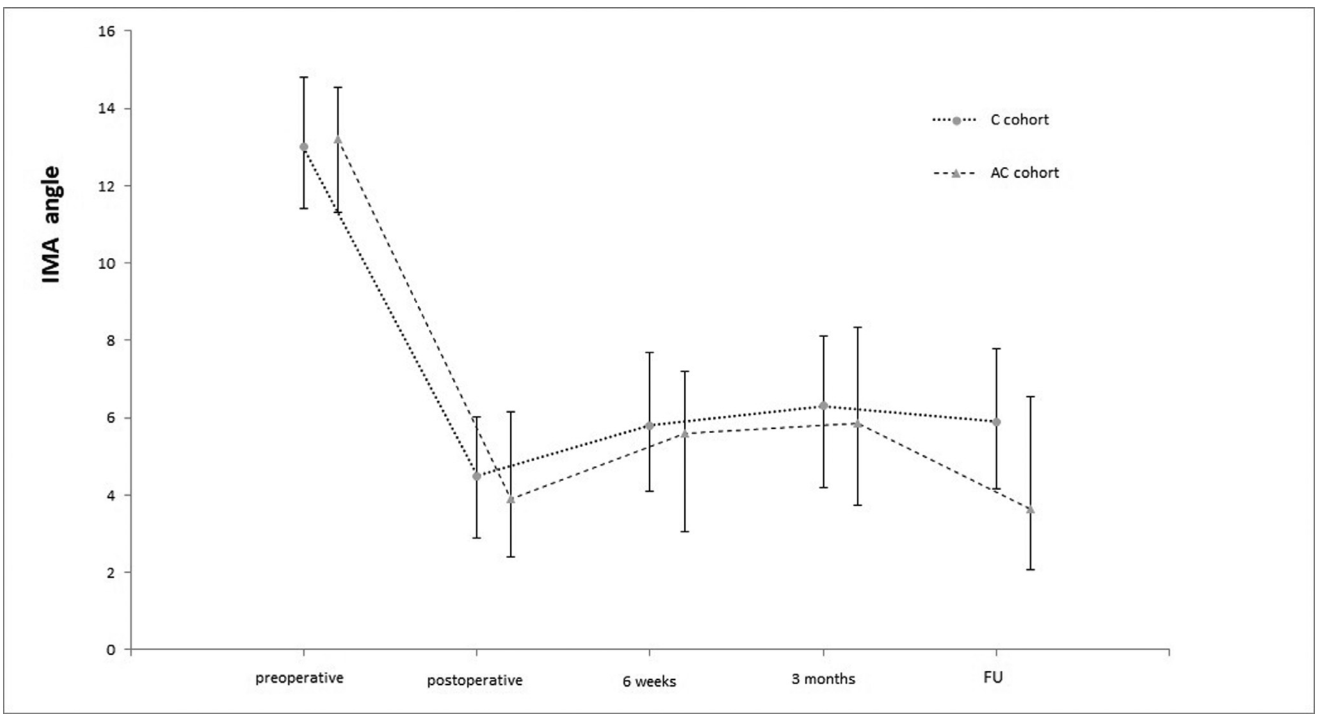

Fig. 3. Chronological sequence of IMA throughout follow-up in both cohorts. The values represent medians, with bars representing 25th to 75th percentiles.

correction was found for all parameters, with the exception of PDPAA. The detected loss of HVA and IMA correction was significantly stronger in Group C <0.001). All postoperative radiological parameters were assessed independently in both cohorts (C and AC) for their interrelation with loss of correction of IMA and HVA after 3 months and after long term follow-up. Table 3 presents the results of Group C and shows multiple significant correlations. Postoperative HVA and DMAA correlated with loss of HVA correction at 3 months and at long term follow-up, whereas positioning of the sesamoids and joint congruity showed a correlation at 3 months only. Postoperative IMA showed a correlation with loss of IMA correction after 3 months and at long term follow-up. In contrast, HVA and DMAA correlated with loss of correction of IMA at long term follow-up only (Table 3). By contrast, in Group AC we found a significant correlation between the postoperative HVA and loss of correction of HVA after 3 months and at long term follow-up, and between postoperative HVA and DMAA at long term follow-up. No radiological parameter showed statistical correlation with loss of IMA correction in this group.

