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⟨ Clinical Research ⟩

Percutaneous Distal Soft Tissue Release–Akin Procedure, Clinical and Podobarometric Assessment With the BioFoot In-Shoe System:

A Preliminary Report

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Abstract: *Hallux valgus (HV) is a common, complex, and progressive deformity of the first ray, leading to biomechanical changes. The purpose of this study is to describe the midterm outcomes of the percutaneous distal soft tissue release–Akin procedure for mild hallux valgus on plantar pressures distribution, clinical outcome, and radiographic parameters. Twenty-six patients (30 feet) who had undergone this procedure were evaluated prospectively. The BioFoot in-shoe system was used for an objective functional evaluation of dynamic plantar pressures in the heel, midfoot, first through fifth metatarsal heads, hallux, and lesser toes. The clinical outcome measurements included preoperative and postoperative American Orthopaedic Foot and Ankle Society (AOFAS) score. The radiological parameters measured were hallux abductus angle (HAA) and first intermetatarsal angle in weight-bearing radiographs. The average follow-up was 12.1 months. There were improvements in the AOFAS rating scale score from 68.7 to 88.1, in HAA from 25.4° to 11.4°, and in the first intermetatarsal angle from 12.0° to 9.2°. The pedobarographic analysis showed a statistically significant decrease (*P < .001*) in the maximum peak pressure (from 1037 to 498 kPa) and mean pressure (from 487 to 159 kPa) under the hallux. The percutaneous distal soft tissue release–Akin procedure improved the patients' clinical status and reduced the plantar pressures beneath the hallux. This improvement could be attributable to the removal of the medial eminence, which avoids pain around the first metatarsophalangeal joint, and to the Akin procedure, which provides a more physiological postoperative position of the hallux.*

Keywords: hallux valgus; plantar pressure; percutaneous surgery; distal soft tissue release; Akin; BioFoot; in-shoe system

Hallux valgus (HV) is a common, complex, and progressive deformity of the first ray. Anatomically, the main features are a medial eminence and increased hallux abductus angle (HAA) due to contracted soft tissue structures on the lateral side of the first metatarsophalangeal joint (1st MTPJ).[1,2] Secondarily, there is medial deviation of the first metatarsal, which increases the first intermetatarsal angle (1st IMA).[3,4] These anatomical alterations lead to relevant biomechanical changes, which mainly concern the propulsive period of gait.[5] Surgical treatment of HV must obtain the functional restoration of the deformity and biomechanics of the first ray. The distal soft tissue release (DSTR) is the basis of HV correction,[6] including tenotomy of

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the adductor hallucis tendon and lateral capsule release. To correct pathological HAA, the Akin osteotomy is needed. This combination of procedures is effective in correcting mild HV[6-8] and could be performed by percutaneous surgery with optimal results.[9-12] One of the advantages of percutaneous surgery is that can be performed without directly exposing the surgical planes. There is hence a minimal degree of trauma to neighboring tissues.[12] Recovery times are considerably shortened, hypertrophic scars deriving from extensive surgical wounds are avoided, and the technique has a great acceptance by offering good esthetic results.

The usual preoperative and postoperative studies on the treatment and correction of HV deformity are based on subjective variables, clinical function, and radiographic measurements.[13] The development of in-shoe pressure measurements has now made it possible to assess dynamic plantar pressures preoperatively and postoperatively.[14,15] Such measurements constitute objective parameters to assess the functional outcome of the procedure.

Since HV is progressive, a mild deformity has a different pressure pattern than moderate or severe deformity.[16] In the beginning of the deformity, the lateral deviation of the hallux will alter the propulsive period of gait, preventing a correct takeoff for the distal zone. This phenomenon provokes an increase of our pressures under the hallux.[17] Since the DSTR-Akin procedure restores the alignment of the hallux, it could be expected that pathological plantar pressures are reduced. However, to the best of our knowledge, we are not aware of any study assessing the effect of this DSTR-Akin procedure on plantar pressures in either open or percutaneous surgery. Thus, the aim of the present study is to describe the effects of the percutaneous DSTR-Akin procedure on plantar pressure distribution, clinical outcome, and radiographic parameters measured at a minimum of 12 months postoperatively.

