Original Article

Title:

Impact of combining medial capsule interposition with modified scarf osteotomy for hallux valgus

Authors:

Kosuke Ebina[1)]*, Makoto Hirao[1)], Hideki Tsuboi[2)], Shoichi Kaneshiro[2)], Masataka Nishikawa[3)], Atsushi Goshima[3)], Takaaki Noguchi[4)], Hiroyuki Nakaya[5)], Yuki Etani[1)], Akira Miyama[1)], Kenji Takami[1)], Jun Hashimoto[6)], and Hideki Yoshikawa[1)]

Affiliations:

1) Department of Orthopaedic Surgery, Osaka University Graduate School of Medicine, 2-2 Yamada-oka, Suita, Osaka 565-0871, Japan

2) Department of Orthopaedic Surgery, Osaka Rosai Hospital, 1179-3 Nagasone-cho, Sakai 591-8025, Japan

3) Department of Orthopaedic Surgery, Japan Community Healthcare Organization, Osaka Hospital, 4-2-78 Fukushima, Fukushima Ward, Osaka City, Osaka 553-0003, Japan

4) Department of Orthopaedic Surgery, National Hospital Organization Osaka Minami Medical Center,

2-1 Kidohigashi, Kawachinagano, Osaka 586-8521, Japan

5) Department of Orthopaedic Surgery, Toneyama National Hospital, 5-1-1 Toneyama, Toyonaka, Osaka 560-8552, Japan

6) Department of Rheumatology, National Hospital Organization Osaka Minami Medical Center, 2-1 Kidohigashi, Kawachinagano, Osaka 586-8521, Japan

Corresponding author:

Kosuke Ebina, MD, PhD, Assistant Professor

Department of Orthopaedic Surgery, Osaka University Graduate School of Medicine,

2-2 Yamada-oka, Suita, Osaka 565-0871, Japan

Phone: +81-6-6879-3552; Fax: +81-6-6879-3559

E-mail: k-ebina@umin.ac.jp

This article contains 6 figures and 2 tables.

Funding:

The authors declare they have no specific funding for this study.

ABSTRACT

Objectives

To clarify the effect of combining medial capsule interposition with modified scarf osteotomy for hallux valgus.

Methods

A multicenter, retrospective study included 64 cases [59 osteoarthritis patients (excluding rheumatoid arthritis); age 68.8 years, range 40 to 93 years) of modified scarf osteotomy which were performed from 2013 to 2017 and followed for 26.6 (range, 13 to 50) months. Patients were treated by either (1) without medial capsule interposition (33 cases) or (2) combined with interposition (31 cases) at each senior surgeon's discretion. The Japanese Society for Surgery of the Foot (JSSF) hallux metatarsophalangeal-interphalangeal scale was evaluated along with radiographic parameters (hallux valgus angle, first and second metatarsals intermetatarsal angles, and Hardy grade).

Results

All JSSF scale and radiographic parameters were similar at baseline and significantly improved at final follow-up in both groups (pre-operation vs. final follow-up: $P<0.001$). However, compared to without interposition group, interposition group showed significantly higher improvement in the JSSF scale (pre-operation to final follow-up: *P*-value between the two groups at final follow-up) for pain (without interposition: 19.4 to 34.2, interposition: 18.4 to 37.1; $P=0.02$), function (without

interposition: 20.8 to 33.6, interposition: 18.3 to 36.6; *P*=0.005), total score (without interposition: 41.5 to 81.8, interposition: 38.5 to 88.5; *P*<0.001), and the metatarsophalangeal joint space (without interposition: 1.4 to 1.5 mm, interposition: 1.6 to 2.6 mm; *P*<0.001) with significant correlation between the total JSSF score (*r*=0.40; *P*=0.001).

Conclusions

Combining medial capsule interposition with modified scarf osteotomy significantly improved mid-term clinical outcomes.

