# Z-osteotomy in hallux valgus: clinical and radiological outcome after Scarf osteotomy

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## Abstract

Correction osteotomies of the first metatarsal are common surgical approaches in treating hallux valgus deformities whereas the Scarf osteotomy has gained popularity. The purpose of this study was to analyze short- and mid-term results in hallux valgus patients who underwent a Scarf osteotomy. The subjective and radiological outcome of 131 Scarf osteotomies (106 hallux valgus patients, mean age: 57.5 years, range: 22-90 years) were retrospectively analyzed. Mean follow-up was 22.4 months (range: 6 months-5 years). Surgical indications were: intermetatarsal angle (IMA) of 12-23°; increased proximal articular angle (PAA>8°), and range of motion of the metatarsophalangeal joint in flexion and extension >40°. Exclusion criteria were severe osteoporosis and/or osteoarthritis. The mean subjective range of motion (ROM) of the great toe post-surgery was 0.8±1.73 points (0: full ROM, 10: total stiffness). The mean subjective cosmetic result was 2.7±2.7 points (0: excellent, 10: poor). The overall post-operative patient satisfaction with the result was high (2.1±2.5 points (0: excellent, 10: poor). The mean hallux valgus angle improvement was 16.6° (pre-operative mean value: 37.5°) which was statistically significant ($p<0.01$). The IMA improved by an average of 5.96° from a pre-operative mean value of 15.4° ($p<0.01$). Neither osteonecrosis of the distal fragment nor peri-operative fractures were noted during the follow-up. In keeping with our follow-up results, the Scarf osteotomy approach shows potential in the therapy of hallux valgus.

## Introduction

Lateral deviation and internal rotation of the great toe is termed hallux abducto valgus. Secondary anomalies, such as painful exostosis and bursitis, second hammer digit syndrome and metatarsalgia concomitant with patient demands often encourage the patient to undertake operative intervention.

Although hallux valgus is a common foot deformity, etiology, course and treatment of this complex condition are still not completely understood and this is indicated by the more than 130 different surgical approaches that have been described in the literature over the last decades.[1,2] This is further pointed out by a study that evaluated the most preferred operative procedure used for treatment of a severe hallux valgus by academic foot and ankle surgeons practicing in the United States.[3] Hereby, a hypothetical case of a symptomatic 50-year-old woman with severe deformity (intermetatarsal angle=20°, hallux valgus angle=42°) who wanted the deformity corrected was sent to well experienced foot surgeons in order to determine their preferred operative treatment for this case. A wide variation in the type of procedure used to correct this severe hallux valgus was observed.

By now, post-operative complications such as limited range of motion (ROM) in the metatarsophalangeal joint (MPJ), hallux varus deformity, sesamoiditis, metatarsalgia and recurrence of the valgus deformity are common findings in the follow-up.

The original description of hallux valgus correction is attributed to Reverdin in 1881 who described a wedge resection of the distal metaphyseal region of the first MPJ.[1] McBride published the capsule tendon balancing and joint preservation procedure in 1928[4] and that was followed by the Keller procedure[5] and the Mitchell osteotomy.[6] The name "Scarf" was given by Borrelli and Weil[7] who compared the osteotomy with the carpentry term "a joint made by beveling two beams to correspond". The Scarf procedure was initially described by Meyer in 1926 who published an operative technique that included a diaphyseal Scarf-like osteotomy of the first metatarsal bone for hallux valgus correction.[8,9] Fifty years later, in 1976, Burutaran[10] described a cut almost similar to the Scarf cut, though not Chevron-ended, that was used to lengthen the first metatarsal. In 2000, Barouk[11] described in detail the surgical technique of an articular preserving Scarf osteotomy for forefoot management.

The interlocking nature of the Scarf-type osteotomies with minimal first metatarsal shortening encouraged many surgeons to employ these techniques over recent decades.[1,7] However, there are few reports in the literature about the clinical and radiological outcome following Scarf osteotomy with a sufficient number of patients. The purpose of the following study was, therefore, to analyze short- and mid-term results in hallux valgus patients who underwent a Scarf osteotomy.

