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Research Article

# A New Shaft/Base Osteotomy for The Correction of a Moderate to Severe Hallux Valgus Using an Intramedullary Locking Plate

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## Abstract

**Background:** The most popular types of osteotomies for the correction of a moderate to severe hallux valgus are the scarf, closing wedge, opening wedge, the crescentic osteotomy and the proximal chevron osteotomy. There are many reports about good results in favorable fitting preoperative anatomical conditions. There are also reports about not satisfying results under non-favorable preoperative anatomic conditions. We tried to find a surgical method which could normalize the well-known important forefoot parameters also under disadvantageous conditions. These parameters are lateralization, plantarization and derotation of the Ist metatarsal head and also a normalization of the Distal Metatarsal Articular Angle (DMAA). Part of the corrective process is also a soft tissue correction.

**Methods:** We developed a new operation technique and new fixation plates with special insertion/drill target devices for the goal of optimum results, without the disadvantages of shortening or the need for unloading. In the same way as in our previous study describing the subcapital osteotomy with intramedullary fixation, we performed a simple transverse lazy-L osteotomy located in the area of the proximal metaphysis and after an additional soft tissue release the distal fragment of the Ist metatarsal was restored to its preplanned optimum position concerning the above mentioned criteria. Fixation was achieved with an intramedullary angle stable transfixed 36 mm titanium plate. Interfragmental compression or solid bone contact were unnecessary due to the extreme rigidity of the implant. The goal was only an optimal correction. All patients were allowed to ambulate with full weightbearing immediately after the operation.

**Results:** We retrospectively reviewed 48 patients (55 feet) who underwent shaft/base osteotomy between January 2011 and December 2012; 42 were women and 6 men; their mean age was 56 years. The follow-up investigation was performed on average after 72 months. The AOFAS Score improved from 48.15 to 98.36 ($t = 39.55$, $p < 0.001$), the IM angle was reduced from 17.15° to 4.60 ° ($t = 74.76$, $p < 0.001$), the HV angle from 33.15° to 9.13 ° ($t = 38.52$, $p < 0.001$). The DMAA was improved from 21.65 ° to 4.09° ($t = 12.24$, $p < 0.001$). The amount of shortening of the first metatarsal was in average of 0.8 mm and no recurrence of the hallux valgus was observed.

**Conclusion:** We present a new access to surgery of moderate to severe hallux valgus. A rigid intramedullary fixation device was the guarantee for rapid bone healing and an interfragmental compression or even interfragmental contact was not necessary. We found no malunion and no recurrence of hallux valgus. The method demonstrated excellent results with a patient satisfaction of 93.75%.

**Keywords:** Angle-Stable Locking Screws; Base Osteotomy; Derotation; Full Weightbearing; Hallux Valgus; Hallux Valgus Surgery; HV-Angle; Improvement of DMAA; IM-Angle; Intramedullary Locking Plate; Lazy-L Osteotomy; Lateralization; Moderate; New Access; Osteotomy of The First Metatarsal; Planarization; Severe; Shaft Osteotomy; Soft Tissue Correction; Toe Deformity

## Introduction

A normal intermetatarsal angle between the $I^{st}$ and $II^{nd}$ metatarsal (IM-angle) is defined to be below 10° and a normal hallux angle is a valgus of 15˚ or less. Moderate to severe hallux valgus is indicated by an IM-angle of 16 - 20˚ and a hallux valgus angle of 31˚ - 50˚. [1-7]. There are more than 130 methods described for correction of hallux valgus. Only few of them use osteotomies in the shaft. The severe or extreme deformities can also be corrected with proximal ostetomies or arthrodesis of the TMT-I joint [8]. The criteria for an optimum operation are: Correction the pathological I[st] intermetatarsal angle and the hallux valgus angle. A pathological pronation rotation should be normalized and a pathological DMAA has to be be corrected to an amount of less than 15˚ valgus. [1-7]. A metatarsus primus elevatus should be corrected by plantarization of the distal fragment. The length of the first metatarsal has to be preserved. A slight shortening can be achieved in cases of a diminished ROM in the I[st] MPJ. Shortenings could cause transfer metatarsalgia.

Furthermore, facilitate immediate mobilization and immediate loading of the operated foot rapid bone healing and avoid joint stiffness, swelling and M. Sudeck. The use of K-wires should be avoided because transfixion of the MPJ I and protrusion out of the toe for weeks may cause stiffness, infection and patient discomfort. Patients should be mobilized without crutches, cast or forefoot unloading shoes, but with elastic shoes with full loading. Patients should exercise their I[st] MPJ to increase the ROM.

The most popular methods for the correction of moderate to severe hallux valgus are the Scarf osteotomy, the closing-wedge osteotomy, the opening wedge osteotomy, the crescentic ostetomy and the proximal chevron osteotomy. Each of the most popular operations show potential problems due to their physical characteristics: The Scarf osteotomy was described by Burutaran 1976 [9]. It is a z-shaped shaft osteotomy for IM angles up to 16° [10]. The DMAA can also be improved. The problems of this method are shortening and troughing. The potential of correction of the IM angle is limited and there is almost no potential of correction of a pronation rotation. The procedure is technically difficult and has a complication rate of 19% with reoperations needed up to 11% [11]. Coetzee wrote 2003: "Scarf osteotomy has multiple potential pitfalls", he reported complications in 47% [12]. The closing wedge osteotomy is also technically demanding and entails the risk of shortening in average 5 mm (from 1mm to 26 mm!), dorsal malalignment, and transfer metatarsalgia. The most important disadvantage is the need of unloading or a cast for 6 weeks as reported by Trnka et.al 1999 [13].

Wanivenhaus et. al reported transfer metatarsalgia in 27% [14]. The opening wedge osteotomy leads to a significant increase of the DMAA which is equal to the closing wedge osteotomy. The osteosynthesis with a low-profile plate has to be unloaded with a special shoe for 6 weeks as reported [15,16]. The so called proximal crescentic osteotomy is a curved osteotomy and surgeons use a curved saw blade as described by Mann in 1992 [17,18]. The osteotomy is stabilized by a screw or plate and needs an unloaded mobilization for 6 weeks. The further disadvantages are the danger of dorsal malunion, Mann reported 28% of dorsiflexion malunion [17] and a worthening of the DMAA due to physical circumstances [19-21]. The proximal chevron osteotomy, popularized by Sammarco 1998 [22] is frequently stabilized by a special designed plate to facilitate early mobilization with partial weight bearing. There was observed no dorsiflexion malunion [23]. The results were reported to be equal to the results of the Ludloff ostetomies [24]. Disadvantages are the low correction potential in terms of DMAA, pronation rotation and plantarization.