Keywords:

Hallux valgus, Interposition arthroplasty, Modified Scarf osteotomy

INTRODUCTION

A recent report demonstrated that the prevalence of radiographic hallux valgus reached 29.8% in an aged cohort (≥65 years) [1], and hallux valgus deformity and the related pain itself impair physical function [2]. The scarf osteotomy is reported as one of the most reliable joint-preserving hallux valgus surgical interventions recommended for the correction of moderate-to-severe hallux valgus deformity [3, 4]. However, some patients develop progressive osteoarthritis (joint space narrowing) after scarf osteotomy [3], so alternative treatment options may be required, especially in severe cases. Good

clinical outcomes of capsular interposition arthroplasty for hallux rigidus have been reported [5, 6]. In addition, the adductor hallucis tendon, which is usually dissected from the hallux proximal phalanx in scarf osteotomy, supports the longitudinal arch (oblique head) and the transverse arch (transverse head). Therefore, we hypothesized that combining medial capsular interposition of the hallux (suturing to the adductor hallucis tendon) with modified scarf osteotomy may improve clinical outcomes, such as pain reduction and maintaining the longitudinal and transverse arches. We have recently reported that this procedure was effective in severe hallux valgus deformity in patients with rheumatoid arthritis [7-9]. The purpose of this study was to clarify the usefulness of combining medial capsular interposition with modified scarf osteotomy for hallux valgus patients (excluding rheumatoid arthritis) by comparing the mid-term clinical outcomes of cases treated with and without medial capsular interposition.

MATERIALS AND METHODS

Patients and clinical assessment

A multicenter, retrospective, observational study identified 73 osteoarthritis (excluding rheumatoid arthritis) cases (67 patients) who had undergone modified scarf osteotomy in 5 institutes by senior rheumatoid surgeons from 2013 to 2017. Nine cases (8 patients) were excluded for incomplete data and less than 12 months' follow-up, and there was no other selection bias in collecting patients' data.

Finally, a total of 64 cases (59 patients, 53 females; mean age 68.8 years, range 40 to 93 years) followed for a mean of 26.6 (range, 13 to 50) months were enrolled. Patients were treated by either (1) without medial capsule interposition (without interposition group, 33 cases, age 65.5 years, follow-up 25.7 months) or (2) combined with medial capsule interposition (interposition group, 31 cases, age 72.3 years, follow-up 27.5 months) depending on each senior surgeon's discretion such as age, severity of hallux valgus, and learning skill of each surgeon.

Patients were evaluated by scores of the Japanese Society for Surgery of the Foot (JSSF) hallux metatarsophalangeal-interphalangeal scale, which was established by modifying the American Orthopaedic Foot and Ankle Society (AOFAS) scale and the Japanese Orthopaedic Association's foot rating (JOA) scale [10, 11]. The validity and inter- and intra-clinician reliability of JSSF scale for evaluating hallux valgus has been demonstrated [11]. In addition, pre-operative and postoperative radiographic parameters were also evaluated. The hallux valgus angle (HVA), first metatarsal and second metatarsal (M1M2) angle, first metatarsal and fifth metatarsal (M1M5) angle, and the joint space of the hallux MTP joint (mm) were defined on anteroposterior weight-bearing radiographs performed pre-operatively and postoperatively, as previously described [12].

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki, and it was approved by the Institutional Ethical Review Board at each center. Informed consent was obtained from each individual patient included in the study.

Operative Technique

Representative pre-operative and postoperative radiographs are shown in Figure 1. The amount of first metatarsal bone resection was determined to be equal to the length of overlap between the first metatarsal bone and the basal phalanx bone in the longitudinal direction as measured on a pre-operative foot radiograph in the standing position (Fig. 1a). The hallux MTP joint gap was measured by the minimum distance between the proximal joint line at the axis of the basal phalanx bone and the first metatarsal head on foot radiographs in the standing position, pre-operatively (Fig. 1b) and postoperatively (Fig. 1c).