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## Design and Methods

### Study population

In this retrospective study, we reviewed medical history forms and radiographs of 130 patients (163 feet) who had Scarf osteotomy in the feet between 1995 and 2001. Indication criteria for Scarf osteotomy were: intermetatarsal angle (IMA) between 12-23°, increased proximal articular angle (PAA>8°), and range of motion of the flexion/extension ROM for the MPJ>40°. Exclusion criteria were severe osteoporosis and/or foot osteoarthritis. Of these 131 patients (163 feet), there were 106 patients (131 feet) with both a complete medical history form and adequate radiographic follow-up. In 24 patients (32 feet) who underwent Scarf osteotomy, the medical history form was incomplete and/or the radiography was of bad quality and thus sufficient retro-

spective analysis was not feasible. Therefore, the post-operative results of 106 hallux valgus patients who underwent 131 Scarf osteotomies (99 females, 7 males) were further analyzed in this study. The mean age at surgery was 57.5 years (range: 22-90 years). In this cohort, 68 right and 63 left hallux valgus deformities were corrected. The mean follow-up was 22.4 months (range: 6 months-5.25 years). The investigation was carried out in accordance with the World Medical Association Declaration of Helsinki in its present form. Informed consent was obtained from all patients prior to the study.

## Operative technique

All surgeries was performed by one well-experienced surgeon (MS). The operative technique was modified according to Weil,[12] (Figure 1). After medial incision and careful identification to preserve the neurovascular structures, a T-shaped or lenticular capsular incision was undertaken removing a small ellipse of the capsule adjacent to the dorsoplantar midline of the first metatarsal head. Capsule and periost were reflected dorsally along the medial side of the metatarsal head and shaft, and distally to the base of the proximal phalanx. After plantar reflection and joint exposure, the suspensory ligament of the fibular sesamoid was released and this was followed by a limited lateral release. A 1.1 mm K-wire was inserted at the upper third of the medial surface of the metatarsal head and was then directed laterally in plantar declination of about 15°. For better orientation, a second K-wire was placed into the first metatarsal bone parallel and proximal to the first K-wire that marked the proximal limitation of the "Z"-osteotomy. An osteotomy guide was placed upon the pins. Subsequently, a dorsal cut 5 mm proximal to the margin of the dorsal cartilage was created by using a 12 mm wide sagittal saw blade. The osteotomy guide was then rotated parallel to the long axis of the metatarsal shaft pointing towards the inferior third. A 10 mm sagittal saw was then used to make the long cut. Based upon the IMA magnitude, the length of the horizontal osteotomy was altered; IMA<13°: short cut, IMA 14-16°: medium cut, and IMA 17-23°: large cut. At the end, the plantar cut was completed by connecting the long cut of the shaft at a 45° angle. Thus the mobilized metatarsal head and shaft sections could be displaced laterally until the pre-operatively planned amount of correction was achieved. This lateral shift of up to 60% of the metatarsal shaft diameter was performed in order to allow sufficient fixation and stability. Either canulated screws (AMP Medinow, 2.7 mm diameter, maximal 2 screws) or partial threaded K-wires were utilized in order to assure a stable fixation of the osteotomy (Figure 2).

Depending on the severity of the hallux deformity, an asymmetric lateral shift of the distal fragment was undertaken that was combined with a medial rotation of the floating fragment to achieve superior PAA correction. In severe hallux valgus deformities (IMA ≥24°), other surgical procedures such as dome or open wedge osteotomies were performed (not included in this retrospective analysis).

The post-operative treatment regimen included full weight bearing in forefoot releasing orthoses for two weeks and afterwards in plain shoes. Each patient received physical therapy and was asked to wear compression stockings for at least four weeks in order to prevent swelling.