There is not one operation described in literature, which meets all the desired criteria without significant disadvantages [25]. The disadvantages of greatest importance are for the authors the necessity of unloaded or partial unloaded mobilization for 6 weeks in all types of base osteotomies, the danger of dorsiflexion malunion, the worthening of the DMAA and the quite high percentage of possible transfer metatarsalgia. To quote Xiaojun Duan 2011 [26]: "The rate of complications in hallux valgus surgery ranges from 10% to 55%. No single procedure can be recommended given the complexity of the deformity." The rates of reoperations range from 5% to 9% [27].

## Materials and Methods

In the year 2007 and 2008 we tried to develop or modify an operation method to come as close as possible to an optimal correction of all criteria which lead to the moderate to severe hallux valgus [28]. The goal was to avoid the use of K-wires and to shorten the I[st] metatatarsal as few as possible. Patients should load their feet immediately after the operation with full weight bearing in an elastic comfort shoe.

We applied our successful concept in the treatment of the mild to moderate hallux valgus [25] with a simple transverse osteotomy fixed with an intramedullary angle stable locking plate to the base osteotomy. To reach these criteria without any accompanying disadvantages, we had to adapt the fixation devices and increased length and thickness of the plates in order to increase stability. We developed a set of 36 mm long intramedullary located and angle stable from cortex to cortex transfixed titanium plates. These plates are fixed intramedullary with 2 or 3 screws with a diameter of 3.5 mm and the osteotomized distal metatarsal fragment is mounted in an angle stable manner on the head of the plate with additional 2 screws of the same diameter. The distal fragment can be placed in stepless fashion in optimum position in terms of lateralization, plantarization, derotation, improvement of DMAA regardless the quality of contact between the bone partners. There are plates with different offsets available, which permit the metatarsal to be shifted 2 mm, 4 mm or 6 mm (Figure 1).

**Figure 1:** The V-tek intramedullary locking plates for the base osteotomy. These plates are thicker than the plates for the subcapital osteotomy- up to 1,2 mm and longer (36 mm). There are 3 offsets available: 2 mm, 4 mm and 6 mm.

Surgical Technique: Skin incision of about 5 to 6 cm, or as a minimally invasive approach with an incision of less than 2 cm, with additional stab incisions for the lateral release, the transfixing locking screws and the optional Akin osteotomy. Then longitudinal incision of the capsule. The pseudoexostosis is removed by a chisel or power saw and a bone cut is performed approximately 2.5 cm distal to the TMT-I-joint as a transverse osteotomy with a lazy-L at the plantar third of the Ist metatarsal (Figure 2).

A generous soft tissue release is performed. The distal metatarsal fragment is now brought to the optimum position. The plate is pushed into the intramedullary space. For this maneuver we use an inserter, which is also a target device for drilling and screwing. The drilling takes place from medial through the medial cortex, through the plate (drilling through holes in the plate) and through the lateral cortex (Figure 3 and Figure 4). There are three threaded holes in the proximal part of each plate. The drill diameter is 2.5 mm and the screw diameter is 3.5 mm.

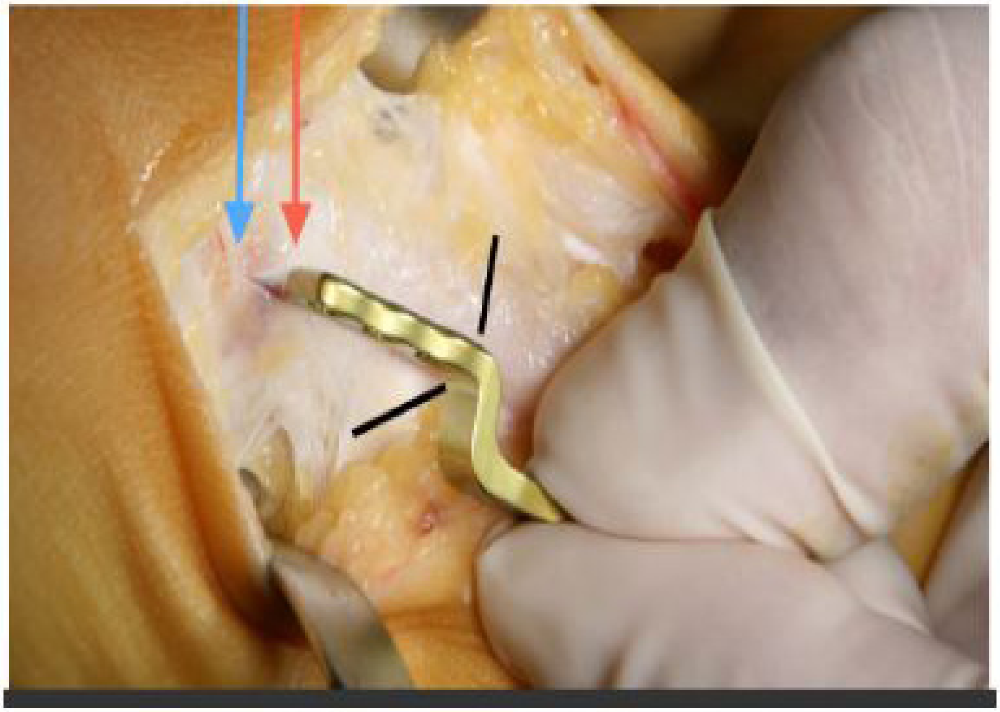

**Figure 2:** Identification of the TMT-I-joint (blue arrow). The tip of the plate must be located 5 mm distal (red arrow) and the osteotomy is marked – lazy-L (black lines).

