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# Long-Term Results After Hallux Valgus Correction with Distal Metatarsal Reversed-L (ReveL) Osteotomy

## Factors That Influence Recurrence and the Clinical Outcome

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**Background:** This study aimed to evaluate the long-term results of hallux valgus correction with a distal metatarsal reversed-L (ReveL) osteotomy.

**Methods:** Eighty-eight patients (131 feet) were evaluated after a mean follow-up of 14.2 years (range, 10 to 18 years). Weight-bearing foot radiographs were analyzed preoperatively, at 6 weeks postoperatively, and at the final follow-up for the following parameters: hallux valgus angle (HVA), intermetatarsal angle (IMA), first metatarsophalangeal joint (MTPJ) congruence angle, sesamoid position, presence of the round sign, and first MTPJ arthritis. The visual analog scale (VAS) and the Foot and Ankle Outcome Score (FAOS) assessed postoperative pain and function. Univariate and multivariable logistic regression analyses identified risk factors for hallux valgus recurrence and an inferior clinical outcome.

**Results:** All radiographic parameters significantly improved at the 6-week follow-up and the final follow-up ($p < 0.001$). The recurrence rate (HVA >20°) was 14%. A preoperative HVA of >28° (odds ratio [OR], 9.1; $p = 0.02$) and a 6-week postoperative HVA of >15° (OR, 4.6; $p = 0.03$) were independent risk factors for recurrence. At the final follow-up, all FAOS subscales resembled high postoperative function (median, 100 points [range of the interquartile range (IQR), 81 to 100 points]). A preoperative body mass index of >30 kg/m$^2$ was associated with lower FAOS quality of life (QOL) ($p = 0.04$), and postoperative hallux varus was associated with lower FAOS activities of daily living ($p = 0.048$). Patients with first MTPJ arthritis of grade 2 or higher at the final follow-up had significantly lower FAOS subscales ($p < 0.01$) except for QOL. Hallux valgus recurrence did not influence the long-term outcome. A symptomatic implant was the main cause of revision (15%). In 94% of cases, the patients were satisfied with the hallux appearance and, in 92% of cases, the patients were satisfied with postoperative pain reduction.

**Conclusions:** Hallux valgus correction with a ReveL osteotomy led to high long-term satisfaction rates. A preoperative HVA of >28° and a 6-week postoperative HVA of >15° increased the risk of hallux valgus recurrence. First MTPJ arthritis was the leading cause of inferior clinical results, whereas radiographic hallux valgus recurrence had no impact on the clinical results. First MTPJ arthritis at the final follow-up was associated with an inferior clinical outcome, whereas radiographic hallux valgus recurrence had no impact on the long-term clinical results.

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

More than 150 different surgical techniques have been described to correct hallux valgus deformity, but none of these techniques has shown clear superior clinical and radiographic outcomes[1-3]. Moreover, only a little is known about the long-term clinical outcome after hallux valgus surgery[4-7].

Joint-preserving techniques commonly include a combination of a soft-tissue release of the first metatarsophalangeal joint (MTPJ) and an osteotomy of the first metatarsal[4,5,8]. The reversed-L (ReveL) osteotomy is a modified chevron osteotomy with a short dorsal vertical limb and a longer plantar horizontal limb that combines the advantages of the distal and more

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proximal metatarsal osteotomies, namely intrinsic mechanical stability and high corrective power[9,10].