Methods

Study Participants

Patients with a diagnosis of mild HV deformity who had undergone a percutaneous DSTR-Akin procedure were studied prospectively. With the approval of the Human Research Committee of the University (Id:102), written consent was obtained from all participating patients after a verbal and written explanation of the project. Anthropometric data of weight and height were recorded prior to data collection. The criteria for inclusion were (1) pain over the medial eminence while wearing a shoe, (2) mild hallux abducto valgus of 15° < HAA ≤ 30°, (3) 1st IMA ≤ 13°, (4) positional deformity, (5) no evidence of osteoarthritis, (6) metatarsus adductus measurements in the reference range (<14°), (7) all data and preoperative and postoperative radiographs available, and (8) patient available for a minimum follow-up of 12 months. A total of 26 patients (30 feet, 16 right and 14 left) met these inclusion criteria for participation in the study. All patients were women.

> “. . . the percutaneous DSTR-Akin procedure improves the patient’s clinical status and decreases the plantar pressure beneath the hallux.”

Clinical and X-ray Examination

Each patient was screened by interview and physical examination with respect to the specifics of pain location and duration, footwear, alignment, and associated keratosis. First ray functions were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) hallux-metatarsophalangeal interphalangeal scale.[18,19] Weight-bearing anteroposterior and lateral x-rays were taken using a standardized technique. Measurements were made on the radiographs of the 1st IMA and HAA. The angles were measured using AutoCAD 2004 (Autodesk Inc, San Rafael, Calif) software. The angles were determined as the lines drawn from the center of the first and second metatarsal shafts (1st IMA) and the center of the first metatarsal and proximal phalanx shafts (HAA).[20] Other researchers[21,22] have proved such angle determinations to be a reliable technique.

Plantar Pressure Equipment

Plantar pressures were measured using the BioFoot (IBV, Valencia, Spain) in-shoe system.[23-26] The system is composed of a pair of thin (0.7 mm), flexible, polyester insoles each with 64 piezoelectric sensors of 0.5-mm thickness and 5-mm diameter (Figure 1). The sensors are distributed in accordance to foot physiology in such a way that there is a greater density of sensors under bony areas where pressures tend to be high, especially under the forefoot. The insoles are available in different sizes, allowing a good match to the shoe interface. The insoles are connected to an amplifier, which in turn is connected to a transmission module attached to the patient’s waist (Figure 1). Data are sent by digital telemetry from the amplifier to a computer. Data are then processed by software that shows the pressure, contact time, and cadence parameters. The system has a range of 200 m, which allows the patients to walk without restrictions. Sampling rates are between 50 and 250 Hz. The BioFoot system is reliable, with low variations (about 5%) between trials and sessions.[24] The insoles were calibrated weekly during the study period following the manufacturer’s instructions.

Procedure

To avoid differences in personal footwear, all participants used the appropriate size of the same brand of shoes (Medical Shoes Zale, Alicante, Spain) during the data collection process. The shoes had a wide toe box, Velcro adjustment at the top, and a heel height of 2.5 cm, providing good stability of the foot. Measurements were taken in a 40-m-long corridor, allowing patients to walk at their own speed while maintaining a constant gait rhythm. The pressure insoles were placed at the shoe-foot interface, and the system's connections were attached to the legs and waist. Patients familiarized themselves with the testing procedure by walking at their own normal pace for 3 to 4 minutes. The software program was then initiated, and the insoles and amplifier were reset under a non-weight-bearing condition. Data were logged in one 8-second trial at a sampling rate of 100 Hz, which is optimal for walking measurements.[27] The trial began when the patients were in the middle of the corridor and had reached a selected cadence (90-110 steps/min), avoiding the beginning and end of the walk. This range of cadence has shown low variability of plantar pressure values.[24,28]

To increase the reliability of our measurements, 3 trials were performed for each patient preoperatively and postoperatively.[29] Each measurement was verified by means of an adjustment to superpose the pressure plots of all the sensors and hence allow any errors to be detected. If the plots were correct, a new trial was begun. A total of 10 to 15 steps of each foot were logged, which is sufficient to provide a high coefficient of reliability for plantar pressures.[29,30]

The clinical examination, radiological measurements, and plantar pressure assessment were performed by the first author.

Figure 1.

(A) Insole with 64 piezoelectric sensors. (B) BioFoot in-shoe system.

