**Minimally Invasive and Open Distal Chevron Osteotomy compared at 2-year follow-up for the correction of Mild-Moderate Hallux Valgus.**

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**ABSTRACT**

**Background**. There is growing evidence supporting minimally invasive surgical (MIS) techniques for correction of symptomatic hallux valgus. The aim of this study is to compare the 2-year outcomes of a 3rd generation MIS distal chevron osteotomy with a comparable traditional open distal chevron osteotomy for mild-moderate hallux valgus.

**Methods.** This was a retrospective cohort study. 79 consecutive feet (49 MIS and 32 open distal chevron osteotomy) were followed up for a minimum 24 months (range 24-58). All patients were clinically assessed using the Manchester-Oxford Foot Questionnaire (MOXFQ). Radiographic measures included hallux valgus angle (HVA), the intermetatarsal angle (IMA), hallux interphalangeal angle (HIA), metatarsal phalangeal joint angle (MPJA), distal metatarsal articular angle (DMAA), tibial sesamoid position (TSP), shape of the first metatarsal head (MHS, and plantar offset (amount of plantar translation of metatarsal head following osteotomy).

**Results.** Clinicalpost-operative scores in all domains were substantially improved in both groups, but there was no statistically significant difference in improvement of any domain (including the combined score) between open and MIS groups. There were significant improvements in all radiological parameters pre and post operatively within each group but there were no differences between the two groups. There were no significant differences in complications between the two groups.

**Conclusion.** The mid-term results of this third generation technique show that it is a safe procedure with good clinical outcomes and comparable to traditional comparable open techniques for symptomatic mild-moderate hallux valgus.

**Keywords**. Hallux valgus, Bunion, Minimally invasive, MIS, Chevron

**Introduction**

Hallux valgus is a common condition with progressive abduction and pronation of the first phalanx, adduction, pronation and elevation of the first metatarsal, and lateral capsular retraction of the first metatarsophalangeal joint (MTPJ). Pain and discomfort are felt because of inflammation of the bursa overlying the medial eminence as well as irritation of the dorsal cutaneous nerve. There have been over 150 procedures described for the treatment of hallux valgus but as yet there is no consensus on the best method.

Distal metatarsal chevron osteotomy is a good option in mild-to-moderate hallux valgus providing good results in the correction of deformity and symptoms([1](#_ENREF_1)). In the last decade there has been a growing interest in the use of minimally invasive techniques for the treatment of this condition but a recent review article concluded that there was not enough evidence to favour minimally invasive surgery over traditional open techniques([2](#_ENREF_2), [3](#_ENREF_3)). This was largely owing to the fact that the majority of studies included in the reviews were case series without comparison or control groups. Indeed MIS forefoot surgery is the subject of much controversy at present in the literature([4](#_ENREF_4)).

Minimally invasive techniques are being adopted in all surgical specialties essentially because of the advantages of less surgical trauma and preserving the blood supply of the healing soft tissues. This has the theoretical advantages of decreasing recovery and rehabilitation times thereby reducing the morbidity associated with both the disease process and the operative intervention. However, it is important not to adopt new techniques simply because of perceived advantages without comparison to a well-established and proven technique.

The majority of the perceived advantages occur in the early post-operative phase as a result of less soft tissue trauma. However, in order to adopt a new surgical technique it is important to look at longer-term outcomes and compare these with established techniques. The aim of this study is to compare a combination technique MIS distal chevron osteotomy([5](#_ENREF_5)) with a cohort of patients who received a traditional open distal chevron osteotomy. The null hypothesis is that there will be no difference in both radiological and clinical outcomes at 2 years post-op.