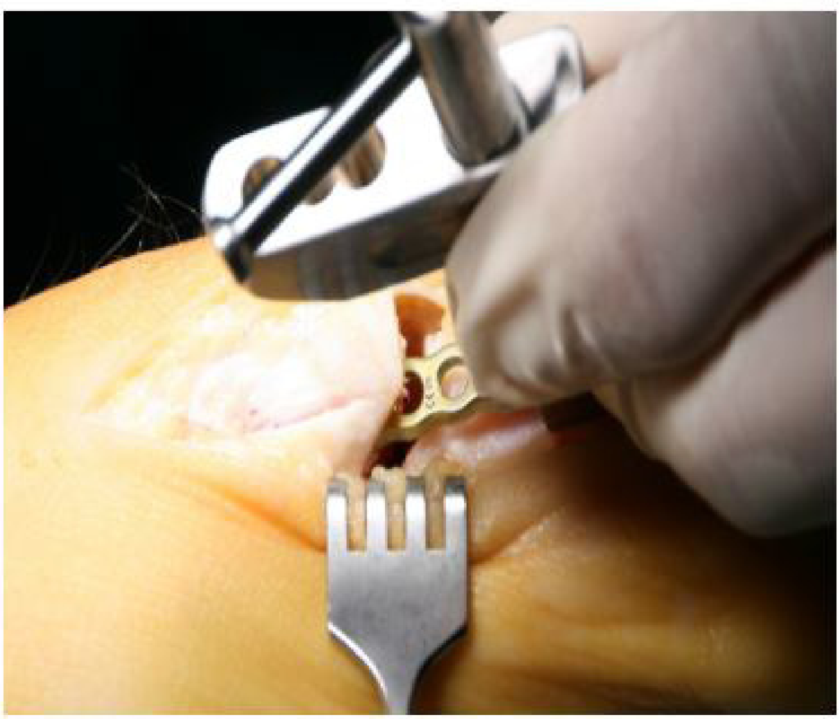

**Figure 3:** Displacement of the distal fragment and insertion of the plate with the inserting/target device.

**Figure 4:** Drilling through the medial cortex, through the plate and through the lateral cortex.

The screws fix the plate angle-stable, due to the corresponding threads in the plates. Screw lengths are usually 12 mm, 16 mm and 18 mm. In some cases, we used only 2 proximal screws. The distal fragment is then aligned and all parameters are corrected. The plate has a straight head with threaded holes for two 3.5 mm screw heads. After the distal fragment is drilled with a 2.5 mm drill, the first metatarsal is now screwed in an angle stable manner to the plate head. The screw length here is usually 16 mm (Figure 5). Given the extremely rigid fixation only a point contact or even no contact is adequate. As a result, a shift of 100% of even more is possible. To demonstrate the extreme potential of the technique, we show a situation which is a result of a too vigorous displacement. The distal fragment was placed beside the proximal fragment with a gap of about 2-3 mm. The patient was mobilized with full load despite a bilateral operation and despite the special situation of a non-contact in the osteotomy site of the left foot. The gap healed within 6 month and after that time the patient started running marathon. (Figures 6-9). In cases of interphalangeal hallux valgus an Akin osteotomy is performed [29]. The osteosynthesis can be fully loaded immediately after surgery and patients can resume their usual activities immediately using postoperative flexible and elastic so-called “medic ballerinas” (Figure 10).

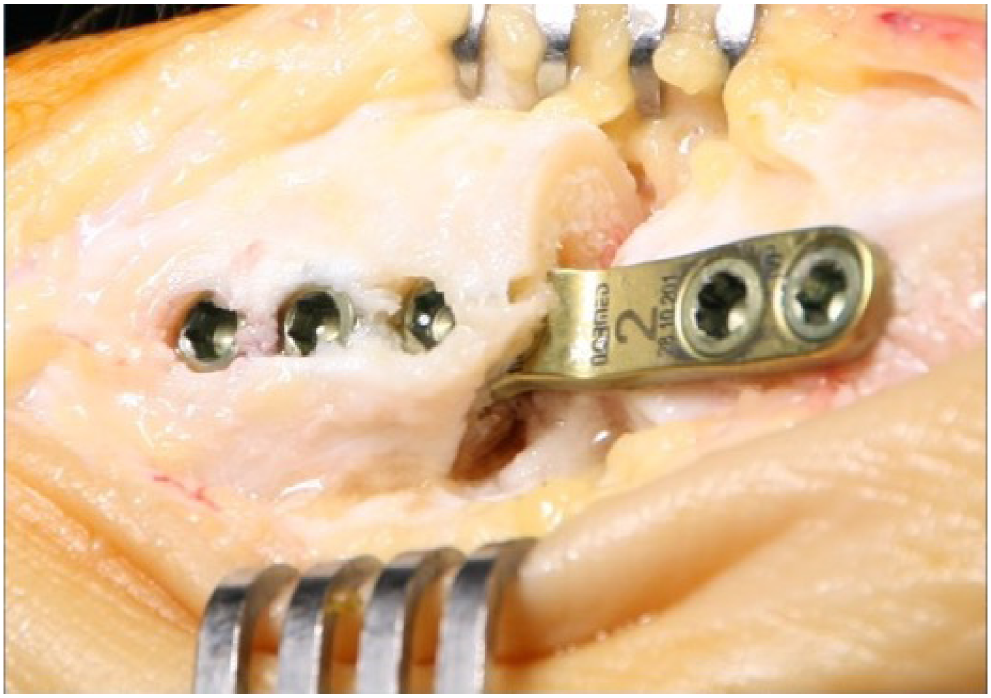

**Figure 5:** Final position of the hardware. The bone edges are shaved off.

**Figure 6:** Preoperative X-rays of patient Nr. 1.

**Figure 7:** Due to a too excessive displacement the distal fragment in the left foot was positioned without any contact to the proximal fragment. Postoperative X-ray. The patient Nr. 1 was mobilized with full loading of both feet.