In the light of our assumption that phalangeal pathology might play a fundamental role in hallux recurrence, an additional analysis was performed. We divided Group C and AC in regard to the preoperative PDPAA above and below 8° and analyzed loss of correction for these subgroups. Outcome in Group AC was superior in both subgroups (Table 4). In Group C we found significantly higher loss of HVA correction in the subgroup above 8° of PDPAA, whereas in the subgroup below 8° loss of correction was comparable to that of Group AC (Table 4).

Table 3
Correlation of postoperative parameters and loss of correction of HVA and IMA for Group C

postoperative	IMA 3 Mo	IMA Long-Term FU	HVA 3 Mo	HVA Long-Term FU
HVA Spearman's rho	-0.015	-0.226	-0.253	-0.201
p value	.694	.001†	<.001†	.003†
IMA Spearman's rho	-0.205	-0.406	-0.059	-0.039
p value	<.001†	<.001†	.122	.567
DMAA Spearman's rho	0.001	0.137	0.119	0.183
p value	.973	.045*	.002†	.007
PDPAA Spearman's rho	0.012	0.08	0.018	0.123
p value	.760	.247	.636	.071
congruity Spearman's rho	-0.021	0.089	0.08	0.058
p value	.577	.194	.035*	.379
sesamoid Spearman's rho	0.002	-0.033	0.116	0.085
p value	.963	.637	.002†	.215

Abbreviations: HVA, Hallux Valgus Angle; IMA, intermetatarsal angle; DMAA, Distal Metatarsal Articular Angle; PDPAA, Proximal to Distal Phalangeal Articular Angle; cohort C, chevron osteotomy solely; mo, months; FU, follow-up; Sesamoid, sesamoid position.
* Correlation is significant at the 0.05 level (*p* value) (2-tailed).
† Correlation is significant at the 0.01 level (*p* value) (2-tailed).

Discussion

One substantial finding of our study was the good corrective power achieved with the chevron osteotomy and with the combined chevron and akin osteotomy. Preoperative deformity and the correction achieved in our study population were comparable to those in the recent literature (32,33), whereas the size of our study cohort was larger. For all measured parameters significant correction at all points of the survey was found in both groups, with the exception of the PDPAA which improved in Group AC only. Mean correction of the HVA showed minor superiority in Group AC. For the IMA a difference of less than one degree was found and can be regarded as negligible. Whereas the corrective power was comparable for Group C and AC, loss of correction was seen to be significantly stronger in Group C. A recent study already reported underestimation of a hallux valgus interphalangeus deformity in hallux valgus patients (34). Thus, the detected stronger loss of correction in Group C may be ascribed to the underestimation of hallux valgus interphalangeus in this cohort.

A recent publication stated that an additional akin osteotomy for hallux valgus correction is of uncertain value (18). However, our study showed significantly greater loss of correction in the subgroup of Group C with a preoperative hallux valgus interphalangeus deformity. Our study showed comparable results for Group AC and Group C with low preoperative PDPAA values. A preoperative PDPAA exceeding 8° has been described as a possible cutoff for determining the need for an additional akin osteotomy in hallux correction (20-22). Additional akin osteotomy has been recommended in cases of a pathological PDPAA of 10° previously (16). An increase of 2° for PDPAA has been described after isolated metatarsal osteotomy as well, indicating an average underestimation of PDPAA of 2° on the preoperative radiographs (34). Therefore, we think that the preoperative PDPAA of 8° determines a pathological HVI deformity more precisely and may be used as cutoff value for decision making for akin osteotomy.

The correction of a phalangeal pathology in terms of hallux valgus interphalangeus deformity in hallux valgus correction has been recommended previously (15). That study recommended that the isolated concepts of hallux valgus and hallux valgus interphalangeus should be replaced with total deformity correction (15). In keeping with that study, the results of our study prove the concept of the total deformity correction to be reasonable.

We regard the determination of specific postoperative radiological parameters affecting loss of correction as the most important finding of our study. Loss of correction is a common finding following bunion surgery and does not inevitably result in recurrence, defined by HVA exceeding 15° (6). The immediate postoperative radiographs may not reflect true weightbearing and therefore might influence the measurements (35). Nevertheless they remain the only accessible tool for evaluating radiological outcome directly after surgical hallux correction in the clinical routine. In the current literature only 4 studies have analyzed postoperative parameters with their influence on outcome (7,13,27,28), one of them focusing on the distal chevron osteotomy (28). Two of these studies showed no correlation with outcome (13,28). However, one study showed, that the HVA and the sesamoid position on the immediate postoperative radiograph might be used to predict hallux outcome (27). Another study showed that sesamoid position on the postoperative film correlated with recurrence (7). Since our study population was larger, we regard the results of our investigation as representative. In accordance with these studies we could determine the HVA and the sesamoids to be predictive factors as well. After grouping of our study cohort, we detected a correlation with outcome for postoperative DMAA and HVA in Group AC and for DMAA, HVA, IMA, sesamoid position and joint congruity in Group C. In previous literature, preoperative DMAA was shown to influence outcome after hallux correction (6,36). A pathological DMAA might result in increased amounts of loss of correction, since the orientation of the joint line determines the positioning of the phalangeal bone as well. Consequently in cases with pathological DMAA, modifications of the surgical technique like derotational chevron or metatarsal double osteotomy might be required. In light of our findings, we conclude that in hallux corrections every aspect of the deformity should be addressed in order to reduce the loss of correction and the risk for recurrence.