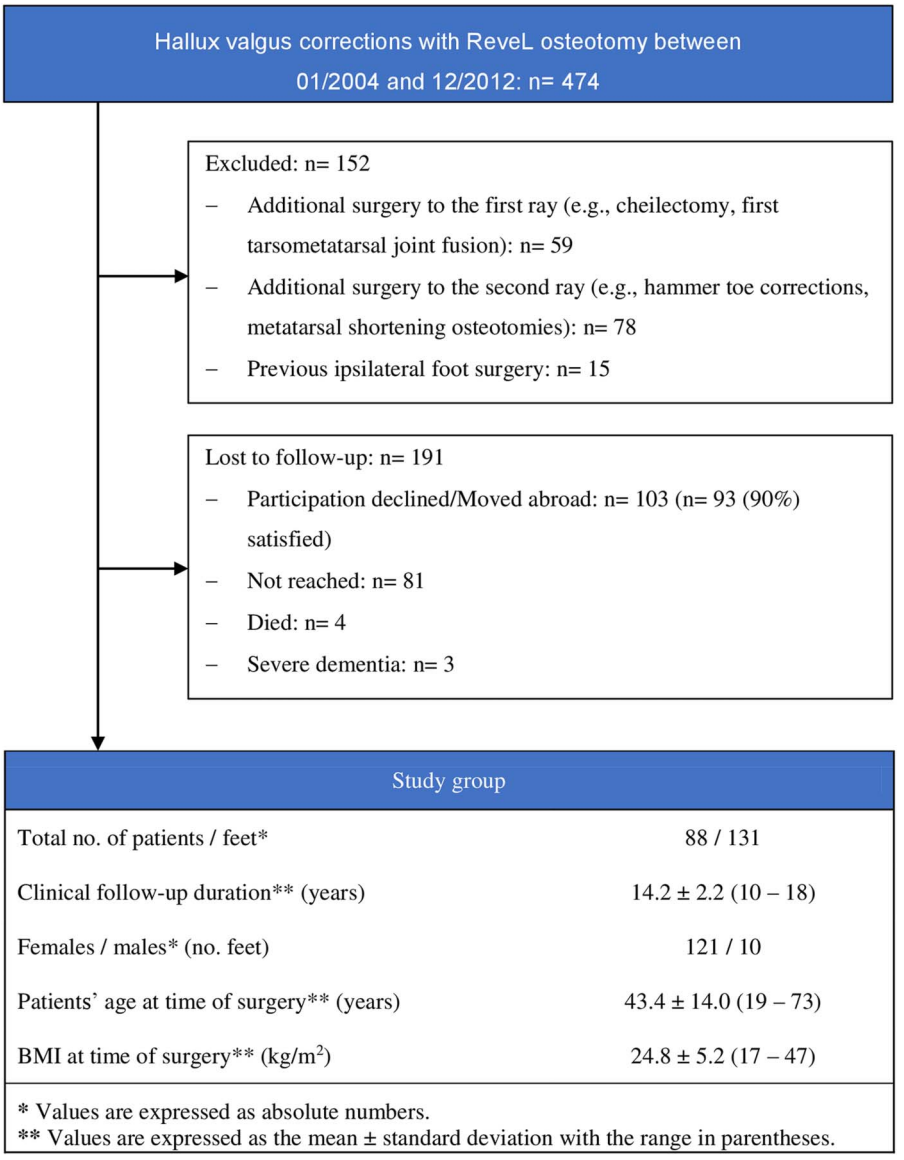
Recurrence of deformity is the most frequent complication after hallux valgus surgery, with recurrence rates ranging from 8% to 73%[4,11,12]. The short-term recurrence rates after ReveL osteotomy are relatively low, but long-term results are still missing[13]. Reported risk factors for recurrence are a higher preoperative hallux valgus angle (HVA)[14,15], an insufficiently corrected postoperative HVA and intermetatarsal angle (IMA)[15], incongruence of the first MTPJ[14,16], an increased distal metatarsal articular angle (DMAA)[12], incomplete reduction of the sesamoids[17], and the presence of a round sign (i.e., round-shaped edge of the first metatarsal head on anteroposterior radiographs according to Okuda et al.[18]). Only a few studies have analyzed these risk factors and their correlations in detail[19,20].

This current study aimed to evaluate the long-term results of hallux valgus correction with a ReveL osteotomy. Furthermore, we assessed the potential risk factors leading to recurrence and to an inferior clinical outcome.

## Materials and Methods

### *Study Participants*

The hospital database was screened for all consecutive patients who underwent ReveL osteotomy, which is the standard procedure at our clinic for the correction of hallux valgus deformity. An exception applies to patients with clinical first tarsometatarsal joint (TMTJ) hypermobility who undergo first TMTJ




| Study group | |
|---|---|
| Total no. of patients / feet* | 88 / 131 |
| Clinical follow-up duration** (years) | 14.2 ± 2.2 (10 – 18) |
| Females / males* (no. feet) | 121 / 10 |
| Patients' age at time of surgery** (years) | 43.4 ± 14.0 (19 – 73) |
| BMI at time of surgery** (kg/m$^2$) | 24.8 ± 5.2 (17 – 47) |

* Values are expressed as absolute numbers.
** Values are expressed as the mean ± standard deviation with the range in parentheses.

Fig. 1

Flowchart showing the exclusion process and demographic data of the study cohort.

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arthrodesis combined with distal osteotomies if necessary. Additionally, patients with clinical (positive grinding test, reduced range of motion) and radiographic first MTPJ arthritis are treated with first MTPJ arthrodesis. A study period of January 2004 to December 2012 was chosen to ensure a minimum follow-up of 10 years. Patients with previous interventions to the ipsilateral foot and additional interventions to the first and second rays apart from Akin osteotomy were excluded to reduce confounding factors (Fig. 1).

After a mean follow-up (and standard deviation) of 14.2 ± 2.2 years (range, 10 to 18 years), 88 patients (131 hallux valgus correction cases) attended our outpatient clinic for a study-specific examination. Patients in another 103 cases, unwilling to attend in person, were interviewed via telephone about their satisfaction with the postoperative outcome to evaluate for selection bias. Because of the missing radiographic and clinical data, however, they were not included in the main analysis.