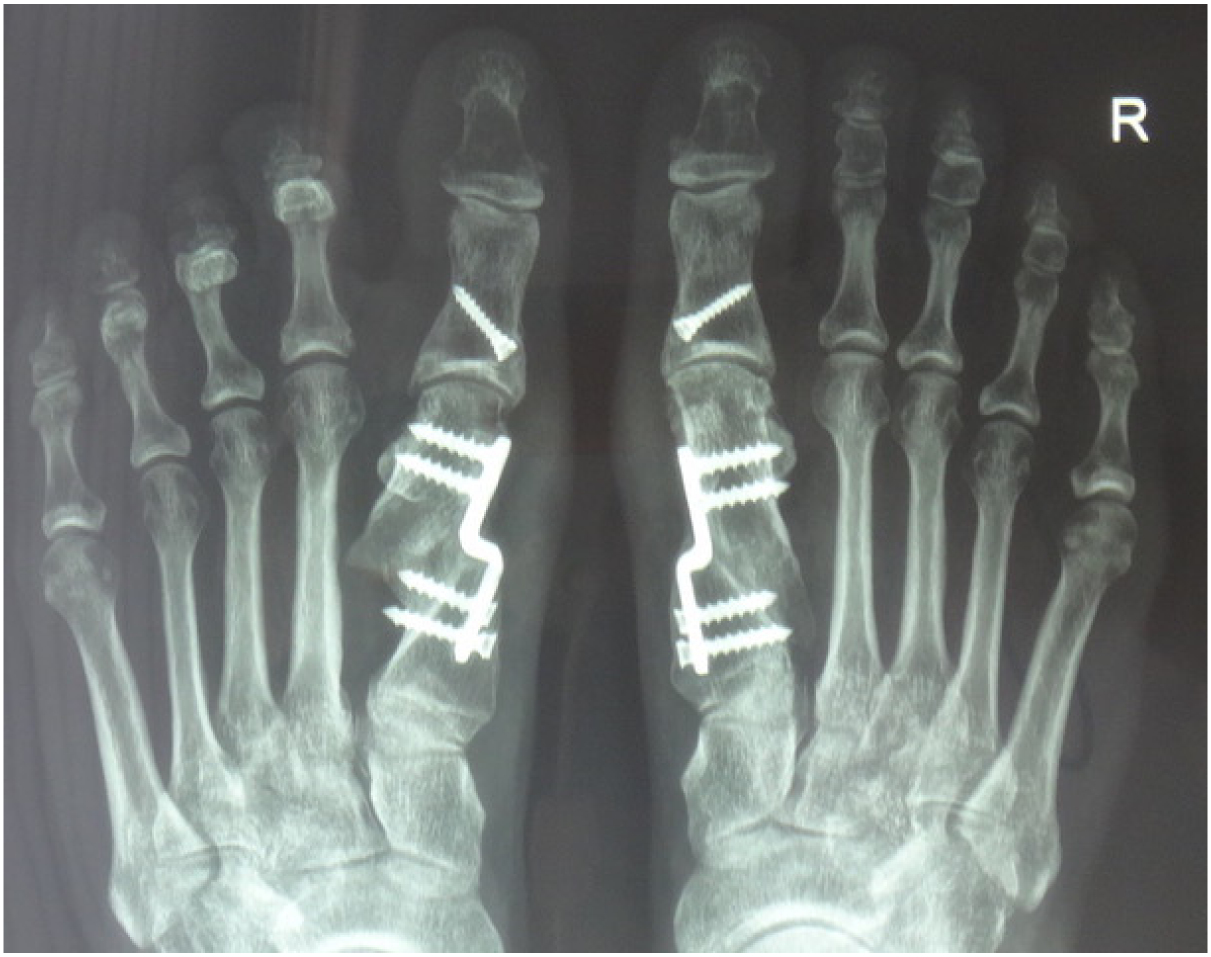


**Figure 8:** Result in patient Nr. 1 after 6 months. The bone gap healed solidly.

**Figure 9:** The feet of patient Nr. 1 before and after the operation.

**Figure 10:** The "medic ballerina" was employed for ambulation in almost all cases immediately after surgery.

## Results

We included 48 patients with 55 operated feet into this retrospective study. The patients were operated between January 2011 and December 2012. There were 42 females and 6 males.

81.25% (39 patients) underwent simultaneously other forefoot surgeries like Akins, FDL-Transfers and PIP arthrodesis for hammertoes, metatarsal shortening osteotomies for the lesser metatarsals or repair of tailor's bunions. Ages ranged from 28 to 86 years (mean age 56 years). The follow up was performed after 72 months in average, from 61 to 84 months. (Figures 11- 30).

We documented pre- and postoperatively and in the follow up evaluation for this study the following parameters: AOFAS Score, the IM angle, the HV angle, the DMAA angle, the angle of pronation rotation of the big toe, the circumference of the foot in the area of the metatarsal heads, the plantarization of the first metatarsal and the amount of shortening of the first metatarsal. X-rays were performed preoperatively, 1st day postoperatively, 6 weeks post operation and at the follow up. The patients were asked about their satisfaction with the operation. As analysis method we used the t-test. The AOFAS Score improved from 48.15 (between 26 and 75) to 98.36 (between 76 and 100) which is highly significant ($t = 39.55$, $p < 0.001$) (Table 1). (Figures 31, 32). The IM angle improved from mean 17.15 ° (from 12 ° to 20 °) to 4.60 ° (from 0 ° to 8 °) which is a difference of mean 12.55° and highly significant ($t = 74.76$, $p < 0.001$) (Table 2). (Figure 33, Figure 34). The Hallux valgus angle (HV) improved also highly significantly ($t = 38.52$, $p < 0.001$) from 33.15 ° preoperative (from 22 ° to 50 °) to 9.13 ° (from 0 ° to 19 °) which is a difference of mean 24.02 ° (Table 3). (Figures 35, 36). The pronation malrotation decreased from 21.67 ° (0 ° - 54 °) to 1.47 ° (0 ° - 5 °) which is also highly significant ($t = 11.04$, $p < 0.001$). (Table 4). (Figures 37, 38).

The DMAA angle decreased from mean 21.65 ° (0 ° - 40 °) to 4.09° (0 ° - 6 °) statistically high significant ($t = 12.24$, $p < 0.001$). (Table 5). (Figures 39, 40). The sesamoid position was improved from mean 5.07 (3-7) to mean 1.13 (1 - 2). This is also statistically high significant ($t = 17.28$, $p < 0.001$). (Table 6). (Figures 41, 42) The circumference of the forefoot measured in the area of the metatarsal heads was preoperative 27.01 cm (24.0 cm to 28.0 cm) and postoperative 25.62 cm (22.1 cm to 27.4 cm) which is a difference of 1.39 cm and statistically significant ($t = 20.02$, $p < 0.001$). (Table 7). (Figures 43, 44). The Ist metatarsal head was plantarized mean 2.4 mm (0 mm - 3.7 mm). The shortening of the first metatarsal was 0.8 mm (between 0 mm and 2 mm). 93.75% of the patients (45 patients) were very satisfied or satisfied with the operation. 6.25% rated the operation as fair (3 patients) and no patient was unsatisfied. Except of the removal of osteosynthesis material in 4.16% (2 patients) no reoperations were necessary.

Complications: We recorded no cases of transfer metatarsalgia or recurrent hallux valgus. Other complications were swellings in almost 100%, delayed wound healing in 2 cases (4.16%) with help of antibiotics. There were no cases of malunion, no deep infection. We had to remove the osteosynthesis material (one screw or all screws and the plate) in 2 cases (4.16%) due patient psychological discomfort with foreign material in the bone.