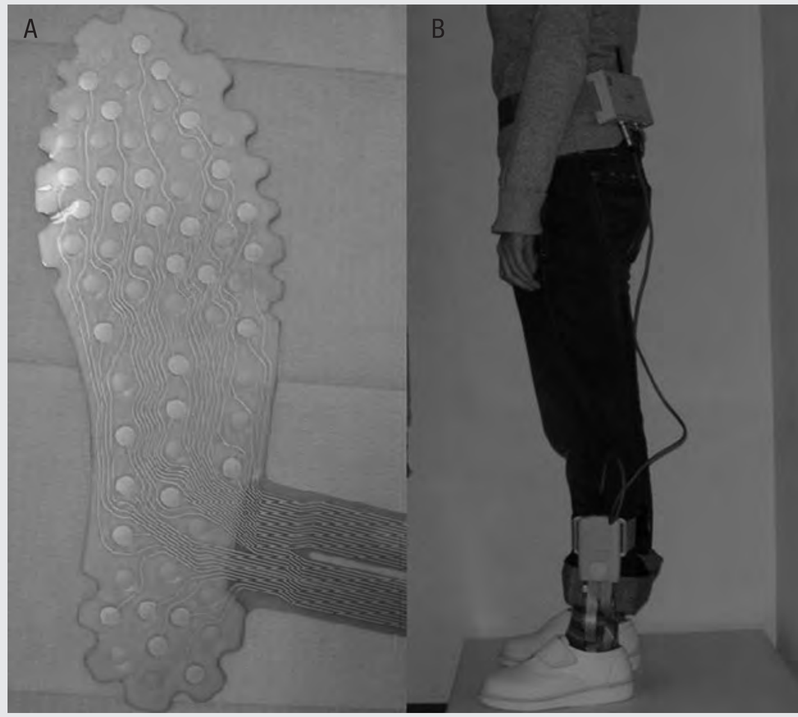
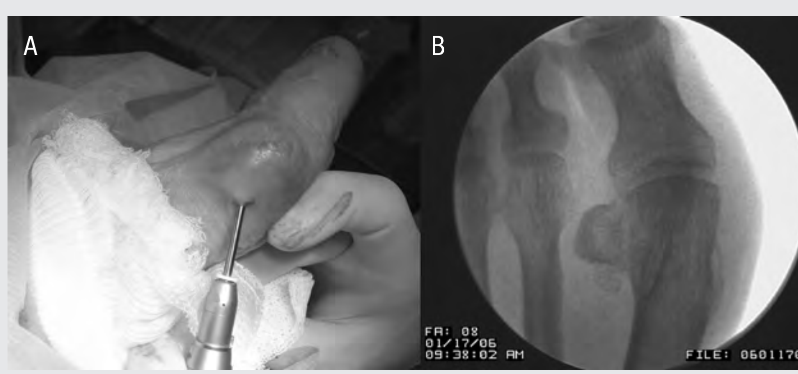


Figure 2.

(A) Removal of the medial eminence. (B) Fluoroscopic view.



Surgical Technique

The complete technique performed to correct the deformity consisted of removal of the medial eminence, tenotomy of the adductor hallucis tendon, lateral capsule release, and Akin osteotomy. All operations were performed at CLINICA ALEJO-LEAL from January to October 2006 by the same surgeon (third author, Alejo Leal-Muro) with patients under ankle block anesthesia and without hemostasis. A surgical fluoroscope (FM Control Inc, Vitoria, Spain) for intraoperative image intensification was used to monitor the procedures. A Beaver 64 MIS blade was used to approach the 1st MTPJ through a 3-mm incision in the plantar-medial side of the metatarsal head, and the joint capsule was dissected using a Freer elevator. The medial eminence was removed using a rotatory wedge burr 4.1 by means of proximal-to-distal movements (Figure 2A) under fluoroscopic view (Figure 2B). Following Piqué-Vidal,[31] the exostectomy was carried out at a maximum 5000 rpm at 20-second intervals to minimize the elevation of temperature of the bone. Through a second incision at the distal first metatarsal space, the adductor hallucis tendon was identified and released from the lateral sesamoid and the base of the proximal phalanx. To aid the release, a rotation movement of the hallux was performed (Figure 3). Through that same incision, a lateral MTPJ capsulotomy

Figure 3.

(A) Detachment of the adductor hallucis tendon. (B) Fluoroscocpic view.