**Materials and Methods**

In this retrospective comparison study two cohorts of consecutive patients were followed up for 2 years. 49 feet in the MIS group were followed-up for a mean of 31 months (range 26-39 months, SD 3.5). 32 feet in the open group were followed-up for a mean of 37 months (range 24-58 months, SD 11.8). There were no significant differences between the groups in terms of demographics or radiological and clinical severity (tables 1 and 2). Hallux valgus angle (HVA) was categorised as mild (15-20 degrees), moderate (21-39 degrees) and severe (≥40 degrees). Intermetatarsal angle (IMA) was categorised as mild (9-11 degrees), moderate (12-17 degrees) and severe (≥18 degrees). Table 1 summarises the radiological severity. In the MIS group 6 patients had a severe IMA and 7 had a severe HVA; 2 patients would be classed as severe on both parameters. In the open group 6 patients had a severe IMA and 4 had a severe HVA; but no patients would be classed as severe on both parameters.

Patients were excluded from the MIS group if they had any other foot procedures in order to concentrate on the MIS technique itself. In the open group, patients were excluded with other foot procedures, except for Akin procedures, which was deemed part of the correction of the hallux valgus. There were 12 (40%) Akin procedures performed in the open group and no Akin procedures in the MIS group.

The senior author performed all procedures. All patients were clinically assessed pre and post-operatively with the Manchester-Oxford Foot Questionnaire (MOXFQ). This scoring system was originally designed as an outcome measure following hallux valgus surgery and has been shown to be effective and comparable to AOFAS and SF-36([6-8](#_ENREF_6)). There are three domains: walking/standing score (W score) (7 items); pain score (P score) (5 item); and a social interaction score (SI score) (4 items). Response options consist of a 5-point Likert scale ranging from no limitation to maximal limitation. An individual score is used for each domain and converted into a metric score 0 to 100, where 100 is the most severe. The MOXFQ was designed to be interpreted as three separate scores although a combined score (similar to the AOFAS scoring system) has also been validated ([9](#_ENREF_9)).

Equal group sample sizes of 33 were calculated to provide 70% power to detect a clinically significant difference in improvement of MOXFQ index score of 20 points at the 0.05 significance level, based on previously published variance ([10](#_ENREF_10)).

Radiographic analysis was performed on standard weight-bearing anteroposterior (AP) and lateral radiographs by 2 different observers (KB, WS). Intra-observer reliability was measured on 10 cases (pre and post-op) and compared with the original measurements. Inter-observer reliability was measured on all cases within the study. Figure 1([11](#_ENREF_11)) illustrates the parameters measured included: hallux valgus angle (HVA), the intermetatarsal angle (IMA), hallux interphalangeal angle (HIA), metatarsal phalangeal joint angle (MPJA), distal metatarsal articular angle (DMAA), tibial sesamoid position (TSP), shape of the first metatarsal head (MHS, and plantar offset (amount of plantar translation of metatarsal head following osteotomy). All clinical and radiological complications were recorded.

**MIS technique**

The technique and early outcomes of our technique have already been published([5](#_ENREF_5)).

This technique can be seen to be a modification of the minimally invasive chevron and akin (MICA) technique described by Redfern and Vernois,([12](#_ENREF_12)) whilst also utilizing some parts of the original "Bosch" technique, which was one of the first MIS techniques used in bunion surgery to improve initial stability of the osteotomy.([13](#_ENREF_13), [14](#_ENREF_14)). The open technique is performed using a traditional technique([15](#_ENREF_15)).

If the neutral alignment of the great toe cannot be achieved with varus pressure on the toe then a percutaneous release of the fibular sesamoid ligaments and conjoined tendon of the adductor hallucis tendon is undertaken using image intensifier, in approximately 10% of cases ([16](#_ENREF_16)). Neutral alignment of the toe with relocation of the sesamoids under the metatarsal head is then checked using the II. A stab incision is made adjacent to the medial proximal nail fold and a 1.8mm titanium wire is inserted superficial to the periosteum of the distal phalanx of the toe, stopping short of the medial eminence of the first metatarsal (Fig 1.). A 5mm extensile incision is made over the first MT neck, cutaneous nerves are carefully sought and if found avoided and the soft tissues are carefully spread down to bone. A mini periosteal elevator is passed around the first MT neck superiorly and inferiorly to create a deep soft tissue pouch to provide a safe working area for the burr.