We found loss of HVA and IMA correction within the first 3 months after surgery and minor, negligible changes thereafter. This may be ascribed partially to the methodology of the immediate postoperative radiograph, but to a greater part this can be regarded as a result of the surgical method, since loss of correction following chevron osteotomy has been previously described (6). Several publications have reported high rates of recurrence following hallux surgery (6,27). Two recently published studies identified postoperative HVA and the positioning of the sesamoids as factors correlating with recurrence (27,37). In contrast to them, our analysis focused on the distal chevron osteotomy and revealed a correlation for HVA, IMA, DMAA, positioning of the

Table 4
Loss of correction (HVA and IMA) as a function of preoperative PDPAA (mean with standard deviation)

C cohort	p.o./ 3 mo (IMA)	p.o./ Long-Term FU (IMA)	p.o./ 3 mo (HVA)	p.o./ Long-Term FU (HVA)
PDPAA < 8°	1.9 ± 2.3	1.6 ± 2.2	4.3 ± 5.4	3.8 ± 5.7
PDPAA > 8°	1.7 ± 2.4	1.7 ± 3.1	5.0 ± 5.6	6.8 ± 6.4
AC cohort	2.2 ± 2.3	0.7 ± 2.1	2.3 ± 5.0	3.2 ± 6.0

Abbreviations: HVA, Hallux Valgus Angle; IMA, Intermetatarsal Angle; PDPAA, Proximal to Distal Articular Angle; C, chevron; AC, chevron and akin; FU, follow-up; p.o./ 3 mo (IMA), loss of IMA correction from postoperative to 3 months; p.o./ long-term FU (IMA), loss of IMA correction from postoperative to long-term follow-up; p.o./ 3 mo (HVA), loss of HVA correction from postoperative to 3 months; p.o./ long-term FU (HVA), loss of HVA correction from postoperative to long-term follow-up.
Means (°) ± standard deviation (°)

sesamoids, and joint congruity with loss of correction and outcome, respectively. The recurrence rate in our study population was lower than in the literature (6). This could be the result of the lateral release, which is performed as a mandatory step in every case in our clinical routine. We regard the lateral release as an essential step in hallux valgus surgery. Well in line with this, a recent study demonstrated the superiority of the combined osteotomies with a soft tissue release (38). Okuda et al even recommend modifications of the surgical technique in cases of incomplete reduction of the sesamoids (37).

We acknowledge that the size of our study groups differed significantly. With regard to the comparable variances detected in both groups, the size of the 2 study groups in our analysis is of minor importance.

We regard the monocentric character and its retrospective nature as the major limitation of this study. Another limitation is the restriction on radiological outcome. Different sample sizes in Group AC and Group C (n1=73, n2=786) may have influenced the observed results as well. A limitation of our investigation is the lack of an explanatory analysis pertaining to confounding and effect modification, which could further explain the observations that we made. Another limitation stems from the methodology of the initial postoperative radiographs. It cannot be guaranteed that full weightbearing was achieved in every case. Additionally, the majority of the patients were still wearing a wound dressing on their foot, when the radiographs were taken (day 1 to 3 after surgery). The most positive aspect is the size of our data pool.

In conclusion, multiple postoperative radiological parameters correlated with loss of correction following distal chevron osteotomy. In Group AC group postoperative HVA and DMAA determined loss of correction only. Correction of the deformity in Group AC group showed greater stability.

Author's Contributions

G. K. conceived of the study, generated its design, carried out parts of the measurements and drafted the manuscript and acts as corresponding author.

M. B. carried out measurements and acts as co-author.

M. W. made the statistical analysis and acts as co-author.

D. P. helped to draft the manuscript.

B. R. carried out measurements.

D. D. participated in the study design, carried out parts of the measurements, helped to draft the manuscript and acts as senior author.