Patients were treated by modified scarf osteotomy of the hallux with the medial longitudinal approach, as previously described [9, 13]. A longitudinal incision was made in the medial aspect of the first metatarsal (Fig. 2a), and the medial capsule was opened with a 10-mm-wide and 40-mm-long flap (Fig. 2b). The osteotomy was parallel to the sole of the foot, and both distal and proximal bone fragments were partially resected owing to the measurements on pre-operative radiographs (Fig. 2c). The distal bone fragment was laterally shifted and then fixed with 3 or 4 AcuTwist® Acutrak® 2.0-mm headless compression screws (Acumed USA, Hillsboro, OR) (Fig. 2d). Next, a longitudinal dorsal incision (about 20 mm) was made between the first and second metatarsals. The adductor hallucis tendon was dissected from the base of the hallux proximal phalanx, and marked by 3-0 PDS suture to avoid its

shortening (Fig. 3a). The capsule between the first metatarsal and the lateral sesamoid was split longitudinally from the proximal phalanx to the middle of the first metatarsal shaft [9]. The medial eminence of the first metatarsal head was minimally excised, and a capsule hole was made in the lateral side of the hallux MTP joint (Fig. 3b). Next, when performing interposition, the flap of the capsule was interposed into the hallux MTP joint (Fig. 3c), and it was then sutured to the adductor hallucis tendon that was dissected from the hallux proximal phalanx (Fig. 3d). Finally, the medial capsule was sutured after some shrinkage due to the interposition of the 10-mm-wide flap into the hallux MTP joint, with the expectation of producing the force needed for varus directions of the hallux [7-9]. When not performing interposition, the medial capsule flap was sutured to the remaining capsule or periosteum with appropriate traction, and the dissected adductor hallucis tendon was detached or sutured to the lateral capsule of the hallux.

A modified metatarsal shortening offset osteotomy was performed in the lesser toes when required, such as rigid claw toes [7, 9, 14]. An Akin osteotomy of the hallux proximal phalanx was performed if the valgus or pronation deformity was not adequately corrected by modified scarf osteotomy. Range-of-motion exercises for the hallux MTP joint were started one day after the operation, and full weight-bearing was allowed 2 to 2.5 weeks postoperatively, after fitting for an arch support.

Statistical analysis

Differences between each study group were tested using the Mann-Whitney U test or the chi-squared test. Changes in each score from pre-operative to postoperative at specified time points were compared using the nonparametric Wilcoxon signed-rank test. Spearman correlation coefficients were calculated for the hallux MTP joint gap (mm) and the JSSF function score or the total JSSF score. A post-hoc calculation was performed to examine adequate sample size. Results are expressed as means ± standard deviation (range). A P value < 0.05 indicated significance. All tests were performed using IBM SPSS Statistics version 22 software (IBM, Armonk, NY, USA).

RESULTS

A post-hoc power analysis in comparing total JSSF score at final follow-up (effect size 0.88, α error 0.05, power 0.8) revealed sufficient sample size as n=22 in each group, which demonstrated adequate sample size of this study.

The clinical characteristics of each group at baseline are shown in Table 1. Generally, both groups showed similar baseline clinical scores and radiographic parameters, although age was significantly older in the interposition group than in the without interposition group (72.3 vs. 65.5 years: P=0.014).

The representative radiographs of both groups are shown in Fig. 4. Patients who underwent scarf osteotomy without interposition showed a stable joint space (Fig. 4a), while patients with interposition showed an enlarged joint space until final follow-up (Fig. 4b). Operation-related outcomes are shown

in Table 2 and Fig. 5. On radiographic evaluation, compared to the without interposition group, the interposition group showed a significantly larger hallux MTP joint gap at both postoperative 1 week (1.8 vs. 3.8 mm; $P<0.001$) and final follow-up (1.5 vs. 2.6 mm; $P<0.001$) (Fig. 5a). Concerning clinical scores, compared to the without interposition group, the interposition group showed significantly higher JSSF pain score (34.2 vs. 37.1; $P=0.02$), function score (33.6 vs. 36.6; $P=0.005$ / subscale score of range of motion; 5.8 vs. 7.1; $P=0.03$), and total score (81.8 vs. 88.5; $P=0.0008$), while no significant difference was observed in the alignment score (13.9 vs. 14.8; $P=0.10$) at final follow-up (Table 2). Focusing on the changes of clinical scores, compared to the without interposition group, the interposition group showed significantly higher improvement of the JSSF function score (12.7 vs. 18.4; $P<0.001$ / subscale score of range of motion; -1.2 vs. 1.1; $P<0.001$) (Fig. 5b) and the total JSSF score (40.3 vs. 50.0; $P=0.0029$) (Fig. 5c).

