Clinical Research on Foot & Ankle

beta coe cients were given together with p-values. e strength of the association between a predictor and an outcome variable is expressed by beta coe cients, meaning that one standard deviation of change in a predictor variable leads to a change of one unit of the outcome variable. e analysis of di erent radiographic parameters and LOC showed statistical power above 90% to detect di erences of 0.1 SD with a 5% level for statistical signi cance.

Results

Mean LOC of IMA from initially postoperative to six weeks postoperatively were 1.4 (SD 2.7), from postoperatively to 12 weeks 3.4 degrees (SD 2.6). LOC of HVA amounted to and 3.5 (SD 5.4) and 7.6 degrees (SD 5.6) respectively.

Multiple signi cant correlations between di erent radiological parameters and LOC were detected in our cohort. Tables 1 and 2 present the p-values of all tested radiographic parameters for LOC of HVA and IMA. Signi cant correlations (Pearson´s correlation at the 0.01 level) were found between LOC of HVA and preoperative HVA, IMA, DMAA and joint congruity as well as for postoperative HVA, PDPAA, joint congruity and sesamoid position. For preoperative sesamoid position as well as for postoperative IMA and DMAA a correlation with minor signi cance could be detected (Pearson´s correlation at the 0.05 level) as well.

e results of the multiple linear regression analysis of the individual radiographic postoperative parameters with regard to LOC from postoperative to six weeks are presented in Table 3 and from six to 12 weeks in Table 4. Radiographic parameters correlating with LOC of HVA with signi cance ($p<0.001$) at 6 weeks were HVA, DMAA and PDPAA, at 12 weeks for HVA only. LOC of IMA correlated signi cantly at 6 weeks with HVA, IMA and joint congruity, at 12 weeks only with HVA. e radiographic parameters in descending order in regard to their speci c importance on LOC from postoperative to 6 weeks postoperative (Table 3) were DMAA, PDPAA, joint congruity (with signi cance $p<0.001$) and sesamoid position. For IMA and HVA only an indirect correlation could be found. e parameters in descending order from six to 12 weeks (Table 4) were HVA and sesamoids with signi cance ($p<0.001$), followed by IMA, PDPAA and joint congruity. For DMAA only an indirect correction could be detected. Interestingly, postoperative HVA and IMA showed an indirect correlation with LOC a er 6 weeks, postoperative DMAA a er 12 weeks.

Discussion

We regard the identi cation and e ect sizing of the postoperative radiographic parameters as the most important nding of our study. We could identify the DMAA, PDPAA and joint congruity to be the most relevant factors correlating with LOC a er 6 weeks and HVA and the sesamoid position a er 12 weeks. In other words, besides the

Table 1: Associations of radiographic parameters with LOC of HVA.

	LOC HVA po to 6 weeks		LOC HVA 6 to 12 weeks po	
preoperative parameter	**Pearson correlation**	**p-value**	**Pearson correlation**	**p-value**
IMA	.094**	.005	.025	.434
HVA	.093**	.005	.116**	<.001
DMAA	.004	.896	.090**	.005
sesamoid position	.080*	.015	-.002	.575
joint congruity	.094**	.005	.038	.238
PDPAA	-.027	.410	-.016	.620
postoperative parameter	**Pearson correlation**	**p-value**	**Pearson correlation**	**p-value**
IMA	-.108**	<.001	.075*	.019
HVA	-.368**	<.001	.150**	<.001
DMAA	.081*	.013	-.001	.982
sesamoid position	-.013	.693	.140**	<.001
joint congruity	.084**	.009	.009	.788
PDPAA	.086**	.008	-.054	.092

* Correlation is signifcant at the 0.05 level (2-tailed)
** Correlation is signifcant at the 0.01 level (2-tailed)

Table 2: Associations of radiographic parameters with LOC of IMA.