**Figure 11:** Patient Nr 2. Preoperative x-ray. IM angle 15°.


**Figure 12:** Patient Nr. 2 oblique x-ray.


**Figure 13:** Patient Nr. 2 side view.


**Figure 14:** Patient Nr. 2. Postoperative reduction of the IM angle to 6°.


**Figure 15:** Patient Nr.2. Postoperative oblique view.


**Figure 16:** Patient Nr. 2. Postoperative side view.


**Figure 17:** Patient Nr. 2. Result after 65 months. The IM angle remains 6°.


**Figure 18:** Patient Nr. 2. Oblique view after 65 months.


**Figure 19:** Patient Nr. 2. Side view after 65 months.

**Figure 20:** Patient Nr. 2. Preoperative view and postoperative view of the right foot after 65 months.


**Figure 21:** Patient Nr. 3. Preoperative X-ray.


**Figure 22:** Oblique view, Patient Nr. 3.


**Figure 23:** Patient Nr. 3. Side view of both feet.


**Figure 24:** Patient Nr. 3. Postoperative x-ray of both feet.

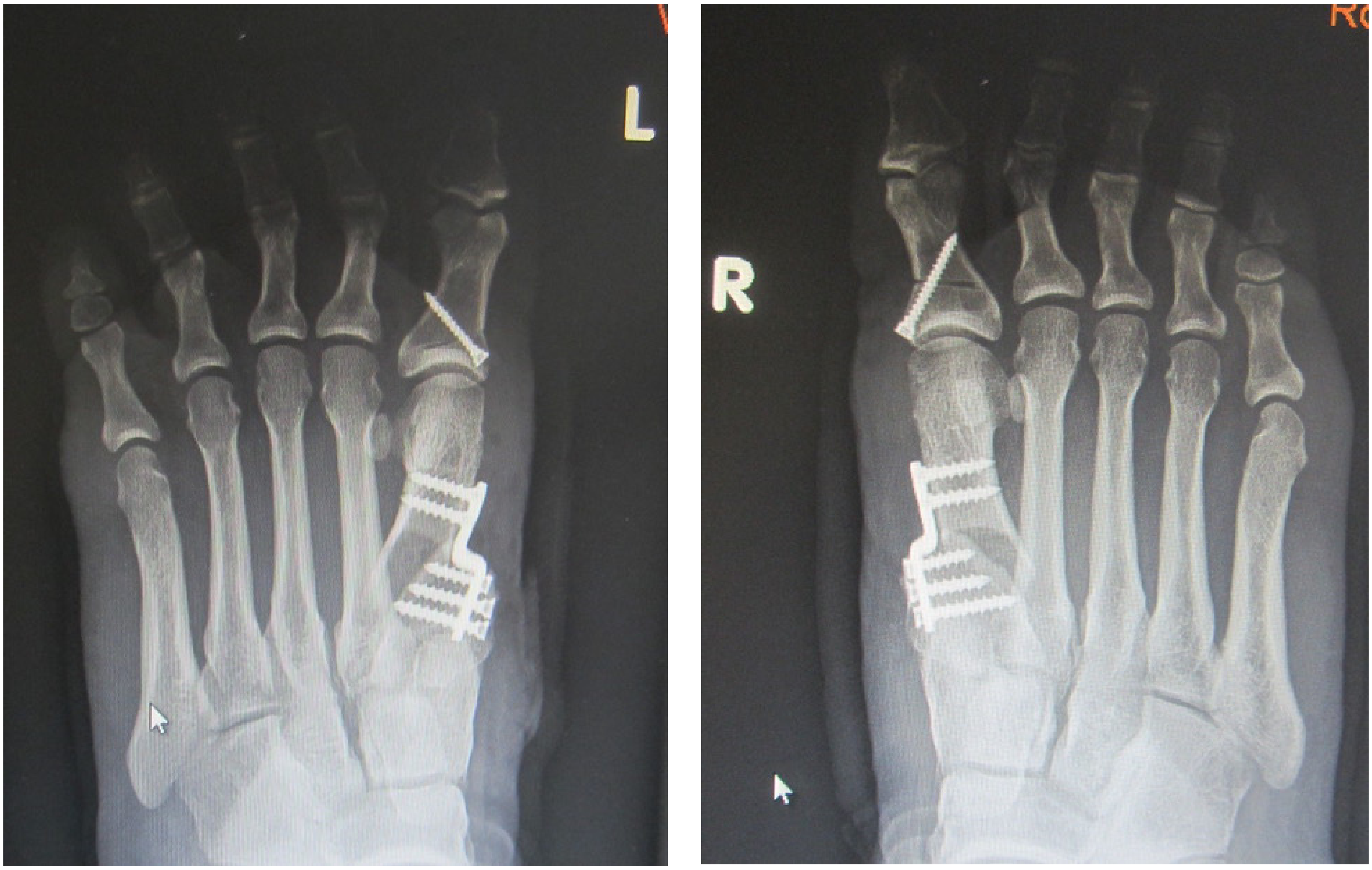


**Figure 25:** Patient Nr.3. Postoperative oblique view.


**Figure 26:** Patient Nr.3. Postoperative side view.


**Figure 27:** Patient Nr.3. Postoperative x-ray of both feet after 70 month


**Figure 28:** Patient Nr.3. Postoperative oblique x-ray of both feet after 70 months.

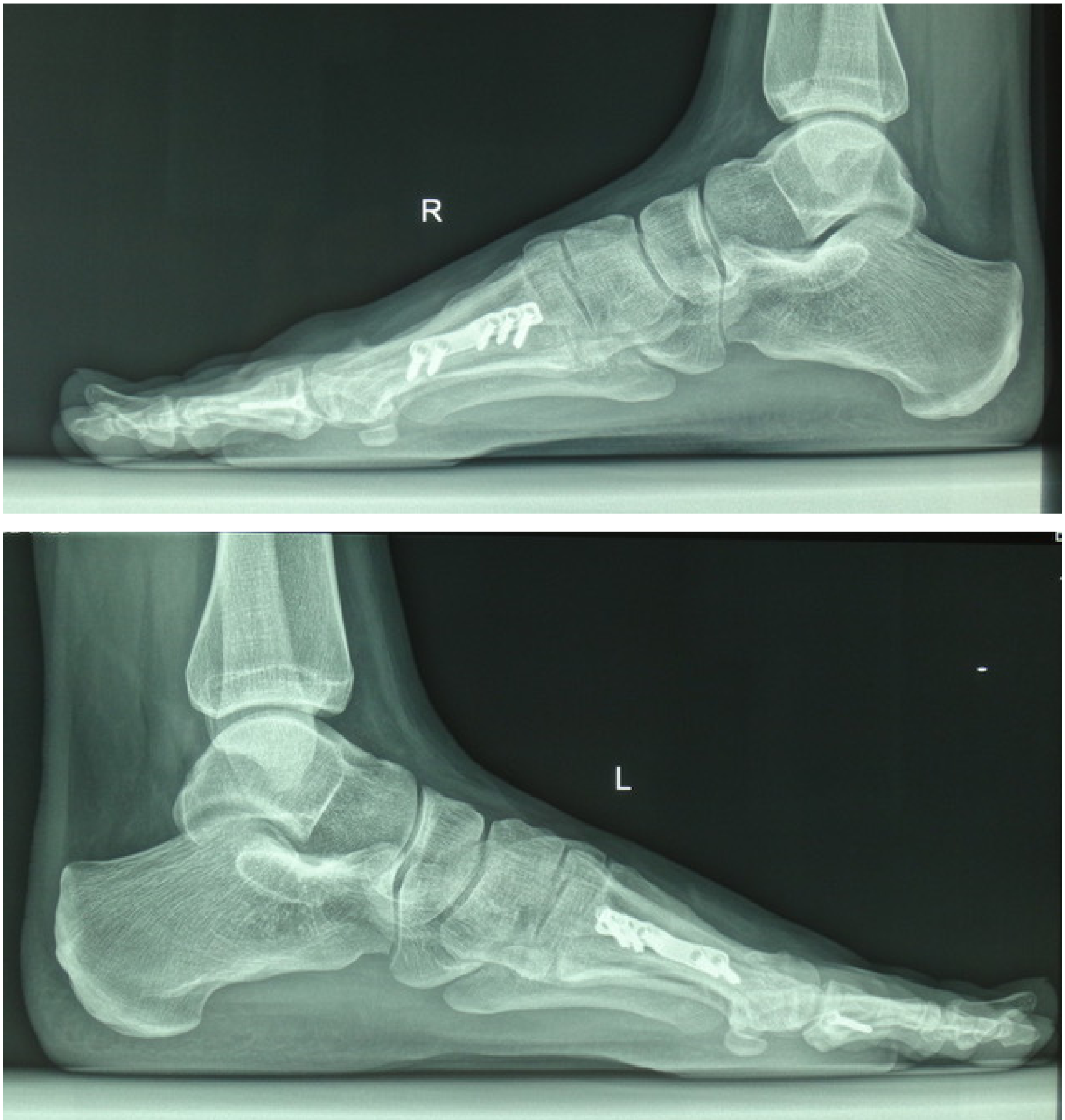


**Figure 29:** Patient Nr.3. Postoperative side view x-ray of both feet after 70 months.

**Figure 30:** Patient Nr.3. Preoperative and postoperative view of both feet.

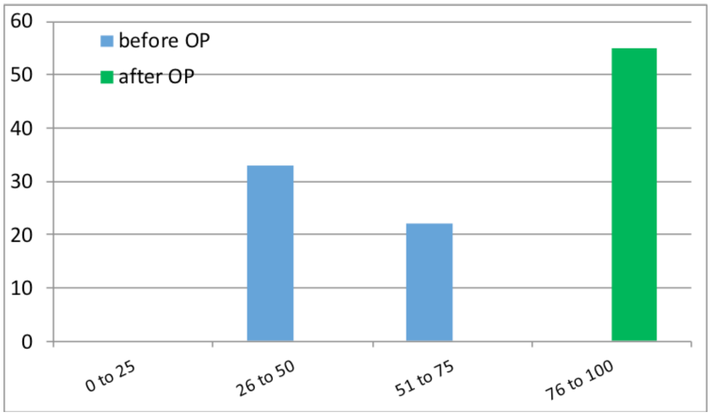


**Figure 31:** AOFAS before and after OP.

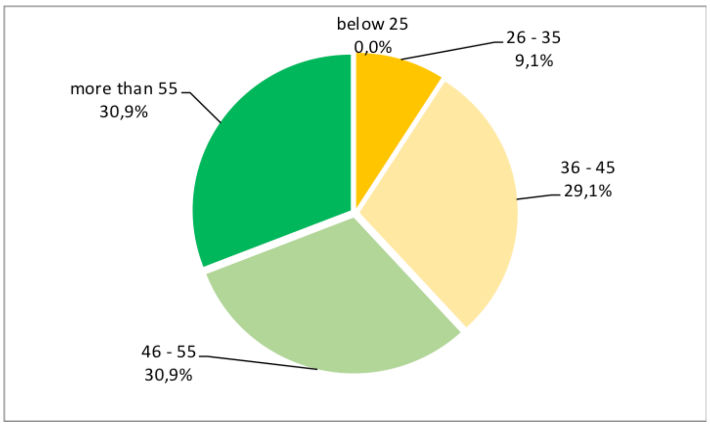