No significant difference was observed in HV angle, M1M2 angle, M1M5 angle, and sesamoid Hardy grade throughout this period (Table 2). Even when focused on only severe cases (baseline HV angle > 40°), these tendencies were similar (Supplemental Table 1).

Finally, the correlation between the hallux MTP joint gap and the clinical scores were evaluated (Fig. 6). Significant correlations were observed between the hallux MTP joint gap and the JSSF function score ($r=0.52$; $P<0.001$) and the total JSSF score ($r=0.40$; $P=0.0011$) at final follow-up. None of the patients in both groups underwent reoperation during the follow-up period.

DISCUSSION

As far as we know, this is the first report to demonstrate the clinical effects of combining medial capsule interposition with modified scarf osteotomy of the hallux valgus, by comparing cases with and without medial capsular interposition.

Adam et al. reported that scarf osteotomy for adult hallux valgus showed good results, with 94% patient satisfaction [15], although some patients developed progressive arthritis [3]. From this point of view, we developed medial capsular interposition of the hallux, aiming to improve clinical outcomes, such as preserving joint space, pain reduction, and maintaining the longitudinal and transverse arches [7-9]. In this study, all of the JSSF scores (total, pain, function, and alignment scores) and radiographic assessment parameters (HV, M1M2, M1M5 angle, Hardy grade) improved postoperatively in both the without and the with interposition groups (P<0.001, respectively), suggesting the promising effects of the modified scarf osteotomy procedure in hallux valgus treatment. Of note, although the alignment score and other bony alignment parameters (HV, M1M2, M1M5 angle, Hardy grade) were similar between the groups, the interposition group showed further higher JSSF pain, function, and total scores, and a larger hallux MTP joint gap compared to the without interposition group. These results indicate that medial capsule interposition may contribute to additional pain reduction and functional recovery, although boney alignment may be mainly determined by the osteotomy procedure, not by the

soft tissue procedure.

Concerning interposition techniques, many previous reports demonstrated their efficacy in the treatment of hallux rigidus. Hamilton et al. demonstrated suturing the extensor hallucis brevis tendon to the flexor hallucis brevis tendon [16] and Aynardi et al. demonstrated good outcomes for the same procedure (patient-reported outcome was good or excellent in 89.5%, with mean follow-up of 62.2 months) [5]. Recently, Vulcano et al. also reported the good-long term outcomes (patient satisfaction of 92.9%, with a mean follow-up of 11.3 years) of this procedure [6], suggesting the long-term efficacy of capsular interposition. A previous report demonstrated that interpositioned-capsule remained as fibrocartilage tissue by biopsy examination [5], which may contribute to pain reduction and improvement of range of motion by preserving sliding surface of articular cartilage in present study.

As for other interposition materials, Coughlin et al. reported excellent functional results when hallux rigidus was treated with interposition arthroplasty using autologous gracilis tendon, which was used as a rolled bundle graft [17]. However, a recent report demonstrated that this rolled tendon allograft for salvage surgery of hallux rigidus showed a high rate of complications [18], and this procedure also poses an additional burden, such as harvesting healthy autologous tissue with another incision.

Concerning hallux valgus treatment, there have been only a few reports demonstrating the effects of interposition. Schulz et al. concluded that resection-interposition arthroplasty is an inadequate

procedure in cases with early arthritis or a positive metatarsal index, and it may show good results if resection of the first phalanx does not exceed one third of the length [19]. Taken together, medial capsule interposition with joint-preserving arthroplasty of the hallux valgus may have some benefits without additional burden. This procedure may also be effective in reefing the medial capsule to strengthen medial tension.