	LOC IMA po to 6 weeks		LOC IMA 6 to 12 weeks po	
preoperative parameter	**Pearson correlation**	**p-value**	**Pearson correlation**	**p-value**
IMA	.170**	<.001	.032	.328
HVA	.996	<.001	.040	.196
DMAA	-.044	.169	-.031	.313
sesamoid position	-.038	.238	-.048	.121
joint congruity	.041	.198	.095**	.002
PDPAA	.139**	<.001	.144**	<.001
postoperative parameter	**Pearson correlation**	**p-value**	**Pearson correlation**	**p-value**
IMA	-.384**	<.001	.197**	<.001
HVA	-.242**	<.001	.228**	<.001
DMAA	.063	.051	-.048	.142
sesamoid position	-.135	<.001	.139**	<.001
joint congruity	.158**	<.001	-.089**	.006
PDPAA	.046	.155	-.032	.320

* Correlation is signifcant at the 0.05 level (2-tailed)
** Correlation is signifcant at the 0.01 level (2-tailed)

restauration of the foot shape (HVA), the correction of the joint line in terms of the DMAA, the correction of a phalangeal deformity in terms of the PDPAA and the restauration of the so tissue pathology in terms of the sesamoid position and the joint congruity are essential for

valgus correction. Various studies have already shown a dependency of radiological outcome a er hallux valgus correction of the IMA [7,9,22]. Our study provides additional data for supporting the idea that the surgical method should be chosen in regard to the severity of the preoperative deformity in terms of IMA and HVA.

Hallux valgus interphalangeus deformity has been presumed to substantially contribute to the total hallux valgus deformity[1]. It has been shown already, that the additional correction of a phalangeal pathology results in better outcome a er hallux valgus correction [7,9]. In this study, we were able to detect a correlation between the pre- and postoperative PDPAA and LOC of HVA and IMA. is nding is regarded to be essential, as it can be assumed that a successful correction of hallux valgus interphalangeus, as determined by the PDPAA, reduces the risk of LOC a er hallux valgus surgery. In a previous study, postoperative IMA correlated signi cantly with radiological outcome a er combined scarf and akin osteotomy, whereas a er scarf osteotomy without correction of an additional hallux valgus interphalangeus deformity, both PDPAA and IMA correlated with outcome [7]. erefore, the results of our studies support the application of an additional akin osteotomy in cases of a hallux valgus interphalangeus deformity.

Additionally, we found a correlation of the sesamoid position and the joint congruity, which both represent the so tissue pathology in hallux valgus deformities. Pathological joint congruity [11] has been linked to poorer radiological outcome a er hallux valgus correction already. For DMAA a correlation could be detected with our study as well. is parameter has been shown to in uence outcome a er hallux valgus correction as well [19,23,25].

In summary, our study supports the idea of total deformity correction in hallux valgus correction. Every contributing pathology of the hallux valgus deformity has to be addressed adequately to reduce the risk of LOC and recurrence. Successful hallux valgus correction comprises selecting an e ective metatarsal osteotomy technique depending on preoperative IMA, correction of DMAA in terms of restoration of the joint line, correction of an additional hallux valgus interphalangeus deformity de ned by the PDPAA, and realignment of the so tissue structures expressed by the joint congruity and the position of the sesamoids.

Strengths and Limitations

e limitations of this study stem from the monocentric character, the retrospective nature, and the single-measurement analysis of the radiographs. Furthermore, the in uence of early LOC on hallux valgus recurrence and revision surgery has not been investigated so far.

e most positive aspect remains the size of the analyzed data pool and the fact that all measurements were performed by an experienced fellow in foot and ankle surgery, therefore avoiding inter-observer variability.

Conclusion

Multiple pre- and postoperative radiological parameters correlate with early loss of correction a er hallux valgus surgery. Relevancy grading revealed the postoperative HVA and sesamoid position to be most important parameters, followed by DMAA, PDPAA and joint congruity. In consequence total deformity correction, taking all aspects of the hallux valgus deformity into account, seems reasonable.

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