The study was approved by the local ethical committee (BASEC No. 2021-01192). Informed consent was obtained from all study participants.

### *Radiographic Evaluation*

Weight-bearing foot radiographs were analyzed preoperatively, at 6 weeks postoperatively, and at the final follow-up. All radiographic parameters were assessed in a standardized manner[21]. Recurrence of hallux valgus deformity was defined by an HVA of >20°, and postoperative hallux varus by an HVA of <0°. The sesamoid position was graded from I to VII according to the Hardy and Clapham classification[22]. Lateral sesamoid displacement was defined as grade V or higher. The morphology of the lateral edge of the first metatarsal head was classified as round, intermediate, or angular as described by Okuda et al.[18]. First MTPJ arthritis was evaluated with the Coughlin and Shurnas classification (grades 0 to 4)[23].

### *Clinical Evaluation*

The clinical evaluation involved the assessment of pain and function based on the Foot and Ankle Outcome Score (FAOS; 0 to 100 points) subscales: pain, symptoms, activities of daily living, sport and recreation, and quality of life (QOL). Patients rated their pain level on a visual analog scale (VAS; 0 to 10 points) and were examined for transfer metatarsalgia and clinical signs of first MTPJ arthritis (grinding test). Patients' satisfaction in terms of pain reduction, the appearance of the hallux, and first MTPJ range of motion was measured on a 4-point Likert scale (very satisfied, satisfied, undecided, dissatisfied).

### *Surgical Technique*

The patient is placed supine with general or regional anesthesia. After a medial skin incision centered at the first MTPJ, the joint capsule is incised longitudinally and sharply released from the medial and dorsal aspects of the metatarsal head, followed by a