A 2 x 20 mm Shannon Burr (WG Healthcare, UK) on a console set at 50NM torque and 250 rpm is used to create a perpendicular hole in the first MT neck. This is angled distally towards the 3rd MT head and plantarward by 20 degrees (Fig 1). This is checked on II. A superior and inferior side cut are made to complete the chevron shape. The inferior limb is longer than the superior limb of the bony cut (Fig 2). The 1.8mm titanium wire is then advanced into the incision. Using a mosquito clip the wire is gently introduced into the intramedullary canal of the first MT. This causes lateral, distal and plantar displacement of the 1st MT head (Fig 3) thereby creating a three-dimensional correction of the deformity as seen in other described techniques ([17](#_ENREF_17)) with good outcomes. The position is checked on the II machine and the wire is advanced to the base of the first MT.

Once the position is accepted, a separate stab incision is made 2cm proximal and medial to the osteotomy site. A 1.1mm guide wire is inserted at this point obliquely and advanced across the osteotomy site into the metatarsal head, remaining outside the joint surface (Fig 4.). This is measured, drilled and countersunk and an appropriate Barouk type screw is inserted over the wire (Fig 4.). An AP and lateral view is taken at the end of the procedure. The osteotomy site wound is closed with a 4.0 nylon mattress suture after irrigation and the screw incision is closed with a steristrip. The 1.8mm wire is bent and cut short distally. The wire is dressed with gelanet and gentamicin sponge, the foot is dressed with gauze, wool and crepe.

**Postoperative management**

The patient is allowed to heel weight bear in a surgical shoe and the k-wire is removed at 4 weeks. A removable Valgulok (Bauerfind, Germany) splint is then applied but the patient is encouraged to remove this 10 to 15 times a day to mobilise the 1st MTPJ. The patient is allowed to increase their weight bearing through the foot at this point.

A standing AP and lateral radiograph is taken at six to eight weeks to ensure bony healing.

**Statistics**

All data were descriptively summarised and analysed in R version 3.0.0([18](#_ENREF_18)). Continuous data were formally analysed with Student's t-tests or Wilcoxon rank-sum test for Normally distributed and non-parametric data respectively, determined with the Shapiro-Wilk normality test. Categorical data were analysed with Peason's Chi-squared test, with continuity correction where required.

**Results**

Tables 1 and 2 present the demographic and pre-operative radiological severity, showing no difference between the two groups. Tables 3 and 4 show the clinical and radiological results. 1 patient in the open group and 3 in the MIS group did not complete a minimum 24-month clinical follow-up and were excluded from clinical analysis. 7 patients in the open group and 8 in the MIS group did not have complete radiographic follow-up and were excluded from radiological analysis.

**Clinical**

Table 3 shows the clinical results of the MOXFQ. Preoperative scores were similar across all domains. Post-operative scores in all domains were substantially improved in both groups, but there was no statistically significant difference in improvement of any domain (including the combined score) between open and MIS groups.

**Radiological**

Table 4 shows the radiographic results. The Pre-operative radiological parameters were very similar between the two groups. The significant difference in the HIA between the two groups pre and post operatively probably reflects the extra Akin procedures that were performed in the open group. The TSP was also more medial in the MIS group, which probably reflects the slightly smaller hallux valgus angle preoperatively in this group. There were no significant differences between the two groups.

**Complications**

In the MIS group there were 4 screw removals, 0 revisions, 1 recurrence and 4 patients with paraesthesia. In the open group there was 1 screw removal, 0 revisions, 1 recurrence, 1 paraesthesia and 1 patient with on-going pain. There was no reoperation for metatarsalgia in either group at final follow up. There was no statistical significance between the groups in terms of screw removal (p 0.6535), revision (p 1.00), recurrence (p 1.00), paraesthesia (p 0.6535), pain (p 0.829), or stiffness (p 0.6709).

There was no avascular necrosis, post-operative infection, hallux varus, nonunion, or dorsal malunion of the distal fragment.

**Discussion**

The results of the present study support the use of this third generation hybrid technique suggesting it is as effective as the traditional open technique. The safety profile of the procedure in terms of complication rates is comparable also.