Declaration

Ethics approval and consent to participate

This study has been approved by the local ethical committee of the Medical University of Innsbruck. The approval reference number is UN5080.

Due to the retrospective nature of this study and its limitation to a radiological analysis no consent to participate was obtained.

Research has been performed in accordance with the Declaration of Helsinki and was approved by the local ethics committee of the Medical University of Innsbruck.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for Publication

Not applicable.

Availability of Data and Material

All data generated or analyzed during this study are included in this published article. This study or contents of this study have not been published or submitted for publication elsewhere.

Acknowledgments

The editors would like to thank Sabine Hofer-Picout for providing language correction and Mary Heaney Margreiter for final proof reading.

References

1. Thordarson DB, Rudicel SA, Ebramzadeh E, Gill LH. Outcome study of hallux valgus surgery—an AOFAS multi-center study. Foot Ankle Int 2001;22:956–959.
2. Hrubina M, Skotak M, Letocha J, Dzupa V. The modified scarf osteotomy in the treatment of tailor's bunion: midterm follow-up. Acta Orthop Belg 2015;81:57–64.
3. Murawski CD, Egan CJ, Kennedy JG. A rotational scarf osteotomy decreases troughing when treating hallux valgus. Clin Orthop Relat Res 2011;469:847–853.
4. Sammarco GJ, Brainard BJ, Sammarco VJ. Bunion correction using proximal Chevron osteotomy. Foot Ankle 1993;14:8–14.
5. Bock P, Kluger R, Kristen KH, Mittlbock M, Schuh R, Trnka HJ. The scarf osteotomy with minimally invasive lateral release for treatment of hallux valgus deformity: intermediate and long-term results. J Bone Joint Surg Am 2015;97:1238–1245.
6. Pentikainen I, Ojala R, Ohtonen P, Piippo J, Leppilahti J. Preoperative radiological factors correlated to long-term recurrence of hallux valgus following distal chevron osteotomy. Foot Ankle Int 2014;35:1262–1267.
7. Shibuya N, Kyprios EM, Panchani PN, Martin LR, Thorud JC, Jupiter DC. Factors associated with early loss of hallux valgus correction. J Foot Ankle Surg 2018;57:236–240.
8. Deenik A, van Mameren H, de Visser E, de Waal Malefijt M, Draijer F, de Bie R. Equivalent correction in scarf and chevron osteotomy in moderate and severe hallux valgus: a randomized controlled trial. Foot Ankle Int 2008;29:1209–1215.
9. Glazebrook M, Copithorne P, Boyd G, Daniels T, Lalonde KA, Francis P, Hickey M. 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 2014;96:1585–1592.
10. Potenza V, Caterini R, Farsetti P, Forconi F, Savarese E, Nicoletti S, ippolito E. Chevron osteotomy with lateral release and adductor tenotomy for hallux valgus. Foot Ankle Int 2009;30:512–516.
11. Oh IS, Choi SW, Kim MK, Lee SY, Lee JS. Clinical and radiological results after modified distal metatarsal osteotomy for hallux valgus. Foot Ankle Int 2008;29:473–477.
12. Choi WJ, Yoon HK, Yoon HS, Kim BS, Lee JW. Comparison of the proximal chevron and Ludloff osteotomies for the correction of hallux valgus. Foot Ankle Int 2009;30:1154–1160.
13. Thordarson D, Ebramzadeh E, Moorthy M, Lee J, Rudicel S. Correlation of hallux valgus surgical outcome with AOFAS forefoot score and radiological parameters. Foot Ankle Int 2005;26:122–127.
14. Park CH, Jang JH, Lee SH, Lee WC. A comparison of proximal and distal chevron osteotomy for the correction of moderate hallux valgus deformity. Bone Joint J 2013;95:649–656.
15. Strydom A, Saragas NP, Ferrao PN. A radiographic analysis of the contribution of hallux valgus interphalangeus to the total valgus deformity of the hallux. Foot Ankle Surg 2017;23:27–31.
16. Arnold H. The Akin procedure as closing wedge osteotomy for the correction of a hallux valgus interphalangeus deformity. Oper Orthop Traumatol 2008;20:477–483.
17. Lechler P, Feldmann C, Kock FX, Schaumburger J, Grifka J, Handel M. Clinical outcome after Chevron-Akin double osteotomy versus isolated Chevron procedure: a prospective matched group analysis. Arch Orthop Trauma Surg 2012;132:9–13.
18. Shibuya N, Thorud JC, Martin LR, Plemmons BS, Jupiter DC. Evaluation of hallux valgus correction with versus without akin proximal phalanx osteotomy. J Foot Ankle Surg 2016;55:910–914.
19. Kaufmann G, Handle M, Liebensteiner M, Braito M, Dammerer D. Percutaneous minimally invasive Akin osteotomy in hallux valgus interphalangeus: a case series. Int Orthop 2018;42:117–124.
20. Kaufmann G, Hofer P, Braito M, Bale R, Putzer D, Dammerer D. Effect of akin osteotomy on hallux valgus correction after scarf osteotomy with hallux valgus interphalangeus. Foot Ankle Int 2019;40:1182–1188.
21. Kaufmann G, Hofmann M, Braito M, Ulmer H, Brunner A, Dammerer D. Need for concomitant Akin osteotomy in patients undergoing Chevron osteotomy can be determined preoperatively: a retrospective comparative study of 859 cases. J Orthop Surg Res 2019;14:277.
22. Kaufmann G, Hofmann M, Ulmer H, Putzer D, Hofer P, Dammerer D. Outcomes after scarf osteotomy with and without Akin osteotomy a retrospective comparative study. J Orthop Surg Res 2019;14:193.
23. Tollison ME, Baxter DE. Combination chevron plus Akin osteotomy for hallux valgus: should age be a limiting factor? Foot Ankle Int 1997;18:477–481.