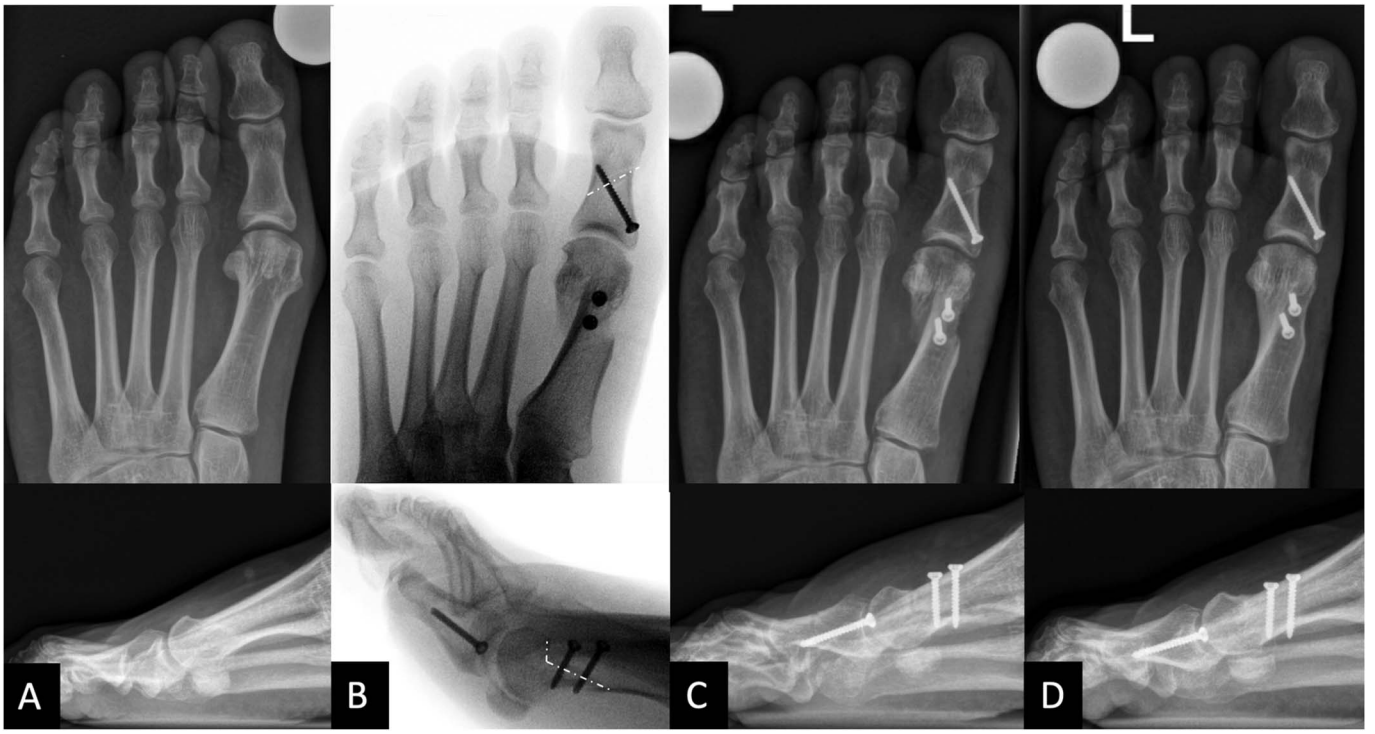


Fig. 2

Dorsoplantar and lateral weight-bearing foot radiographs showing the preoperative hallux valgus deformity (**Fig. 2-A**), intraoperative correction (**Fig. 2-B**, in which the dashed-dotted white lines mark the osteotomy lines of the ReveL and Akin osteotomies), 6-week postoperative correction (**Fig. 2-C**), and no hallux valgus recurrence at the 11-year follow-up (**Fig. 2-D**).

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**TABLE I Radiographic Preoperative and Postoperative Data***

| Parameter | Preoperative† | 6-Week Follow-up† | Final Follow-up† | P Value† | | |
|---|---|---|---|---|---|---|
| | | | | Preop. vs. 6-Week Follow-up | 6-Week vs. Final Follow-up | Preop. vs. Final Follow-up |
| HVA *(deg)* | 25.2 (20.1 to 29.9) | 10.6 (6.6 to 14.6) | 11.7 (6.1 to 17.0) | **<0.001** | 0.17 | **<0.001** |
| IMA *(deg)* | 10.5 (8.5 to 12.4) | 4.0 (2.4 to 5.7) | 5.0 (3.4 to 6.8) | **<0.001** | **<0.001** | **<0.001** |
| First MTPJ incongruence *(deg)* | 11.9 (6.0 to 16.9) | −0.2 (−4.9 to 3.4) | 1.3 (−2.1 to 6.7) | **<0.001** | **<0.001** | **<0.001** |
| Sesamoid position§ | IV (III to V) | I (I to II) | III (I to III) | **<0.001** | **<0.001** | **<0.001** |
| Round sign# | 1 (0 to 2) | 0 (0 to 1) | 0 (0 to 1) | **<0.001** | 0.64 | **<0.001** |
| First MTPJ arthritis** | 0 (0 to 1) | NA | 1 (0 to 1) | NA | NA | **<0.001** |

*MTPJ = metatarsophalangeal joint, and NA = not applicable. †Wilcoxon signed-rank test. Bold indicates significant p values. ‡The values are given as the median, with the interquartile range in parentheses. §Graded as I through VII according to the Hardy and Clapham classification. #Classified according to Okuda et al. as round (2), intermediate (1), or angular (0). **Graded as 0 through 4 according to the Coughlin-Shurnas classification.

lateral release of the capsule and the metatarsosesamoid ligament over the top of the metatarsal head. The plantar attachment containing the blood supply to the metatarsal head is preserved.

The first cut of the ReveL osteotomy is vertical and perpendicular to the second metatarsal shaft axis, preventing any shortening or lengthening of the first metatarsal. The second cut is parallel to the sole of the foot, preventing any elevation of the metatarsal head. After the osteotomy, the distal fragment is shifted laterally by up to 50% to 60% of the metatarsal head width (according to the IMA). After fluoroscopic control of the IMA correction, the osteotomy is fixed with two 2.4-mm cortical screws. The first (distal) screw is directed into the head fragment and is placed unicortically to avoid damage to joint cartilage. The second (proximal) screw is directed more perpendicular to the first metatarsal and is placed bicortically for increased stability (Fig. 2). The osteotomy is finalized by the resection of the medial osseous prominences. An Akin osteotomy is added in cases with hallux valgus interphalangeus, performed as an open, medially based, closing-wedge osteotomy of the proximal phalanx and fixed with another 2.4-mm cortical screw. The medial capsule is closed with absorbable sutures. A hallux valgus dressing is applied to unload the medial capsule and maintain the corrected position. Patients are instructed to bear weight on the heel in a postoperative rigid-soled shoe for 6 weeks.

### *Statistical Analysis*

The clinical and radiographic outcome variables did not fulfill the criteria for normality and are presented as the median and the interquartile range (IQR), and were compared with use of the Mann-Whitney U test. The Wilcoxon signed-rank test was used to compare changes in the variables between follow-ups. Categorical variables were compared with the chi-square test. A 2-sided $p < 0.05$ was considered significant. Receiver operating