Proponents of open surgery have largely criticised MIS based on the earlier techniques due to unacceptably high complication rates ([4](#_ENREF_4)). It should be noted that MIS surgery is not a single technique rather a philosophical approach to the surgery that often reproduces existing established bony techniques. This paper describes our version of a minimally invasive approach. MIS bunion surgery has evolved, like any other technique and the rationale behind these evolutions is discussed below:

1. Stability - First generation minimally invasive techniques were originally described by Bosch,([13](#_ENREF_13)) and later a second generation modification using a screw for fixation was described([12](#_ENREF_12)). There have been concerns about the quality of the fixation after the osteotomy is created with a 2mm burr as the relative shortening “decompresses” the osteotomy rendering it more mobile than the traditional bone cuts with a saw([4](#_ENREF_4)). The originators of this technique have changed the fixation method four times to address this problem. The original Bosch technique of using an axial wire is a very powerful way of displacing and maintain the metatarsal head in the initial few weeks and is further enhanced with the application of a screw and a chevron shaped bone cut to improve the stability and also to compress the osteotomy site.
2. Dorsal malunion – This was a particular problem in Meyerson’s series([19](#_ENREF_19)) and can be mitigated with the use of a chevron bone cut and screw stabilisation.
3. 1st metatarsal shortening([20](#_ENREF_20)) - One of the criticisms of using a burr is that it can shorten the first metatarsal potentially causing transfer metatarsalgia ([20](#_ENREF_20)), although there is no consensus on the amount of shortening that might lead to pain. In Turnbull and Grange’s([21](#_ENREF_21)) series they found shortening of up to 8mm acceptable and our previous study found no correlation between degree of shortening and clinical outcome([22](#_ENREF_22)). In our series MIS and open surgery had no mean differences in shortening (Open 5.36mm, MIS 5.2mm p 0.55). If the burr is directed in a distal direction then when the lateral translation occurs there is a relative restoration in length of the metatarsal.
4. Bone damage([4](#_ENREF_4)) – the use of high torque low-speed burr mitigates these problems. It has been observed, in this series, that being a closed procedure the swath generated from the burr aids radiological earlier union (a separate study is currently being conducted to better evaluate this observation), rather analogous to the use of a bone graft.
5. Timing of lateral soft tissue release([4](#_ENREF_4)) – in our series if the hallux is not clinically reducible a lateral soft tissue release is performed prior to osteotomy. This aids reduction of the sesamoids under the metatarsal head. The amount of translation can be as much as 90% and this also relaxes the adductor hallucis tendon.
6. Lack of medial capsular plication – A stable union in a reduced anatomically favourable position mitigates the need for this procedure as seen in these 2-year results. It remains to be seen whether or not the lack of soft tissue repair causes the deformity to recur, although Giannini et al.([14](#_ENREF_14)) did not find this to be the case in their study with >5 year follow-up and Faour-Martin et al. ([23](#_ENREF_23)) also found the results of their MIS technique were sustained over a 10 year period. Over-correction into hallux varus is not a problem that has been reported with MIS hallux valgus surgery and this may be due to the absence of medial soft tissue tightening
7. Avascular necrosis - It is an extra-capsular procedure and therefore protects the blood supply to the metatarsal head([13](#_ENREF_13)).
8. Stiffness - Being extra-articular is also protective of post-operative stiffness associated with open techniques, being reported as high as 38%([24](#_ENREF_24)).
9. Transfer metatarsalgia – an angulated chevron cut from dorsomedial to plantarlateral means that lateral translation of the head also causes plantar displacement aiming to reload the 1st metatarsal head and reduce the risk of transfer metatarsalgia (see also point 1 above).

It should be noted that open procedures are also not without their complications([25](#_ENREF_25)), perhaps explaining the vast number of surgical options. There is no doubt that MIS hallux valgus surgery has a steep learning curve and therefore these results may be difficult to reproduce although the senior author feels that with adequate training and supervision this technique is much easier and reproducible compared to the earlier MIS techniques for hallux valgus surgery.