## Medical history form and subjective evaluation

Reflecting common goals of hallux valgus surgeries (congruous joint, pain-free mobility, full range of motion, improved cosmetic result and ability to wear different styles of shoes, minimum post-operative disability and minimal interference with normal daily activities), the following parameters were selected for evaluation: 1) ROM within the MPJ summarized in a subjective ranking scale system ranging from 0 (full ROM) to 10 (total stiffness); 2) subjective sensory disturbance ranging from 0 (no disturbance) to 10 (numbness); 3) subjective cosmetic evaluation ranging from 0 (excellent) to 10 (poor); and 4) overall patient satisfaction with the surgical outcome ranging from 0 (excellent) to 10 (poor). Furthermore, perioperative complications such as persistent swelling, superficial wound infection, traumatic fragment dislocation, recurrence of pseudobursitis, tenderness, avascular osteonecrosis, intra-operative fractures, hardware dislocation, and post-operative troughing were evaluated.

## Radiographic analyses

Standard anterior-posterior (a.p.) and lateral radiographs taken pre-operatively and at the further follow-up were analyzed. The radiographic analysis was performed by an independent radiologist experienced in musculoskeletal imaging and included the following parameters: 1) HVA[13-15] (normal=10-15°, overcorrection=HVA<10°, malcorrection=increased HVA compared to the pre-operative HWA); 2) IMA[13-15] (normal=6-8°, overcorrec-

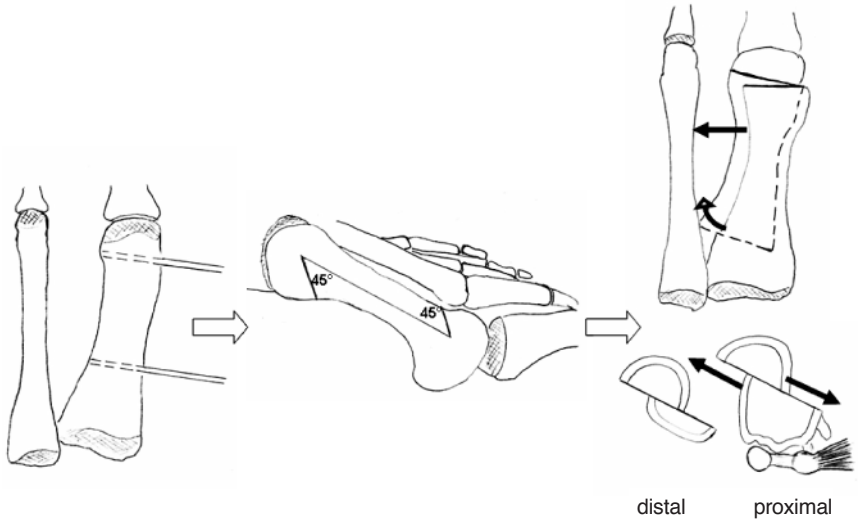


**Figure 1. The Scarf bone cuts: according to Barouk[11] the osteotomy on the dorsomedial surface begins proximally 2-3 mm above the medial and 5 mm distally from the proximal margin of the proximal plantar exposure and proceeds forward and dorsally. The two parallel K-wires serve as orientation and protect the metatarsal bone. The longitudinal osteotomy crossing the metatarsal follows the lateral plantar obliquity of the medioplantar surface. This technique enables the surgeon to lower the plantar head fragment when it is laterally displaced preserving the lateral surface, that acts as a strong sagittal structure. A medial rotation of the fragment allows a correction of the distal articulation angle.**