**TABLE II Preoperative Radiographic Risk Factors for Hallux Valgus Recurrence***

| Parameter | Hallux Recurrence (N = 18 [14%]) | Nonrecurrence (N = 113 [86%]) | Univariate P Value† |
|---|---|---|---|
| HVA‡ *(deg)* | 31.9 (29.1 to 35.0) | 24.1 (19.7 to 28.6) | **<0.001**§ |
| IMA‡ *(deg)* | 10.9 (8.7 to 13.7) | 10.3 (8.5 to 12.2) | 0.44§ |
| First MTPJ incongruence‡ *(deg)* | 14.7 (9.7 to 13.4) | 11.3 (5.7 to 16.1) | **0.01**§ |
| Sesamoid position# | | | 0.14** |
| IV or less (n = 72 [55%]) | 7 (10%) | 65 (90%) | |
| Greater than IV (n = 59 [45%]) | 11 (19%) | 48 (81%) | |
| Round sign# | | | **0.009**** |
| Negative (n = 80 [61%]) | 6 (8%) | 74 (92%) | |
| Positive (n = 51 [39%]) | 12 (24%) | 39 (76%) | |

*Hallux valgus recurrence was defined as an HVA of >20° at the final follow-up. †Bold indicates significant p values. ‡The values are given as the median, with the interquartile range in parentheses. §Mann-Whitney U test. #The values are given as the absolute number, with the row percentage in parentheses. **Chi-square test.

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**TABLE III Postoperative Radiographic Risk Factors for Hallux Valgus Recurrence*†**

| Parameter | Hallux Recurrence (N = 18 [14%]) | Nonrecurrence (N = 113 [86%]) | Univariate P Value‡ |
|---|---|---|---|
| HVA§ *(deg)* | 17.1 (14.3 to 21.4) | 10.1 (6.2 to 13.6) | **<0.001#** |
| IMA§ *(deg)* | 5.1 (2.7 to 6.8) | 3.9 (2.3 to 5.5) | 0.19# |
| First MTPJ incongruence§ *(deg)* | 3.6 (1.1 to 9.1) | −1.4 (−6.1 to 1.9) | **<0.001#** |
| Sesamoid position | | | |
| IV or less (n = 131 [100%]) | NA | NA | NA |
| Greater than IV (n = 0 [0%]) | | | |
| Round sign** | | | 0.16†† |
| Negative (n = 116 [89%]) | 15 (13%) | 101 (87%) | |
| Positive (n = 15 [11%]) | 4 (27%) | 11 (73%) | |

*Hallux valgus recurrence was defined as an HVA of >20° at the final follow-up. †NA = not applicable. ‡Bold indicates significant p values. §The values are given as the median, with the interquartile range in parentheses. #Mann-Whitney U test. **The values are given as the absolute number, with the row percentage in parentheses. ††Chi-square test.

characteristic curve analyses determined cutoff values for the significant radiographic values. The variables were dichotomized for the logistic regression analysis according to the cutoff values. The results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). All data were assessed using SPSS version 28.0 (IBM).

## Results

All radiographic parameters significantly improved from preoperatively to the 6-week postoperative follow-up and the final follow-up ($p < 0.001$). First MTPJ arthritis significantly deteriorated from preoperatively to the final follow-up (Table I). Eighteen (14%) of 131 cases showed hallux valgus recurrence. The recurrence rates did not significantly differ ($p = 0.66$) between the 38 cases (16% recurrence) in which patients underwent an additional Akin osteotomy and 93 cases (13% recurrence) in which patients did not undergo the procedure. In the univariate risk factor analyses, the preoperative and 6-week postoperative HVA, the preoperative and postoperative first MTPJ congruence angle, and a preoperative positive round sign were significantly correlated with hallux valgus recurrence (Tables II and III). Multivariable logistic regression analysis found a preoperative HVA of >28° (OR, 9.1; $p = 0.02$) and a 6-week postoperative HVA of >15° (OR, 4.6; $p = 0.03$) to be independent risk factors for hallux valgus recurrence (Table IV).

**TABLE IV Multivariable Logistic Regression Analysis of Radiographic Risk Factors for Hallux Valgus Recurrence***

| Parameter | OR† | Multivariable P Value‡ |
|---|---|---|
| HVA | | |
| Preoperative | 9.1 (1.5 to 56.7) | **0.02** |
| Postoperative | 4.6 (1.2 to 17.2) | **0.03** |
| First MTPJ incongruence | | |
| Preoperative | 1.3 (0.3 to 6.3) | 0.71 |
| Postoperative | 3.3 (0.8 to 13.0) | 0.09 |
| Preoperative round sign | 2.1 (0.6 to 7.5) | 0.25 |

*Hallux valgus recurrence was defined as an HVA of >20° at the final follow-up. †The values are given as the OR, with the 95% confidence interval in parentheses. ‡Bold indicates significant p values.

The median FAOS subscales were as follows: pain, 100 (IQR, 94 to 100); symptoms, 100 (IQR, 96 to 100); activities of daily living, 100 (IQR, 100 to 100); sport and recreation, 100 (IQR, 100 to 100); and QOL, 100 (IQR, 81 to 100). Patients in 107 (82%) of 131 cases stated that they had marked pain relief (median VAS, 0 [IQR, 0 to 0]). In 90% of the 103 cases in which the patients were unwilling to attend the outpatient clinic in person, patients were still satisfied with the postoperative course and therefore did not see the point of attending another examination.