**Conclusion**

We conclude that this hybrid MIS technique is a safe and effective procedure for the correction of symptomatic mild-to-moderate hallux valgus but longer-term randomised controlled studies are required before it is universally adopted.

**Conflict of Interest**

The authors declare that they have no conflict of interest.

**References**

1. Schneider W, Aigner N, Pinggera O, Knahr K. Chevron osteotomy in hallux valgus. Ten-year results of 112 cases. The Journal of bone and joint surgery British volume. 2004;86(7):1016-20.

2. Maffulli N, Longo UG, Marinozzi A, Denaro V. Hallux valgus: effectiveness and safety of minimally invasive surgery. A systematic review. British medical bulletin. 2011;97:149-67.

3. Trnka HJ, Krenn S, Schuh R. Minimally invasive hallux valgus surgery: a critical review of the evidence. Int Orthop. 2013;37(9):1731-5.

4. Perera AM, A. Redfern, D. Singh, D. Lomax, A. Minimally Invasive Forefoot Surgery. JTO. 2015;3(1):50-5.

5. Brogan K, Voller T, Gee C, Borbely T, Palmer S. Third-generation minimally invasive correction of hallux valgus: technique and early outcomes. Int Orthop. 2014;38(10):2115-21.

6. Dawson J, Coffey J, Doll H, Lavis G, Cooke P, Herron M, et al. A patient-based questionnaire to assess outcomes of foot surgery: validation in the context of surgery for hallux valgus. Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation. 2006;15(7):1211-22.

7. Dawson J, Boller I, Doll H, Lavis G, Sharp R, Cooke P, et al. The MOXFQ patient-reported questionnaire: assessment of data quality, reliability and validity in relation to foot and ankle surgery. Foot (Edinb). 2011;21(2):92-102.

8. Dawson J, Boller I, Doll H, Lavis G, Sharp R, Cooke P, et al. Responsiveness of the Manchester-Oxford Foot Questionnaire (MOXFQ) compared with AOFAS, SF-36 and EQ-5D assessments following foot or ankle surgery. The Journal of bone and joint surgery British volume. 2012;94(2):215-21.

9. Morley D, Jenkinson C, Doll H, Lavis G, Sharp R, Cooke P, et al. The Manchester-Oxford Foot Questionnaire(MOXFQ): Development and validation of a summary index score. Bone Joint Res. 2013;2(4):66-9.

10. Morley D, Jenkinson C, Doll H, Lavis G, Sharp R, Cooke P, et al. The Manchester-Oxford Foot Questionnaire (MOXFQ): Development and validation of a summary index score. Bone Joint Res. 2013;2(4):66-9.

11. Laporta DM, Melillo, T.V., Hetherington, V.J. Pre-operative assessment in Hallux Valgus. In: Hetherington VJ, editor. Textbook of Hallux Valgus & Forefoot Surgery. 1. Ohio: Vincent J. Hetherington 2000; 1994. p. 107-24.

12. Walker RR, D. Minimally Invasive Hallux Valgus Correction: The MICA technique. The Journal of bone and joint surgery British volume. 2012;94-B(Supp XXII ):38.

13. Bosch P, Wanke S, Legenstein R. Hallux valgus correction by the method of Bosch: a new technique with a seven-to-ten-year follow-up. Foot and ankle clinics. 2000;5(3):485-98, v-vi.

14. Giannini S, Faldini C, Nanni M, Di Martino A, Luciani D, Vannini F. A minimally invasive technique for surgical treatment of hallux valgus: simple, effective, rapid, inexpensive (SERI). Int Orthop. 2013;37(9):1805-13.

15. Coughlin MRaS, C.L. Ch2 Surgery of the Foot and Ankle. Philadelphia2007.

16. Morgan SR, I. Benerjee, R. Palmer, S. Minimally Invasive chevron osteotomy; functional outcome and comparison with open chevron osteotomy. The Journal of bone and joint surgery British volume. 2012;94-B(Supp XLIII):67.