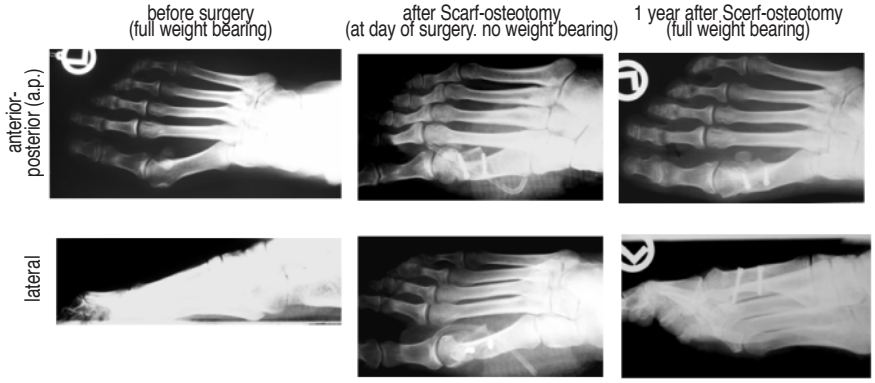


**Figure 2. Pre- and post-operative standing a.p.-radiographs in a 49-year old female hallux valgus patient who underwent Scarf osteotomy. The post-operative radiograph confirms a good correction of the deformity that is also noted at the one year follow-up. In some patients, an additional Akin-osteotomy may be indicated.**

tion=post-operative IMA<6°, mal-correction=IMA>the pre-operative IMA); 3) distal articulation angle (DAA)[14,15] (normal≤8°, mal-correction DAA>8° post-operative); 4) distal metatarsal articular angle (DMAA)[14,15] (normal≤8°), 5) (PAA)[14,15] (normal≤8°); 6) subluxation of the MPJ[14,15] (incongruence quantification in mm from the medial and lateral MPJ); and 7) existence or non-existence of collapsing of the proximal fragment into the distal fragment (troughing). All radiographic parameters that were used in this study are illustrated in Figure 3.

### Statistical analysis

Mean values (x) and standard deviations (±) were measured. The Student's t-test (paired samples) was utilized to evaluate the statistical significance. *p*-values<0.01 indicated high statistical significance, *p*-values<0.05 statistical significance, and *p*-values>0.05 proved no statistical significance.

## Results

### Subjective post-operative evaluation

The following results were noted: 1) ROM score=0.8±1.7 points; 2) sensory disturbance score=0.85±1.9 points; 3) cosmetic score=2.67±2.7 and 4) overall patient satisfaction score=2.1±2.5 points. Post-surgery, 46 of 106 patients (43.4%) were able to use any footwear without restrictions. A total of 39 patients (36.7%) were still limited in their choice of footwear. In 21 patients (19.8%), there was no clear statement given on the subject. Perioperative complications were: persistent swelling of the hallux in three feet (2.3%), superficial wound infection in 17 feet (13.0%), traumatic fragment dislocation in one foot (0.8%), recurrence of a painful pseudobursitis in ten feet (7.6%), tenderness under the first metatarsal head in 24 feet (18.3%), hardware (pin) movement in two feet (1.6%), and post-operative troughing in six feet (4.6%). We found no avascular osteonecrosis of the distal fragment and no intra-operative fractures.

### Radiographic evaluation

The results of the radiographic analysis are illustrated in Figure 4. All radiographic angles showed highly significant statistical difference: HVA decrease from 37.5±8.5° to 21.0±9.7° ($p$=0.0005), IMA decrease from 15.4±3.85° to 9.4±4.7° ($p$<0.0001) and DMAA change from -0.6±7.82° to -3.1±8.45° ($p$<0.0001). Osteoarthritic changes were noted in 4 feet: a decrease of the metatarso-phalangeal joint space and joint incongruence (n=3) and subchondral sclerosis (n=1).

## Discussion

There is much interest in the Scarf osteotomy procedure. However, the database documenting the outcome of this intervention is still insufficient. There are few reports in the literature about the clinical and radiological outcome following Scarf osteotomy but the numbers of patients included in these studies were low. The aim of this retrospective study was to analyze the potential of Scarf