Prognostic factors for the long-term FAOS results are shown in Table V. A preoperative body mass index (BMI) of >30 kg/m$^2$ was associated with poorer FAOS QOL ($p = 0.04$), and a postoperative hallux varus was associated with lower FAOS activities of daily living ($p = 0.048$). Preoperatively, 124 (95%) of 131 cases showed no or only mild first MTPJ arthritis (grades 0 or 1), whereas 7 cases (5%) had grade-2 arthritis. The preoperative arthritis grade had no influence on the long-term clinical outcome. However, first MTPJ arthritis that was grade 2 or higher at the final follow-up was associated with significantly lower scores in almost all FAOS subscales and VAS pain. Age at the time of the surgical procedure, hallux valgus recurrence, and sesamoid position did not impact the long-term outcome.

Complications were reported in 42 cases (32%) (Table VI). A symptomatic implant was the main reason for revision (15%). None of the 4 symptomatic hallux valgus recurrences (3%) underwent revision surgery. All 8 cases (6%) with postoperative hallux varus were asymptomatic. In 121 cases (92%),

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**TABLE V Prognostic Factors for the Long-Term Clinical Outcome According to the FAOS and VAS Pain**

| | FAOS* | | | | | | | | | | VAS Pain* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Factors | Pain† | P Value‡ | Symptoms† | P Value‡ | Activities of Daily Living† | P Value‡ | Sport and Recreation† | P Value‡ | QOL† | P Value‡ | Pain† | P Value‡ |
| Age at surgery | | 0.99 | | 0.67 | | 0.95 | | 0.89 | | 0.41 | | 0.25 |
| >50 years (n = 43) | 100 (92 to 100) | | 100 (96 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 100 (88 to 100) | | 0 (0 to 0) | |
| ≤50 years (n = 88) | 100 (95 to 100) | | 100 (93 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 94 (81 to 100) | | 0 (0 to 0) | |
| BMI at surgery | | 0.10 | | 0.80 | | 0.11 | | 0.37 | | **0.04** | | 0.12 |
| >30 kg/m$^2$ (n = 18) | 100 (89 to 100) | | 100 (89 to 100) | | 100 (97 to 100) | | 100 (99 to 100) | | 91 (74 to 100) | | 0 (0 to 1.3) | |
| ≤30 kg/m$^2$ (n = 113) | 100 (100 to 100) | | 100 (96 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 100 (88 to 100) | | 0 (0 to 0) | |
| Recurrence at final follow-up§ | | 0.73 | | 0.46 | | 0.73 | | 0.65 | | 0.85 | | 0.79 |
| Yes (n = 18) | 100 (99 to 100) | | 100 (91 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 94 (83 to 100) | | 0 (0 to 0) | |
| No (n = 113) | 100 (94 to 100) | | 100 (96 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 100 (75 to 100) | | 0 (0 to 0) | |
| Hallux varus at final follow-up | | 0.38 | | 0.47 | | 0.048 | | 0.05 | | 0.06 | | 0.10 |
| Yes (n = 8) | 100 (75 to 100) | | 100 (83 to 100) | | 100 (93 to 100) | | 100 (86 to 100) | | 81 (55 to 98) | | 0 (0 to 3.8) | |
| No (n = 123) | 100 (97 to 100) | | 100 (96 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 100 (86 to 100) | | 0 (0 to 0) | |
| Sesamoid position at final follow-up | | 0.88 | | 0.32 | | 0.61 | | 0.64 | | 0.33 | | 0.99 |
| Grades I to IV (n = 121) | 100 (97 to 100) | | 100 (96 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 100 (88 to 100) | | 0 (0 to 0) | |
| Grades V to VII (n = 10) | 100 (94 to 100) | | 98 (96 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 91 (69 to 100) | | 0 (0 to 0) | |
| Preoperative first MTPJ arthritis | | 0.73 | | 0.36 | | 0.20 | | 0.20 | | 0.40 | | 0.52 |
| Grades 0 to 1 (n = 124) | 100 (96 to 100) | | 100 (96 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 94 (81 to 100) | | 0 (0 to 0) | |
| Grades 2 to 4 (n = 7) | 100 (93 to 100) | | 100 (86 to 100) | | 100 (92 to 100) | | 100 (88 to 100) | | 100 (94 to 100) | | 0 (0 to 1) | |
| First MTPJ arthritis at final follow-up | | 0.008 | | **0.002** | | 0.008 | | 0.009 | | 0.08 | | **0.003** |
| Grades 0 to 1 (n = 104) | 100 (100 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 100 (100 to 100) | | 100 (88 to 100) | | 0 (0 to 0) | |
| Grades 2 to 4 (n = 27) | 100 (83 to 100) | | 96 (82 to 100) | | 100 (94 to 100) | | 100 (95 to 100) | | 94 (63 to 100) | | 0 (0 to 3) | |