There are several limitations in this study. First, this was a retrospective, non-randomized study, and the selection of the methods was dependent on each surgeon's discretion, which resulted in higher age of the interposition group. Second, the follow-up period was relatively short, and whether these effects may continue in longer period should be evaluated in future study, because the difference of joint gap between the groups tend to decrease at final follow-up. Third, in regards to the assessment of longitudinal arch, we failed to collect enough data of lateral standing radiograph, which should be evaluated in future study.

In conclusion, combining medial capsule interposition with modified scarf osteotomy for hallux valgus significantly improved clinical outcomes and the MTP joint space compared to no interposition in mid-term follow-up.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Shigeyoshi Tsuji, Dr. Koichiro Takahi, Dr. Hajime Owaki, Dr.

Yasuo Kunugiza, Dr. Akihide Nampei, and Dr. Yoshio Nagayama for their excellent cooperation in conducting the study.

CONFLICT OF INTEREST

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subjects of this article.

FIGURE LEGENDS

Figure 1. (a) The amount of bone resection (arrow 1) is determined to be equal to the length of overlap between the first metatarsal bone and the basal phalanx bone in the longitudinal direction as measured on radiographs in the standing position. The hallux metatarsophalangeal joint gap is measured by the minimum distance between the proximal joint line at the axis of the basal phalanx bone and the first metatarsal head on radiographs in the standing position, (b) pre-operatively (arrow 2) and (c) postoperatively (arrow 3).

Figure 2. Operative procedures. (a) A longitudinal incision is made in the medial aspect of the first metatarsal. (b) The medial capsule is opened with 10-mm-wide and 40-mm-long flap. (c) The osteotomy is parallel to the sole of the foot, and both distal and proximal bone fragments are partially

resected based on measurements on the pre-operative radiographs. (d) The distal bone fragment is shifted laterally, then fixed with AcuTwist® Acutrak® 2.0-mm headless compression screws.

Figure 3. Operative procedures. (a) The adductor hallucis tendon is dissected from the base of the hallux proximal phalanx, and marked by 3-0 PDS suture. (b) A capsule hole is made in the lateral side of the hallux metatarsophalangeal (MTP) joint. (c) A medial capsule flap is interposed into the hallux MTP joint (d) and sutured to the adductor hallucis tendon that was dissected from the hallux proximal phalanx.

Figure 4. Representative sequential radiographs of both modified scarf osteotomy groups. (a) Without interposition. (b) Combined with interposition.

Figure 5. Mean pre-operative and postoperative (a) hallux metatarsophalangeal (MTP) joint gaps (mm), (b) changes of JSSF function scores (full score 45 points), and (c) changes of total JSSF scores. Bars indicate standard deviations.

JSSF, Japanese Society of Surgery of the Foot; N.S., not significant.

** $P < 0.01$, *** $P < 0.001$, without interposition vs. interposition group.

Figure 6. Scatter plots for the hallux metatarsophalangeal (MTP) joint gap (mm) and (a) JSSF function score and (b) total JSSF score at final follow-up.

JSSF, Japanese Society of Surgery of the Foot; IP, interposition; MTP, metatarsophalangeal.