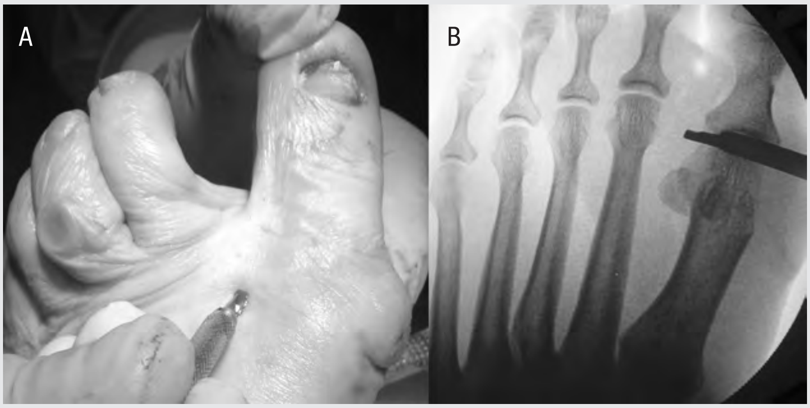


Figure 4.

(A) Akin osteotomy. (B) Fluoroscopic view. Lateral cortex intact remains intact.

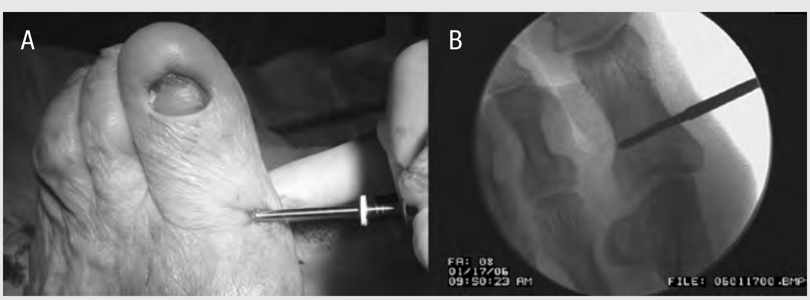


Figure 5.

(A) Postoperative alignment. (B) Abductor bandaging and osteotomy stabilizer.

was also performed. The Akin procedure was performed through a third incision (Beaver 64 MIS blade) on the medial aspect of the base of the proximal phalanx of the hallux. Using a long Isham Shannon burr, an osteotomy was performed from dorsal to plantar cortex, parallel to the base of the phalanx (Figure 4A). Under fluoroscopic observation, the lateral cortex at the base was left intact (Figure 4B). The results of the osteotomy and the metatarsophalangeal alignment were confirmed (Figure 5A). The 3 incisions were closed with a silk 0000 suture. No internal fixation was made for the Akin procedure. An abductor and stabilizer bandage were applied to compress the osteotomy (Figure 5B). Walking was permitted with a postoperative shoe. Bandages were renewed every 4 days until 4 weeks after surgery.

The final clinical, baropodometric, and x-ray examination was done at a mean of 12.1 months (range, 12-13 months).

Data Collection and Statistical Analysis

To analyze the pressure distribution, the foot was divided by the software into 9 areas corresponding to heel, midfoot, first through fifth metatarsal heads, hallux, and lesser toes (second to fifth). The following variables were calculated for each patient (1) whole foot contact time, (2) cadence, (3) peak pressure (PP; the greatest pressure measured), and (4) mean pressure (MP; the mean of all the sensors at that location). PP and MP were calculated at each location for each step. To assess the intrarater reliability of the pressure variable measurements, intraclass correlation coefficients (ICCs) were calculated from the 3 trials of each patient preoperatively and postoperatively. The ICC values found were 0.81 and 0.82 for the preoperative and postoperative peak pressures, respectively. For the mean pressures, the ICC values were 0.90 and 0.91. These results indicated good to excellent reliability between trials, so that the 3 trials were used to assess the maximum peak and mean pressures. All the variables were then averaged over the 10 to 15 steps logged for that patient.

Table 1.