*The Mann-Whitney U test was used to analyze potential risk factors for a poorer outcome. †The values are given as the median, with the interquartile range in parentheses. ‡Bold indicates significant p values. §Hallux valgus recurrence was defined as an HVA of >20° at the final follow-up.

patients were satisfied with the postoperative pain reduction; in 123 cases (94%), patients were satisfied with the postoperative appearance of the hallux; and in 122 cases (93%), patients were satisfied with the postoperative first MTPJ range of motion (Table VII). Patients were also asked whether they would undergo the surgical procedure again; patients in 5 cases (4%) answered no, patients in 14 cases (11%) answered that they did not know, and patients in 112 cases (86%) answered yes.

## Discussion

Hallux valgus deformity is among the most common orthopaedic foot disorders, yet larger case series reporting on the long-term clinical outcome and risk factors that lead to a poorer clinical outcome after hallux valgus correction are scarce[4-7]. To our knowledge, this study reports the longest follow-up after hallux valgus surgery. We found a 92% satisfaction rate after ReveL osteotomy at a mean follow-up of 14.2 years, with excellent function (median FAOS, 100) and low pain levels (median VAS, 0).

A higher first MTPJ arthritis grade of ≥2 at the final follow-up was the leading cause of an inferior clinical outcome after hallux valgus correction in our study. This relationship was also found by Fuhrmann et al.[14], who investigated the mid-term results of 178 Scarf osteotomies after a mean follow-up of 3.7 years. They also found preoperative arthritic changes to be associated with an inferior outcome, which we could not confirm. However, statistical assessment was limited, as only 7 cases in our

**TABLE VI Complications and Revision Surgeries**

| Complications (N = 42 [32%]) | Revision Surgeries (N = 23 [18%]) |
|---|---|
| Symptomatic implant: 21 (16%) | Implant removal: 19 (15%) |
| Hallux rigidus: 5 (4%) | Cheilectomy: 2 (2%) |
| | Implant removal and arthrolysis: 1 (1%) |
| Symptomatic hallux valgus recurrence*: 4 (3%) | Removal of thread granuloma: 1 (1%) |
| Hallux varus: 8 (6%) | — |
| Medial dorsal cutaneous nerve neuropathy: 1 (1%) | — |
| Transfer metatarsalgia: 1 (1%) | — |

*Hallux valgus recurrence was defined as an HVA of >20° at the final follow-up.

study showed preoperative first MTPJ arthritis with grade 2 or higher.

Hallux valgus recurrence has been described as 1 of the most common complications after hallux valgus surgery. The long-term hallux valgus recurrence rate in this study was 14% (3% symptomatic recurrence), which falls within the range of other long-term studies[4-7,12]. However, comparison between studies is difficult because of various definitions of recurrence. Bock et al.[4] investigated 93 Scarf osteotomies after a mean 10-year follow-up. Using an HVA of ≥20° as a cutoff, they reported a recurrence rate of 30% and a symptomatic recurrence rate of 6.5%. The higher rates may be explained by the inclusion of more severe deformities in their study (HVA, 31° compared with 25°). Early postoperative hallux correction was similar to our study (10.3° compared with 10.6°) and therefore was not the reason for their higher recurrence rates.

Surprisingly, we found no significant correlation between hallux valgus recurrence and a poorer clinical outcome. Although the FAOS is a validated patient-reported outcome measure for hallux valgus surgery[24], we detected a substantial ceiling effect in all FAOS subscales (i.e., >20% of the cases had the best possible score). This may have prevented us from finding a correlation between recurrence and a poorer clinical outcome. Bock et al.[4] also found only a weak correlation between the final HVA and the FAOS pain scale. Ling and Lui[7] evaluated 85 cases after endoscopy-assisted hallux valgus correction with a minimum 10-year follow-up. Although they only had 3 cases with recurrence (HVA of >15°), all FAOS subscale results (range, 72.6 to 89.3 points) were considerably lower than in our study. Postoperative first MTPJ stiffness, which was the main complication in their study, may have contributed to the poorer FAOS performance. Other previous long-term studies have lacked any patient-reported outcome data, which makes the comparison with our results difficult. Veri et al.[6] investigated 20 crescentic proximal osteotomies at a mean 12.2-year follow-up. The satisfaction rate was 90%, 11% showed recurrence, and 5% showed hallux varus. Schneider et al.[5] assessed 112 chevron osteotomies after a mean follow-up of 12.7 years. They reported 1 symptomatic hallux valgus recurrence but did not provide the radiographic recurrence rate.