24. Mitchell LA, Baxter DE. A Chevron-Akin double osteotomy for correction of hallux valgus. Foot Ankle 1991;12:7–14.
25. Rettedal D, Lowery NJ. Proximal phalangeal osteotomies for hallux abductovalgus deformity. Clin Podiatr Med Surg 2014;31:213–220.
26. Kaufmann G, Sinz S, Giesinger JM, Braito M, Biedermann R, Dammerer D. Loss of correction after chevron osteotomy for hallux valgus as a function of preoperative deformity. Foot Ankle Int 2018;40:287–296.
27. Park CH, Lee WC. Recurrence of hallux valgus can be predicted from immediate postoperative non-weight-bearing radiographs. J Bone Joint Surg Am 2017;99:1190–1197.
28. Shi GG, Henning P, Marks RM. Correlation of postoperative position of the sesamoids after chevron osteotomy with outcome. Foot Ankle Int 2016;37:274–280.
29. Venning P. Sources of error in the production and measurement of standard radiographs of the foot. Br J Radiol 1951;24:18–26.
30. Wulker N. Hallux valgus. Orthopade 1997;26:654–664.
31. Hardy RH, Clapham JC. Observations on hallux valgus; based on a controlled series. J Bone Joint Surg Br 1951;33-B:376–391.
32. van Groningen B, van der Steen MC, Reijman M, Bos J, Hendriks JG. Outcomes in chevron osteotomy for Hallux Valgus in a large cohort. Foot (Edinb) 2016;29:18–24.
33. Pochatko DJ, Schlehr FJ, Murphey MD, Hamilton JJ. Distal chevron osteotomy with lateral release for treatment of hallux valgus deformity. Foot Ankle Int 1994;15:457–461.
34. Dixon AE, Lee LC, Charlton TP, Thordarson DB. Increased Incidence and severity of postoperative radiographic hallux valgus interphalangeus with surgical correction of hallux valgus. Foot Ankle Int 2015;36:961–968.
35. Tanaka Y, Takakura Y, Takaoka T, Akiyama K, Fujii T, Tamai S. Radiographic analysis of hallux valgus in women on weightbearing and nonweightbearing. Clin Orthop Relat Res 1997;336:186–194.
36. Coughlin MJ. Hallux valgus in men: effect of the distal metatarsal articular angle on hallux valgus correction. Foot Ankle Int 1997;18:463–470.
37. Okuda R, Kinoshita M, Yasuda T, Jotoku T, Kitano N, Shima H. Postoperative incomplete reduction of the sesamoids as a risk factor for recurrence of hallux valgus. J Bone Joint Surg Am 2009;91:1637–1645.
38. Grle M, Vrgoc G, Bohacek I, Hohnjec V, Martinac M, Brkic I, Lovro S, Zdravko J. Surgical treatment of moderate hallux valgus: a comparison of distal chevron metatarsal osteotomy with and without lateral soft-tissue release. Foot Ankle Spec 2017;10:524–530.