Results of the American Orthopaedic Foot and Ankle Society (AOFAS) Scores

	Preoperative	Postoperative
Range of AOFAS scores	42 – 85	72 – 97
Mean ± SD AOFAS score	68.7 ± 11.9	88.1 ± 7.8
Pain		
No pain	0	24
Mild	25	6
Moderate	5	0
Activity		
No limit	8	24
Recreational	21	6
Daily	1	0
Shoes		
Any shoe	12	23
Comfort	18	7
Total 1st MTPJ		
>75°	19	23
30°–74°	11	7
<30°	0	0
Hallux IPJ motion		
No restriction	25	28
Restriction	5	2
Hallux MTPJ + IPJ stability		
Stable	23	25
Unstable	7	5
Callus (MTPJ, IPJ)		
No	2	25
Symptomatic		
MTPJ	8	2
IPJ	20	3
Hallux alignment		
Good	9	27
Fair	21	3

Abbreviations: IPJ, interphalangeal joint; MTPJ, metatarsophalangeal joint.

The pressures variables are expressed in kPa (1 Pa = 1/98 kg/cm^2). Every operated foot was treated as a single patient. Using means and standard deviations for all 30 feet, a paired Student *t* test was used to compare the clinical and radiological parameters and the pressures underneath each area before and after surgery. The level of significance was assumed as $P \leq .05$. To identify the significance of plantar pressures to the clinical outcome and radiological measurements, correlation tests were performed between the pressure variables with AOFAS scores, 1st IMA, and HAA by means of the Pearson correlation tests.

Results

The mean age of the patients was 50.3 (range, 36-72) years, their mean height was 162 (range, 155-187) cm, and their mean weight was 68 (range, 52-89) kg. The average follow-up was 12.1 months. The mean time from surgery to surgical discharge was 29.8 days (range, 24-36 days). Any complications arising—such as infections and hematomas—were resolved by physical treatment and medication. Final follow-up showed no failed procedures, hallux varus, or dorsiflexion of the hallux.

The average preoperative AOFAS hallux metatarsophalangeal-interphalangeal score was 68.7 (range, 42-85) and improved significantly ($P = .001$) to 88.1 (range, 72-97) at final follow-up (Table 1). Twenty-four of the 30 feet were completely pain free, and 6 were reported to have mild or occasional pain in the hallux or metatarsal head in some recreational activities but not in daily life. This discomfort was described as located over the first metatarsal head, not concerning at gait. Twenty feet showed preoperatively painful callus beneath the hallux. Only 3 feet showed postoperatively callus under this zone, although they were asymptomatic (Table 1).

Preoperative and postoperative radiological results are presented in Table 2. The HAA improved from 25.4° ± 3.9° preoperatively to 11.4° ± 2.8° postoperatively. This change was found to be statistically significant ($P = .001$). The 1st IMA showed a significantly ($P = .003$) correction from 12.0° preoperatively to 9.2° postoperatively.

Preoperative contact time was 0.83 (±0.9) seconds, and postoperative time was 0.85 (±0.9) seconds; preoperative cadence was 99 steps per minute, and postoperative cadence was 101 steps per

Table 2.

Preoperative and Postoperative Radiological Parameters

	Preoperative	Postoperative	Significance
IMA, range, °	11.4 – 12.7	8.1 – 10.7	
IMA, mean ± SD, °	12.0 ± 0.3	9.2 ± 0.6	.003
HAA, range, °	16.5 – 29.9	5.2 – 17.1	
HAA, mean ± SD, °	25.4 ± 3.9	11.4 ± 2.8	.001

Abbreviations: HAA, hallux abductus angle; IMA, intermetatarsal angle.

minute, with no significant differences in either of these parameters (P = .891). In the pressure variables (Figure 6, Table 3), the raised peak, 1037 kPa, and mean, 487 kPa, pressures in the hallux decreased significantly (P < .001) to 498 kPa and 159 kPa, respectively, postoperatively. No significant changes were found for the rest of the areas, but a slight increase in pressures was found beneath the fourth and fifth metatarsal heads. The only significant correlations were (1) a negative correlation between postoperative AOFAS score and both peak pressure (r = –0.662, P = .012) and mean pressure (r = –0.517, P = .027) underneath the hallux and (2) a positive correlation between HAA and peak pressure (PRE: r = 0.465, P = .001; POST: r = 0.711, P = .003) and mean pressure (PRE: r = 0.512, P = .002; POST: r = 0.603, P = .004) underneath the hallux.