**Figure 32:** AOFAS – difference before and after OP.

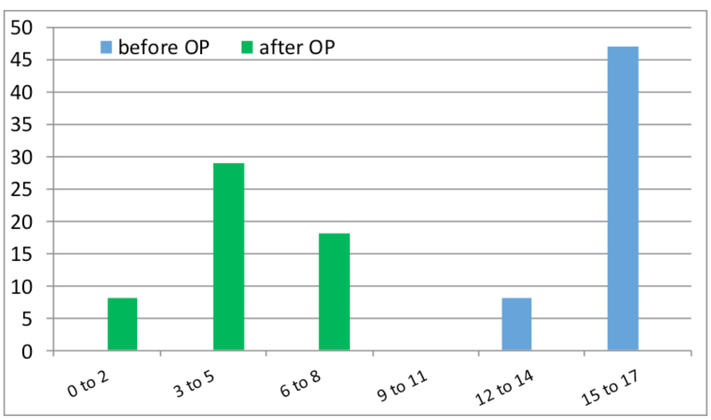


**Figure 33:** IM angles before and after OP.

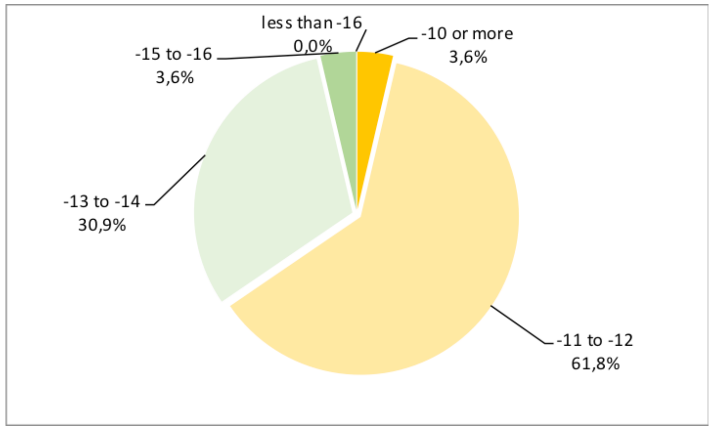


**Figure 34:** IM angle - difference before and after OP.

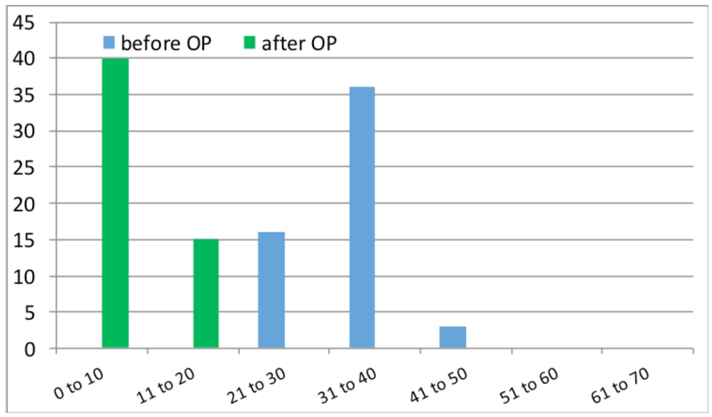


**Figure 35:** HV angles before and after OP.

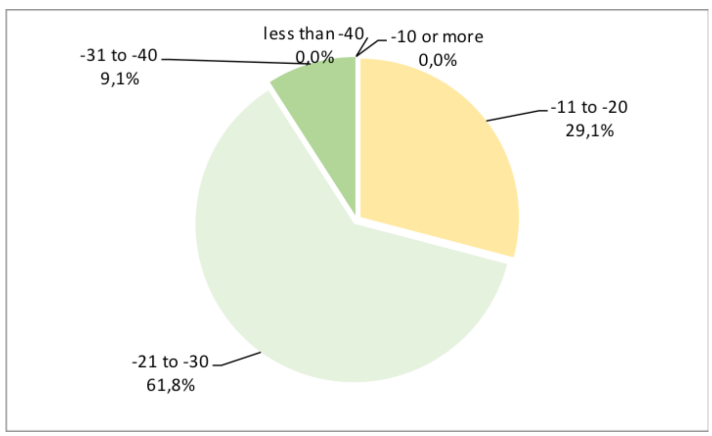


**Figure 36:** HV angle – difference before and after OP.

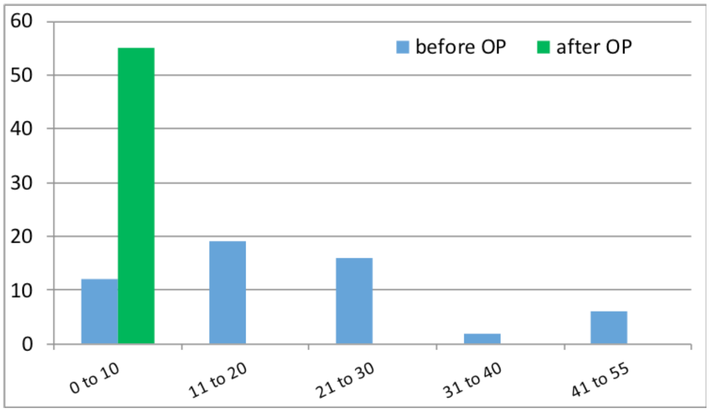


**Figure 37:** Pronation-angles before and after OP.

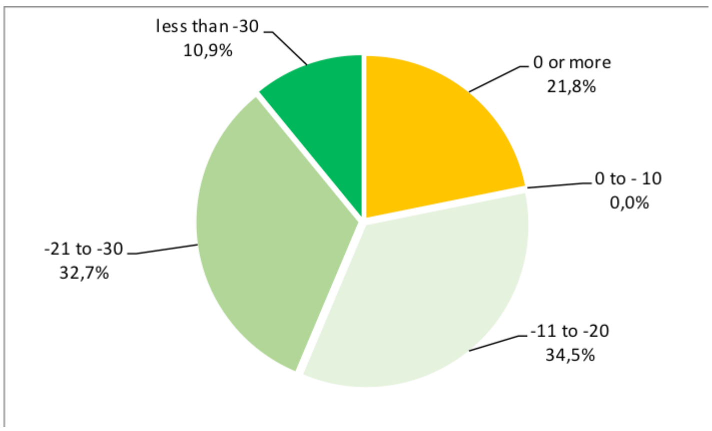


**Figure 38:** Pronation angles- difference before and after OP.

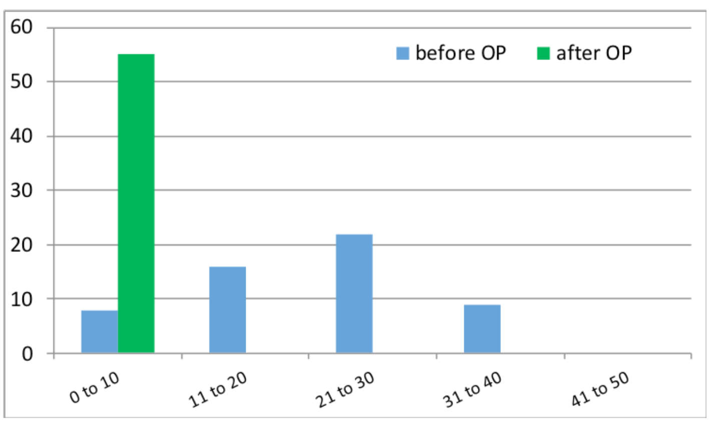


**Figure 39:** DMAA before and after OP.

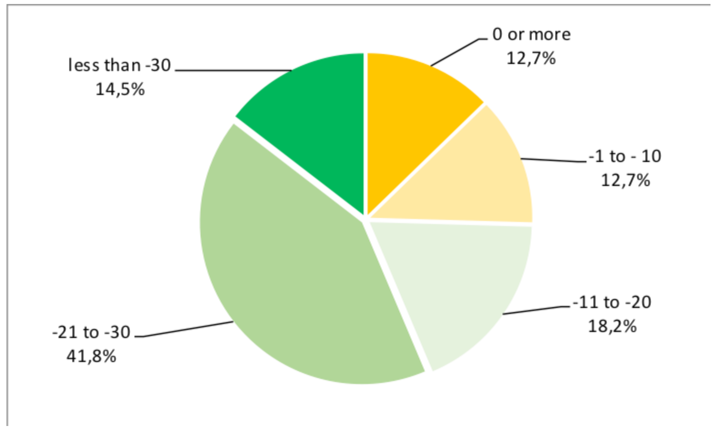


**Figure 40:** DMAA - difference before and after OP.

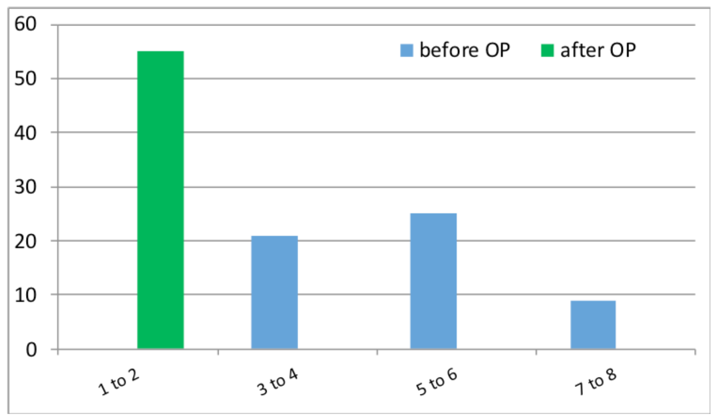


**Figure 41:** Sesamoid-Positions before and after OP.

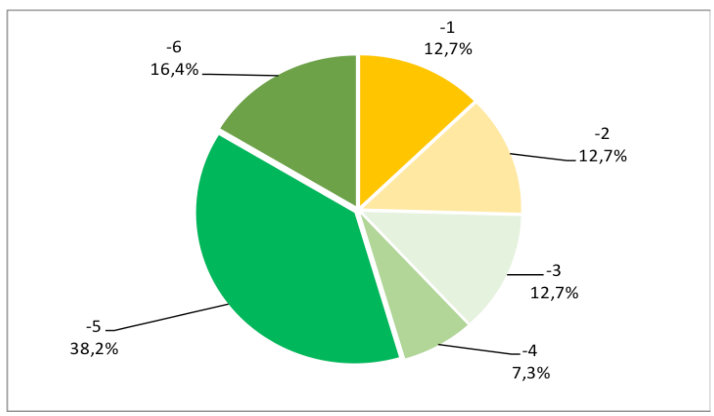


**Figure 42:** Sesamoid-Positions difference before and after OP.

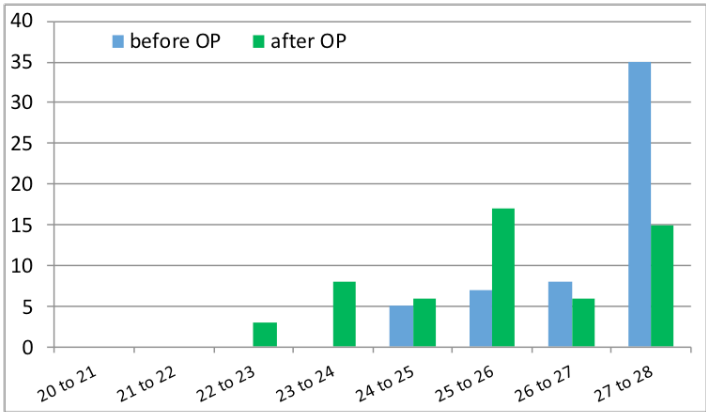


**Figure 43:** Circumference before and after OP.

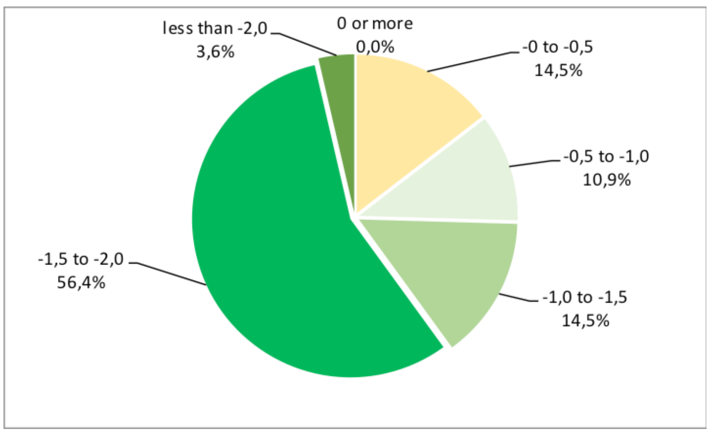


**Figure 44:** Circumference - difference before and after OP.

| | Date | | | | | |
|---|---|---|---|---|---|---|
| | before OP (n=55) | | after OP (n=55) | | Difference | |
| Variable | mean | s.d. | mean | s.d. | mean | s.d. |
| AOFAS | 48,15 | 10,78 | 98,36 | 2,37 | 50,22 | 9,42 |

**Table 1:** AOFAS before and after OP.

| | Date | | | | | |
|---|---|---|---|---|---|---|
| | before OP (n=55) | | after OP (n=55) | | Difference | |