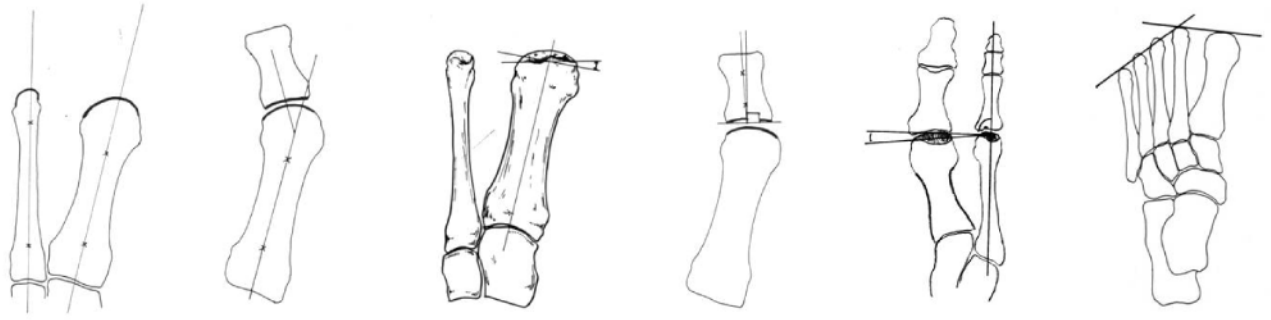


**Figure 3. Overview of the different angles for evaluation of the post-operative outcome in patients after Scarf osteotomy modified by Marcinko.[16]**

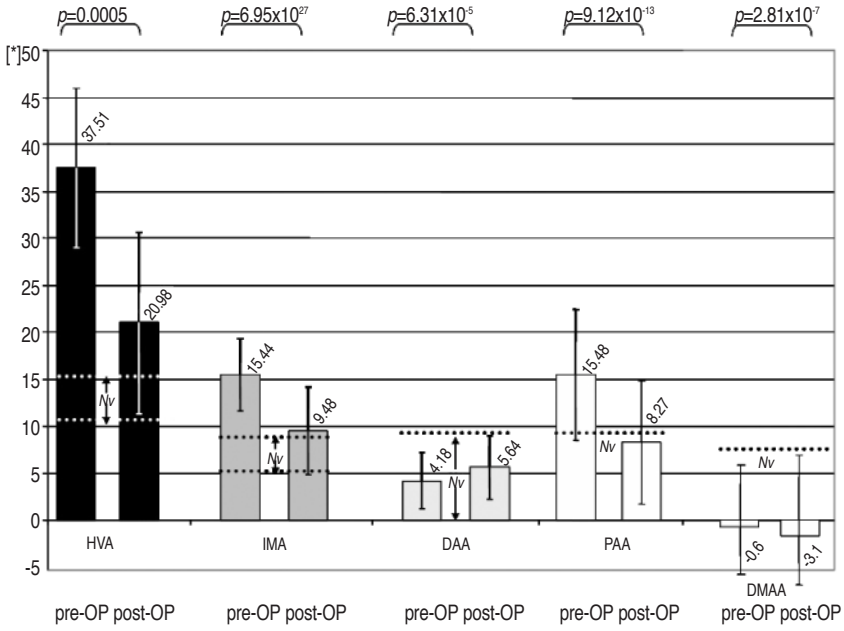


**Figure 4. Radiographic findings post-Scarf osteotomy in 127 patients (159 feet). The graphs illustrate mean angles (°), normal values (Nv)/ranges (horizontal bars) and standard deviation. Hallux valgus angle (HVA), intermetatarsal angle (IMA), distal articulation angle (DAA), proximal articulating angle (PAA). Improvement of all evaluated angles was highly statistically significant ($p$ values < 0.01).**

osteotomies in hallux valgus correction intervention in a large study cohort of 106 patients (131 feet). Hereby, we noted a good clinical outcome in patients with hallux valgus deformities following Scarf osteotomy. Radiographic analyses also revealed significant improvements.

Perugia *et al*.[17] studied the outcome after Scarf osteotomy in 33 patients (45 feet) in a follow-up of 26 months. Post-surgery they observed a HVA improvement from 21.1° to 32.1°. In our study, the HVA could be reduced from 37.5° to 21.0°. Similar results were seen regarding the IMA. While Perugia *et al*.[17] reported an IMA improvement of 9.9°, we observed an IMA improvement of 6.0°.