Discussion

In the present study, the highest presurgery peak and mean pressures were beneath the hallux. After 1 year postsurgery, there was a significant reduction in the pressures beneath the hallux but no changes in the pressures under the rest of the foot. These results are consistent with the literature in mild or mild-to-moderate HV.[15,32-35]

Saro et al[15] used the Pedar in-shoe system to compare changes in plantar pressure between chevron and Lindgren osteotomies. They found that neither technique significantly improved plantar pressures, but the pressure beneath the hallux decreased significantly in both groups. Bryant et al[32] evaluated the Austin (chevron) technique for mild and mild-moderate HV. In this type of foot, they found increased pressures beneath the hallux, which had normalized at 24 months postsurgery, although the pressures under the first, second, and third heads remained relatively unchanged. Surgery had returned the radiographic values to normal. Kernozek and Sterriker[33] also evaluated the chevron osteotomy. The raised plantar pressures beneath the central forefoot continued to be altered 12 months postsurgery, although some pressure parameters were reduced in the region of the hallux. Dhukaran et al[34] also found that Mitchell osteotomy reduced the pressure beneath the hallux but increased it beneath the second and third metatarsal heads. In the present study, some increased values (although not significant) in the PP and MP were noted at the fourth and fifth metatarsal heads. The results of the present study agree with those of Mittal et al,[35] who evaluated the McBride technique. They found that after surgery there was a significant reduction in the peak pressure beneath the hallux together with an increased contact area in that zone. It seems that the type of procedure influences the postoperative loading pattern. Thus, distal procedures or osteotomies decrease plantar pressures at the hallux.[15,32,33]

The present results showed a reduction in the pressures beneath the hallux. Thus, these postoperative values are close to the normal established values.[24] The explanation for this improvement is as follows. In the pathological mechanics of HV, the hallux is laterally deviated, and the valgus deviation modifies muscle functions, converting the abductor into solely a plantar flexor. There is a resulting mechanical inequality with the advantage on the side of the adductor, while flexors and extensors help to fix the deformity. Since the hallux is deviated laterally, it will cause liftoff to occur not correctly from the tip of the toe but from the mid part of the interphalangeal joint. We believe that these conditions produce the increased pressure beneath the hallux that is observed in the preoperative measurements, since on the AOFAS scale, 20 of the 30 feet presented a painful pinch callous at the interphalangeal joint and 17 disappeared postoperatively. The postsurgery decline of pressure beneath the hallux may be related to improved muscle-tendon balance, which, after the tenotomy of the adductor tendon and the relaxation of the lateral capsule, distends the soft tissues to allow a better positioning of the metatarsophalangeal joint. The Akin osteotomy normalizes the position of the hallux, aligning it with respect to the first metatarsal, allowing normal liftoff from the zone of the tip of the toe and reducing plantar pressure under the hallux.

The positive correlation between postoperative HAA and pressure variables (peak, r = 0.711; mean, r = 0.603) shows that a decrease in the HAA due to Akin

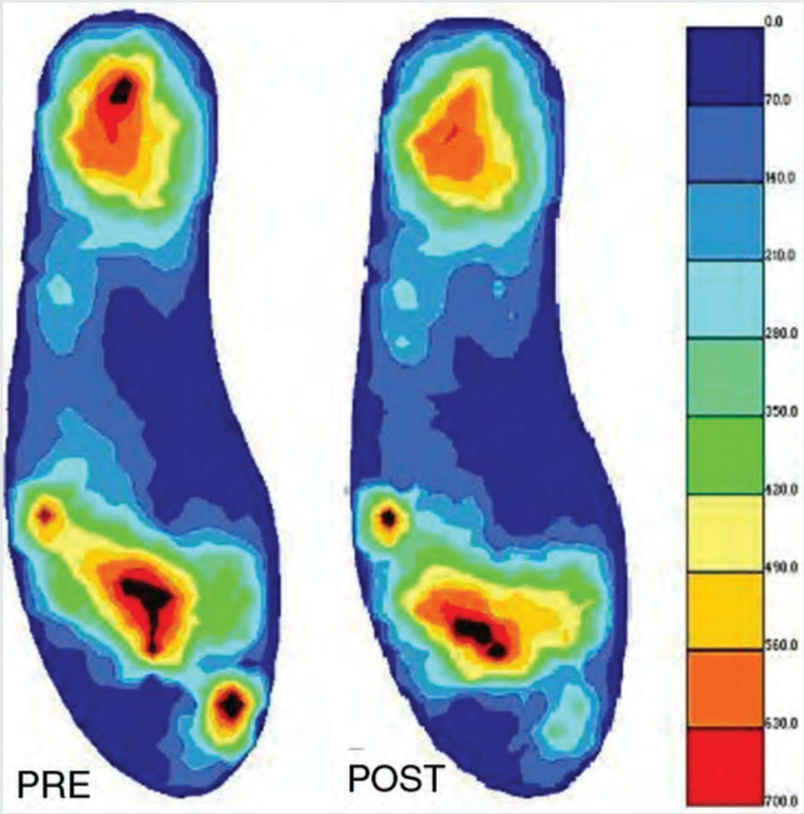
Table 3.