| Variable | mean | s.d. | mean | s.d. | mean | s.d. |
| IM | 17,15 | 1,94 | 4,60 | 1,59 | 12,55 | 1,24 |

**Table 2:** IM angles before and after OP.

| | Date | | | | | |
|---|---|---|---|---|---|---|
| | before OP (n=55) | | after OP (n=55) | | Difference | |
| Variable | mean | s.d. | mean | s.d. | mean | s.d. |
| HV | 33,15 | 3,99 | 9,13 | 2,43 | 24,02 | 4,62 |

**Table 3:** HV angle - difference before and after OP.

| | Date | | | | | |
|---|---|---|---|---|---|---|
| | before OP (n=55) | | after OP (n=55) | | Difference | |
| Variable | mean | s.d. | mean | s.d. | mean | s.d. |
| Pron | 21,67 | 15,29 | 1,47 | 2,63 | 20,20 | 13,57 |

**Table 4:** Pronation angles before and after OP.

| | Date | | | | | |
|---|---|---|---|---|---|---|
| | before OP (n=55) | | after OP (n=55) | | Difference | |
| Variable | mean | s.d. | mean | s.d. | mean | s.d. |
| DMAA | 21,65 | 10,44 | 4,09 | 3,32 | 17,56 | 10,64 |

**Table 5:** DMAA before and after OP.

| | Date | | | | | |
|---|---|---|---|---|---|---|
| | before OP (n=55) | | after OP (n=55) | | Difference | |
| Variable | mean | s.d. | mean | s.d. | mean | s.d. |
| SESAM | 5,07 | 1,49 | 1,13 | 0,34 | 3,95 | 1,69 |

**Table 6:** Sesamoid-Positions before and after OP.

| | Date | | | | | |
|---|---|---|---|---|---|---|
| | before OP (n=55) | | after OP (n=55) | | Difference | |
| **Variable** | mean | s.d. | mean | s.d. | mean | s.d. |
| CIRC | 27,01 | 1,19 | 25,62 | 1,44 | 1,39 | 0,51 |