REFERENCES

1. Nishimura A, Kato K, Fukuda A, Nakazora S, Yamada T, Uchida A, et al. Prevalence of hallux valgus and risk factors among Japanese community dwellers. J Orthop Sci. 2014;19(2):257-62.
2. Nishimura A, Ito N, Nakazora S, Kato K, Ogura T, Sudo A. Does hallux valgus impair physical function? BMC Musculoskelet Disord. 2018;19(1):174.
3. Choi JH, Zide JR, Coleman SC, Brodsky JW. Prospective study of the treatment of adult primary hallux valgus with scarf osteotomy and soft tissue realignment. Foot Ankle Int. 2013;34(5):684-90.
4. Sayli U, Akman B, Tanriover A, Kaspar C, Guven M, Ozler T. The results of Scarf osteotomy combined with distal soft tissue procedure are mostly satisfactory in surgical management of moderate to severe hallux valgus. Foot Ankle Surg. 2017.
5. Aynardi MC, Atwater L, Dein EJ, Zahoor T, Schon LC, Miller SD. Outcomes After Interpositional Arthroplasty of the First Metatarsophalangeal Joint. Foot Ankle Int. 2017;38(5):514-8.
6. Vulcano E, Chang AL, Solomon D, Myerson M. Long-Term Follow-up of Capsular Interposition Arthroplasty for Hallux Rigidus. Foot Ankle Int. 2018;39(1):1-5.
7. Ebina K, Hirao M, Hashimoto J, Nampei A, Shi K, Tomita T, et al. Comparison of a self-administered foot evaluation questionnaire (SAFE-Q) between joint-preserving arthroplasty and resection-replacement arthroplasty in forefoot surgery for patients with rheumatoid arthritis. Mod Rheumatol. 2016:1-12.
8. Ebina K, Hirao M, Takagi K, Ueno S, Morimoto T, Matsuoka H, et al. Comparison of the effects of forefoot joint-preserving arthroplasty and resection-replacement arthroplasty on walking plantar pressure distribution and patient-based outcomes in patients with rheumatoid arthritis. PLoS One. 2017;12(8):e0183805.
9. Kushioka J, Hirao M, Tsuboi H, Ebina K, Noguchi T, Nampei A, et al. Modified Scarf Osteotomy with Medial Capsule Interposition for Hallux Valgus in Rheumatoid Arthritis: A Study of Cases Including Severe First Metatarsophalangeal Joint Destruction. J Bone Joint Surg Am. 2018;100(9):765-76.
10. Niki H, Aoki H, Inokuchi S, Ozeki S, Kinoshita M, Kura H, et al. Development and reliability of a standard rating system for outcome measurement of foot and ankle disorders I: development of standard rating system. J Orthop Sci. 2005;10(5):457-65.
11. Niki H, Aoki H, Inokuchi S, Ozeki S, Kinoshita M, Kura H, et al. Development and reliability of a standard rating system for outcome measurement of foot and ankle disorders II: interclinician and intraclinician

reliability and validity of the newly established standard rating scales and Japanese Orthopaedic Association rating scale. J Orthop Sci. 2005;10(5):466-74.

12. Coughlin MJ. Rheumatoid forefoot reconstruction. A long-term follow-up study. J Bone Joint Surg Am. 2000;82(3):322-41.

13. Kristen KH, Berger C, Stelzig S, Thalhammer E, Posch M, Engel A. The SCARF osteotomy for the correction of hallux valgus deformities. Foot Ankle Int. 2002;23(3):221-9.

14. Hirao M, Ebina K, Tsuboi H, Nampei A, Kushioka J, Noguchi T, et al. Outcomes of modified metatarsal shortening offset osteotomy for forefoot deformity in patients with rheumatoid arthritis: Short to mid-term follow-up. Mod Rheumatol. 2017;27(6):981-9.

15. Adam SP, Choung SC, Gu Y, O'Malley MJ. Outcomes after scarf osteotomy for treatment of adult hallux valgus deformity. Clin Orthop Relat Res. 2011;469(3):854-9.

16. Hamilton WG, O'Malley MJ, Thompson FM, Kovatis PE. Roger Mann Award 1995. Capsular interposition arthroplasty for severe hallux rigidus. Foot Ankle Int. 1997;18(2):68-70.

17. Coughlin MJ, Shurnas PJ. Soft-tissue arthroplasty for hallux rigidus. Foot Ankle Int. 2003;24(9):661-72.

18. Thomas D, Thordarson D. Rolled Tendon Allograft Interposition Arthroplasty for Salvage Surgery of the Hallux Metatarsophalangeal Joint. Foot Ankle Int. 2018;39(4):458-62.

19. Schulz CU, Feitenhansl A, Pellengahr C, Maier M. [Resection-interposition arthroplasty in symptomatic hallux valgus: a revision of indication and technique]. Z Orthop Ihre Grenzgeb. 2003;141(4):440-4.