Pressure Variables and Their Significance

	Peak Pressure				Mean Pressure			
Area	Preoperative	Postoperative	SD	Significance (*P*)	Preoperative	Postoperative	SD	Significance (*P*)
Heel	632 ± 184	642 ± 219	268.6	.852	265 ± 115	269 ± 123	149.6	.751
Midfoot	277 ± 150	310 ± 128	181.1	.371	55 ± 42	63 ± 49	42.5	.232
First metatarsal head	654 ± 369	638 ± 356	520.6	.855	357 ± 223	343 ± 213	315.2	.846
Second metatarsal head	672 ± 333	598 ± 279	446.7	.389	422 ± 163	355 ± 161	310.5	.265
Third metatarsal head	566 ± 282	574 ± 253	370.8	.912	384 ± 149	367 ± 156	272.2	.730
Fourth metatarsal head	441 ± 269	463 ± 239	479.7	.266	258 ± 198	301 ± 171	256.8	.251
Fifth metatarsal head	246 ± 153	276 ± 141	110.1	.180	156 ± 123	174 ± 129	82.7	.255
Hallux	1037 ± 491	498 ± 233	610.4	.001	487 ± 101	159 ± 65	101.7	.001
Lesser toes	413 ± 228	497 ± 225	393.7	.271	102 ± 69	123 ± 67	97.1	.163

Figure 6.

Baropodometric outcome of the procedure.



osteotomy carries a decrease in peak and mean pressure under the hallux. Also, the negative correlation between the postoperative AOFAS score and peak (r = –0.662) and mean (r = –0.517) pressures in the hallux signifies that patients with adequate (less) pressure in the hallux have better clinical outcomes. No correlation was found between the pressure underneath the first metatarsal head and the AOFAS scores or pressure variables. Therefore, in this case series, the weight-bearing function of the first metatarsal head does not have any significance to the clinical outcome.

According to the literature we reviewed, it seems unlikely to find major changes in the values and distribution of plantar pressure after HAV surgery. Except for Dhukaran et al, who evaluated Scarf osteotomy,[34] there have been no reports of changes in plantar pressure in the rearfoot or midfoot. Postsurgery changes are localized, with increased or decreased pressures in zones near the osteotomies. Neither does the literature report any great changes for the forefoot or any redistribution of plantar pressures bringing the foot back closer to normality. In the present study, therefore, the improvement in clinical status seems to be directly related to the removal of the medial eminence, which avoids pain around the first MTPJ, and reduced pressure beneath the hallux.

Although Kadakia et al[36] found poor results in percutaneous distal metatarsal osteotomy, this case series did not encounter important complications such as hallux varus, insufficient bunionectomy, or transfer metatarsalgia. The percutaneous DSTR-Akin procedure gives acceptable results in the ranges of the 1st IMA and HAA explained in the inclusion criteria.

The present study has limitations, one of them being the small number of patients. Although the results presented here are preliminary, and further work is needed, we believe our conclusions are significant because of the consistent pressure reductions beneath the hallux. Future research will aim to study a far greater number of patients and hence increase the precision of the results and conclusions. By increasing the number of patients, we believe that further conclusions could be drawn to better define effective techniques that reduce pathological plantar pressures.

Conclusion

With the cases included in this present study, comparison of the preoperative and postoperative means of the angles shows that the surgical correction was adequate. The AOFAS score indicated good clinical improvement, and all the patients expressed satisfaction with the clinical outcome. This improvement could be related to the reduction of pressure beneath the hallux and the correction of the pathological HAA. We concluded that the percutaneous DSTR-Akin procedure improves the patient's clinical status and decreases the plantar pressure beneath the hallux. The results can be compared with those obtained with open techniques, with the advantages of a minimally invasive procedure. FAS

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