17. Lucijanic I, Bicanic G, Sonicki Z, Mirkovic M, Pecina M. Treatment of hallux valgus with three-dimensional modification of Mitchell's osteotomy: technique and results. Journal of the American Podiatric Medical Association. 2009;99(2):162-72.

18. (2014) RCT. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>.

19. Kadakia AR, Smerek JP, Myerson MS. Radiographic results after percutaneous distal metatarsal osteotomy for correction of hallux valgus deformity. Foot Ankle Int. 2007;28(3):355-60.

20. Jung HG, Zaret DI, Parks BG, Schon LC. Effect of first metatarsal shortening and dorsiflexion osteotomies on forefoot plantar pressure in a cadaver model. Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society. 2005;26(9):748-53.

21. Turnbull T, Grange W. A comparison of Keller's arthroplasty and distal metatarsal osteotomy in the treatment of adult hallux valgus. The Journal of bone and joint surgery British volume. 1986;68(1):132-7.

22. Travis EC, Tan RS, Funaki P, McChesney SJ, Patel SC, Brogan K. Clinical Outcomes of Total Hip Arthroplasty for Fractured Neck of Femur in Patients Over 75 Years. J Arthroplasty. 2014.

23. Faour-Martin O, Martin-Ferrero MA, Valverde Garcia JA, Vega-Castrillo A, de la Red-Gallego MA. Long-term results of the retrocapital metatarsal percutaneous osteotomy for hallux valgus. Int Orthop. 2013;37(9):1799-803.

24. Austin DW, Leventen EO. A new osteotomy for hallux valgus: a horizontally directed "V" displacement osteotomy of the metatarsal head for hallux valgus and primus varus. Clinical orthopaedics and related research. 1981(157):25-30.

25. Coetzee JC. Scarf osteotomy for hallux valgus repair: the dark side. Foot Ankle Int. 2003;24(1):29-33.

Table 1. Pre-operative radiological severity.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | MIS group (n41) | Open Group (n 24) | p |
| HVA | Mild(15-20 degrees) | 12 | 9 | 0.9254† |
|  | Moderate (21-39 degrees) | 30 | 19 |  |
|  | Severe (≥40 degrees) | 7 | 4 |  |
| IMA | Mild (9-11 degrees) | 4 | 2 | 0.4736† |
|  | Moderate (12-17 degrees) | 31 | 14 |  |
|  | Severe (≥18 degrees) | 6 | 6 |  |
| † Pearson's Chi-squared test | |  |  |  |

Table 2. Demographics

|  |  |  |  |
| --- | --- | --- | --- |
|  | MIS group (n=46) | Open Group (n=30) | p |
| Age (Years) mean (SD) | 53 (10.8) | 57 (10.9) | 0.1087† |
| Gender | 46 Female (94%) | 32 Female (100%) | 0.4096‡ |
| † Student's two-sample t-test |  |  |  |
| ‡ Pearson's Chi-square test with continuity correction | |  |  |

Table 3. Clinical results

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **MIS** |  | **Open** |  |  |
| Metric MOXFQ summary scores |  | Mean | SD | Mean | SD | **p** |
| Walking | Preoperative | 42.64 | 21.9 | 51.79 | 26.6 |  |
|  | Postoperative | 9.226 | 16.9 | 14.73 | 19.5 |  |
|  | **Difference** | **-33.56** | **29.6** | **-37.05** | **25.4** | **0.57†** |
| Pain | Preoperative | 49.17 | 19.2 | 51.72 | 25.3 |  |
|  | Postoperative | 16.46 | 19.65 | 13.4 | 16.9 |  |
|  | **Difference** | **-32.66** | **25.8** | **-38.28** | **23.67** | **0.32†** |
| Social Interaction | Preoperative | 49.09 | 20.9 | 53.52 | 22.5 |  |
|  | Postoperative | 13.41 | 21.1 | 21.09 | 22.8 |  |
|  | **Difference** | **-36.3** | **31.8** | **-32.42** | **27.9** | **0.56†** |
| Combined | Preoperative | 46.58 | 16.3 | 52.34 | 21.5 |  |
|  | Postoperative | 13.03 | 16 | 16.42 | 18.7 |  |
|  | **Difference** | **-33.55** | **23.8** | **-35.92** | **22.1** | **0.98‡** |
| † Student's two-sample t-test |  |  |  |  |  |  |
| ‡ Wilcoxon rank sum test |  |  |  |  |  |  |