Skotak *et al*.[18] investigated the outcome in 49 patients (62 Scarf osteotomies) and reported a significant improvement in terms of the clinical and radiographic findings (decrease of HVA from 37° to 18° and IMA from 16° to 9°). They also pointed out that IMAs between 10° to 20° is an optimal indication for Scarf osteotomies; this is similar to our IMA inclusion range. Those results correspond with Freslon *et al*.[19] who noted excellent clinical and radiological results in 87 patients (123 feet) after a mean follow-up of 56 months. Considering our results, the authors agree with Perugia *et al*,[17] Skotak[18] and other authors[19-22] that the Scarf osteotomy provides an effective approach for the treatment of severe bunion deformity.

Nyska *et al*.[23] evaluated the change in position of the first metatarsal head using a three-dimensional (3D) digitizer in saw-bone models. They observed that Scarf and proximal Chevron osteotomies provided less angular correction, similar lateral displacement and less shortening in comparison to the basilar angular osteotomies such as the Mau[24] and Ludloff osteotomy.[25] They concluded that Scarf osteotomies are more reliable for patients with mild to moderate deformities, a short first metatarsal or an intermediate deformity with large DMAAs (Figure 5).

Although Scarf osteotomy has gained popularity and is seen as the treatment of choice for hallux valgus deformities in parts of Europe, there are reports that point out limitations of this fixation technique. Smith *et al*.[26] found an overall perioperative complication rate of 6% in 100 patients after Scarf osteotomy that involved a split first metatarsal, shearing of the K-wire and post-operative stress fractures. Coetzee[27] reported multiple complications in 20 patients (mean age 41 years, female: male=12 : 8) with moderate primus varus (IMA 13-20°) - and hallux valgus deformities (IMA<40°) six and 12 months after Scarf osteotomy. The post-operative treatment was non-weight-bearing for two weeks followed by four weeks of partial weight-bearing in a cast shoe. Troughing of the metatarsal with loss of height occurred in 35%, delayed bone union was found in 5% and rotational malunion was noted in 30%. Additionally, proximal fractures were seen in 10%, infections in 5% and early recurrence of the deformity in 25%. The mean American Orthopaedic Foot and Ankle Society (AOFAS) score was 53 (pre-surgery), 54 (six months post-surgery) and 62 (12 months post-surgery). Forty-five percent (9/20) of the patients were unsatisfied after one year and would not recommend the surgery to a friend. These results correspond with Acevedo *et al*.[28] who analyzed the relative fatigue endurance of five different first-metatarsal osteotomies (proximal crescentic, proximal Chevron, Mau, Ludloff, and Scarf) and noted that Mau and Ludloff osteotomies were significantly more stable than the other osteotomies mentioned.

In contrast to the high complication rates reported,[26-28] the retrospective analysis of our study revealed a relatively low complication rate and a high level of subjective satisfaction. The low complication rate and good outcome in our study are in keeping with other studies that proved good results with the Scarf osteotomy procedure. Kirsten *et al*.[9] investigated clinical and radiographic parameters in 89 patients (111 feet) after Scarf osteotomy after a three year follow-up. Hereby, the following results were noted: IMA decrease from 19.1° to 6.6°, persistence or recurrence of hallux deformity in 6%, and overall complication rate 5.4%.

In order to prevent recurrences in severe hallux deformities, we recommend a sufficient lateral shift of the plantar head fragment combined with a modest medial rotation, and, if necessary, shortening as described by Barouk.[11] Furthermore the Scarf technique allows an additional Akin-osteotomy for further correction in special cases as recommended by Roukis[29] and Jones.[8] Reflecting recent papers and our results the authors point out that Scarf osteotomies provide an effective method for the treatment of severe bunion deformities. However, common complications should be considered by the surgeon.