**Table 7:** Circumferences before and after OP.

## Discussion

The shaft/base osteotomy fixed with a very stable intramedullary angel-stable locked plate is able to correct all parameters which lead to a moderate to severe hallux valgus. Our goal was only to achieve a good reposition of all particular deformities despite of good bone contact between the osteotomy partners. We did not try to achieve bone compression to avoid shortening. Bone healing occurred in all cases, we did not observe any nonunion of the osteotomies, even in cases of poor contact of the osteotomized bone partners and even if a gap of some Millimeters resulted. The intramedullary plates are very rigid titanium implants and we could mobilize all patients the same day after the operation. Even the bilaterally operated patients loaded their feet with full weight-bearing in a so-called medic ballerina elastic comfort shoe. Bone healing occurred usually within eight weeks. There was no changing of angles or hardware position between the postoperative and the follow up x-rays. As the study demonstrates all desired parameters of a moderate to severe hallux valgus could be normalized or improved statistically significant. These parameters are: IM angle, HV angle, DMAA, Sesamoid position, pronation malrotation, circumference of the foot, elevation of the I$^{st}$ metatarsal. We noticed a minimum shortening of the I$^{st}$ MPJ. 93.75% of the patients were very satisfied or satisfied with the result of the operation.

Ethical Clearance: The authors declare no conflict of interests. The informed consent was obtained from all patients before the operation.

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