Table 4. Radiological results

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **MIS** |  | **Open** |  |  |
|  |  | Mean | SD | Mean | SD | **p** |
| IMA**°** | Preoperative | 11.69 | 4.43 | 13.35 | 4.6 |  |
|  | Postoperative | 6.79 | 3.62 | 6.68 | 3.36 |  |
|  | **Difference** | **-4.92** | **5.27** | **-6.74** | **5.6** | 0.20† |
| HVA**°** | Preoperative | 26.55 | 10.56 | 30.83 | 10.14 |  |
|  | Postoperative | 10.43 | 5.69 | 9.91 | 5.92 |  |
|  | **Difference** | **-16.23** | **10.89** | **-20.53** | **9.51** | 0.10† |
| HIA**°** | Preoperative | 4.31 | 5.26 | 4.67 | 11.93 |  |
|  | Postoperative | 10.03 | 3.35 | 7.25 | 4.74 |  |
|  | **Difference** | **5.72** | **5.11** | **1.25** | **5.55** | 0.0002† |
| 1st MT (mm) | Preoperative | 11.44 | 0.72 | 10.39 | 3.17 |  |
|  | Postoperative | 10.94 | 0.73 | 10.61 | 0.6 |  |
|  | **Difference** | **-0.5** | **0.85** | **0.75** | **3.28** | 0.93‡ |
| 2nd MT(mm) | Preoperative | 11.35 | 0.83 | 11.76 | 2.66 |  |
|  | Postoperative | 11.17 | 0.86 | 10.98 | 0.83 |  |
|  | **Difference** | **-0.18** | **0.92** | **-0.83** | **2.9** | 0.47‡ |
| DMAA**°** | Preoperative | 9.22 | 7.42 | 11.63 | 8.96 |  |
|  | Postoperative | 1.16 | 8.44 | 11.38 | 9.92 |  |
|  | **Difference** | **7.56** | **10.54** | **0.94** | **9.59** | 0.3† |
| RML**°** | Preoperative |  |  |  |  |  |
|  | Postoperative |  |  |  |  |  |
|  | **Difference** |  |  |  |  |  |
| TSP | Preoperative | 3.78 | 1.53 | 5.66 | 2.58 |  |
|  | Postoperative | 2.75 | 1.25 | 3.06 | 1.29 |  |
|  | **Difference** | **1.03** | **1.89** | **2.43** | **2.79** | 0.16‡ |
| MJA**°** | Preoperative | 12.47 | 14.47 | 17.57 | 13.93 |  |
|  | Postoperative | 3.42 | 10.19 | 6.06 | 14.25 |  |
|  | **Difference** | **9.06** | **14.28** | **7.77** | **13.7** | 0.76† |
| Toe length (mm) | Preoperative | 116.1 | 12.25 | 114.8 | 5.35 |  |
|  | Postoperative | 114.6 | 13.08 | 112.9 | 8.06 |  |
|  | **Difference** | **2.06** | **6.84** | **3.79** | **5.45** | 0.32† |
| MT length(mm) | Preoperative | 60.47 | 4.57 | 58.77 | 3.51 |  |
|  | Postoperative | 55.44 | 5.14 | 55.06 | 4.86 |  |
|  | **Difference** | **5.2** | **4.6** | **4.24** | **5.8** | 0.55† |
| Plantar Offset (mm) | Postoperative | 2.65 | 1.67 | 0.15 | 0.67 | 0.0000002071‡ |
|  |  |  |  |  |  |  |
| † Student's two-sample t-test |  |  |  |  |  |  |
| ‡ Wilcoxon rank sum test |  |  |  |  |  |  |