Figure 1

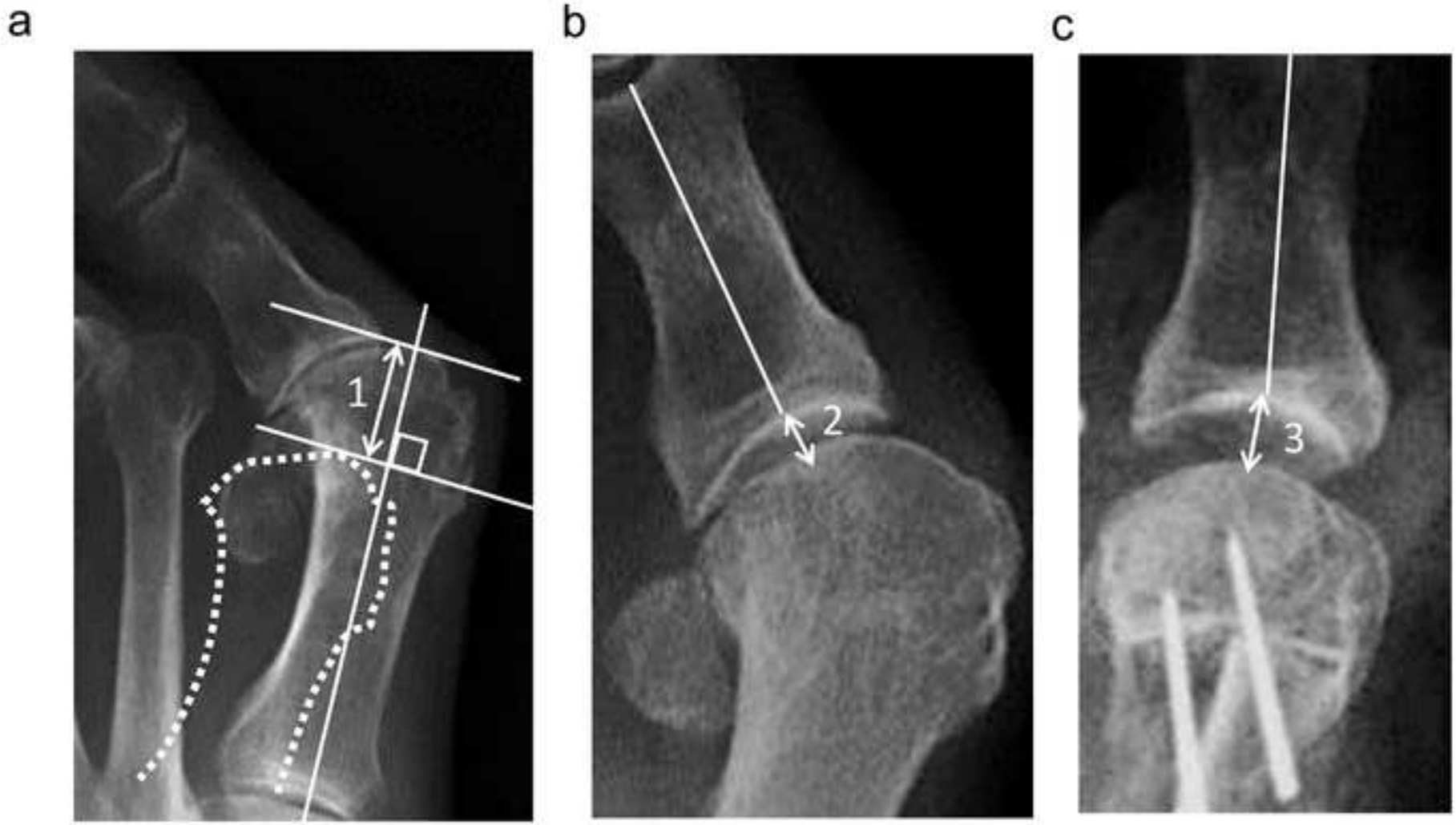