Previous studies have detected several risk factors for hallux valgus recurrence[14-19,25,26], of which we only confirmed a preoperative HVA of >28° (OR, 9.1) and a 6-week HVA of >15° (OR, 4.6) to be independent risk factors. Bock et al.[4] found a higher preoperative and 6-week HVA and a higher 6-week IMA to increase the risk of recurrence but did not perform a logistic regression analysis to adjust for confounding factors. Park and Lee[19] investigated 117 cases with proximal metatarsal osteotomies after a minimum 2-year follow-up. They reported an immediate postoperative HVA of ≥8° to be the most important risk factor for recurrence (OR, 28.0; $p < 0.001$). Other previous studies also described the DMAA as a risk factor for recurrence[4,12]. Because of its low intraobserver and interobserver reliability and its overestimation on conventional radiographs[27,28], we decided against using the measurement of the DMAA. First MTPJ incongruence was identified as another risk factor in a few studies[14,16,29]. We found both preoperative and 6-week postoperative first MTPJ incongruence to be significantly correlated with recurrence in the univariate analyses but not to be independent risk factors in the logistic regression model. Sesamoid position was identified as a risk factor for hallux valgus recurrence by Okuda et al.[17], who found significantly higher recurrence rates in cases with postoperative incomplete reduction of the sesamoids (13% compared with 59%). Incomplete sesamoid reduction as a risk factor has been confirmed in other studies[4,19,20,29]. Shibuya et al.[20] defined recurrence as an HVA loss of ≥3° after ≥6 months postoperatively. They found an incomplete sesamoid reduction to be the only independent risk factor (OR, 1.4). Their study had potential selection bias due to the exclusion of a high number of patients with missing postoperative radiographs. Furthermore, several techniques of hallux valgus correction were included, and no clinical outcome measures were reported. Park and Lee[19] found incomplete sesamoid reduction of grade IV or higher to be the second highest risk factor for recurrence (OR, 9.7; $p = 0.007$). We were unable to detect any correlation between postoperative sesamoid position and hallux valgus recurrence, as none of our cases showed incomplete sesamoid reduction at the 6-week follow-up.

Interest has grown in evaluating hallux valgus as a 3-dimensional deformity, with first metatarsal pronation as a key pathology[18,30-34]. Okuda et al.[18] suggested that a round sign indicates increased metatarsal pronation and may be a risk

**TABLE VII Postoperative Patient Satisfaction***

| Satisfaction | Pain | Appearance | Range of Motion |
|---|---|---|---|
| Dissatisfied | 4 (3%) | 6 (5%) | 2 (2%) |
| Undecided | 6 (5%) | 2 (1%) | 7 (5%) |
| Satisfied | 17 (13%) | 40 (31%) | 29 (22%) |
| Very satisfied | 104 (79%) | 83 (63%) | 93 (71%) |

*The values are given as the number of cases, with the percentages in parentheses.

factor for recurrence. A recent systematic review concluded that there is insufficient evidence to suggest that correction of metatarsal pronation reduces recurrence rates and improves the clinical outcome after hallux valgus surgery[35]. In the current study, the recurrence rate of patients with a persistent round sign was higher but the difference did not reach significance (27% compared with 13%; p = 0.16), which may have been due to an insufficient sample size. Another reason may be the low accuracy of the round sign in predicting metatarsal pronation, as found in more recent studies using weight-bearing computed tomographic (CT) scans as the gold standard[36-38]. Furthermore, most traditional distal metatarsal osteotomies have a limited capacity to correct rotational deformity[13].

The current study was limited by its retrospective design with missing preoperative functional scores and the lack of a control group. The exclusion of concomitant procedures may have led to a selection bias with regard to more severe hallux valgus deformities that were probably associated with additional deformities of the lesser toes. Furthermore, the relatively low preoperative IMAs in this study were likely secondary to the surgeons' preference to perform first TMTJ arthrodesis in hallux valgus deformities with clinical TMTJ hypermobility, which are associated with larger IMAs. However, we deliberately excluded patients with additional surgical procedures to minimize possible confounding factors that may have affected the results of the ReveL osteotomy. Moreover, the study may have been underpowered for certain subgroup analyses.

However, this study is one of the largest published series of patients undergoing hallux valgus surgery and has the longest clinical and radiographic follow-up thus far, to our knowledge. We found an overall high satisfaction rate and excellent long-term functional results after ReveL osteotomy and can therefore recommend this technique for hallux valgus correction.

In conclusion, the ReveL osteotomy showed good postoperative hallux valgus correction and high long-term satisfaction rates. A preoperative HVA of >28° (OR, 9.1) and a 6-week postoperative HVA of >15° (OR, 4.6) increased the risk of hallux valgus recurrence. First MTPJ arthritis at the final follow-up was associated with an inferior clinical outcome, whereas radiographic hallux valgus recurrence had no impact on the long-term clinical results. ■

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