In a recent study,[30] the Scarf osteotomy was compared to the Chevron osteotomy in 115 (136 feet) patients with mild, moderate or

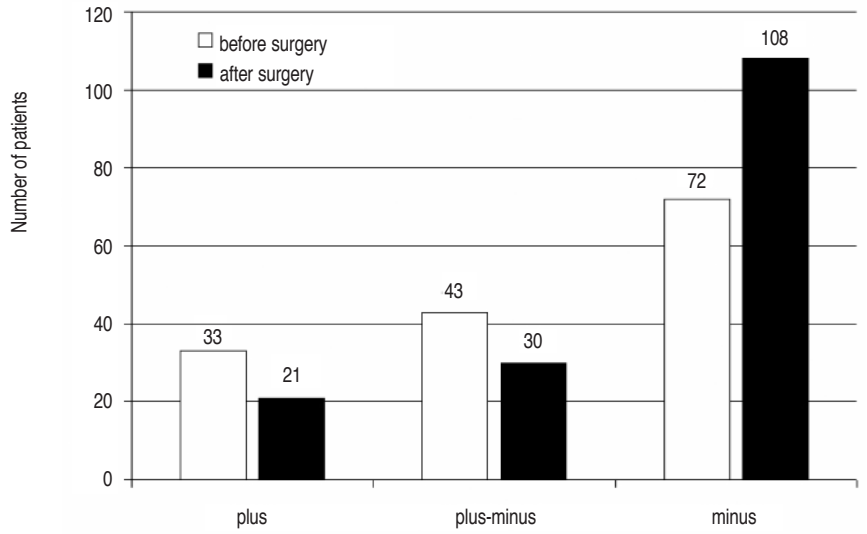


**Figure 5. Influence of the Scarf osteotomy on the length of the first metatarsal in 159 feet. Although in most patients there no difference in length was noted, a significant length reduction was observed in 36 feet (plus: length 1st metatarsal bone>length 2nd metatarsal bone, plus-minus: length 1st metatarsal bone=length 2nd metatarsal bone, minus: length 1st metatarsal bone=length 2nd metatarsal bone).**

severe hallux valgus. The results were graded according to IMA, HVA and DMAA analysis. Here, there were no statistically significant differences noted in the study cohorts with mild or moderate hallux valgus deformities. In the study cohort with severe hallux valgus, the Chevron osteotomy seemed to correct the hallux valgus deformity better than the Scarf osteotomy. However, this comparison was limited by the small number of patients with severe hallux valgus (n=12).

Garrido *et al*.[31] reviewed the results of patients with moderate and severe hallux valgus deformities who received Scarf osteotomy (n=30, 37 feet). For result evaluation, patient satisfaction and clinical and radiographic analyses were performed. In this study cohort, subjective, clinical and radiographic measurements revealed significant improvements for both moderate and severe hallux valgus. Thus, the authors conclude that the Scarf procedure has value in obtaining promising correction results in patients with moderate to severe hallux valgus deformities. The complication rate (19%) was similar in our data review. However, in contrast to our study, this retrospective analysis is limited by the small study sample.

Further studies pointing out the potential of the Scarf approach were recently reported.[32,33] However, they were not focused on complications. In a prospective study[34] that involved the large amount of 475 feet, the incidence of complications after Scarf osteotomy was analyzed. Here, complications were rare. This further points toward favoring use of this osteotomy. The MPJ 1 stiffness was the most frequent complication. This decreased in relation to post-operative time: 41.7% at day 35 and 5.7% at day 120. Prolonged wound healing was noted in 5.7% and secondary osteotomy displacement in 1%. The incidence of other complications such as perioperative infection was less than 1%. General hospitalization complications were reflex dystrophy (1.3%) and deep vein thrombosis (0.6%). Other complications, e.g. nonunion after osteotomy, great toe claw or symptomatic iatrogenic hallux valgus, were not observed.

## Conclusion

Although technical demanding, the Scarf osteotomy provides both good clinical and radiographic results in hallux valgus deformities at the mid-term follow-up.

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