Figure 2

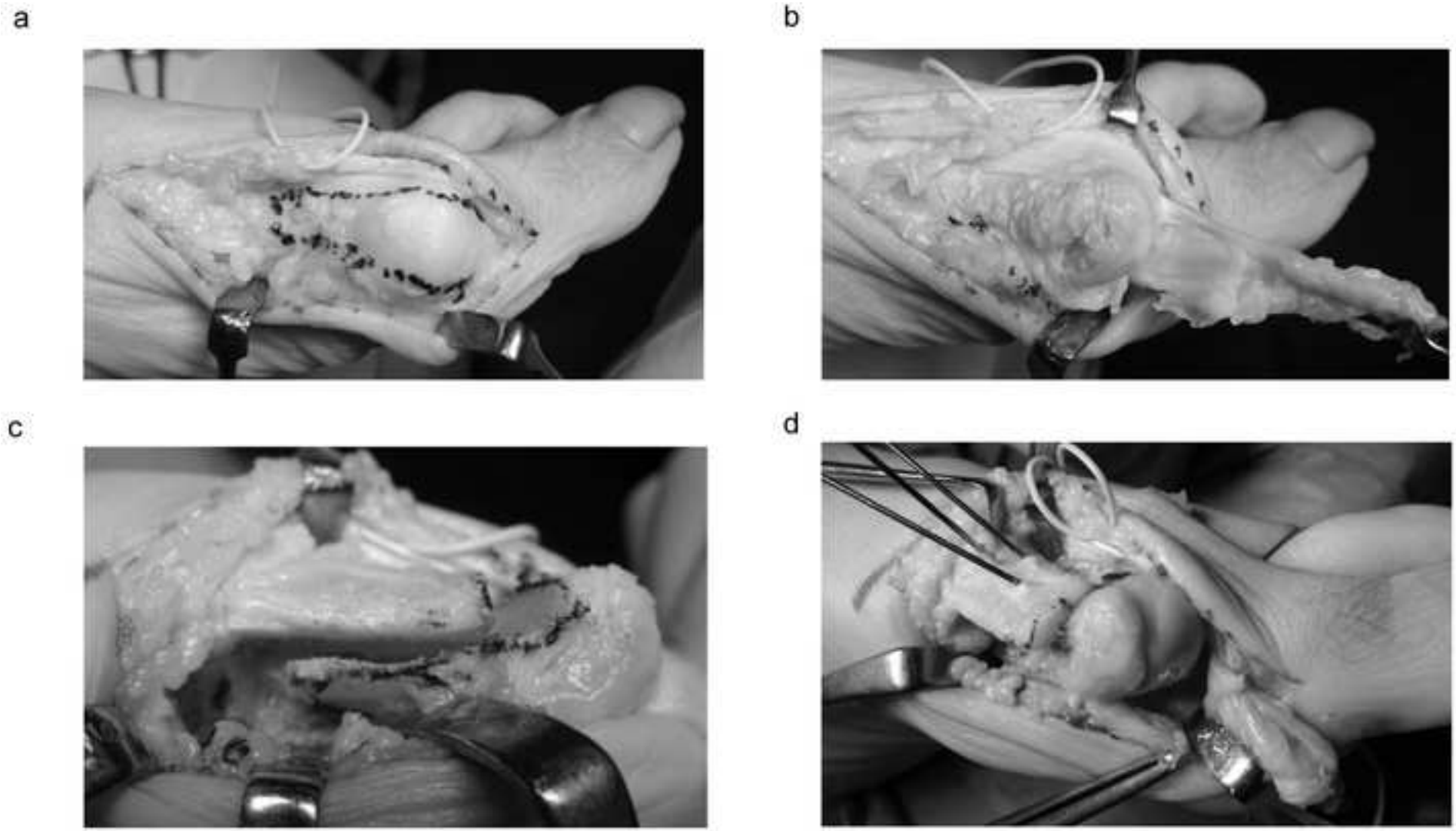

Figure 3

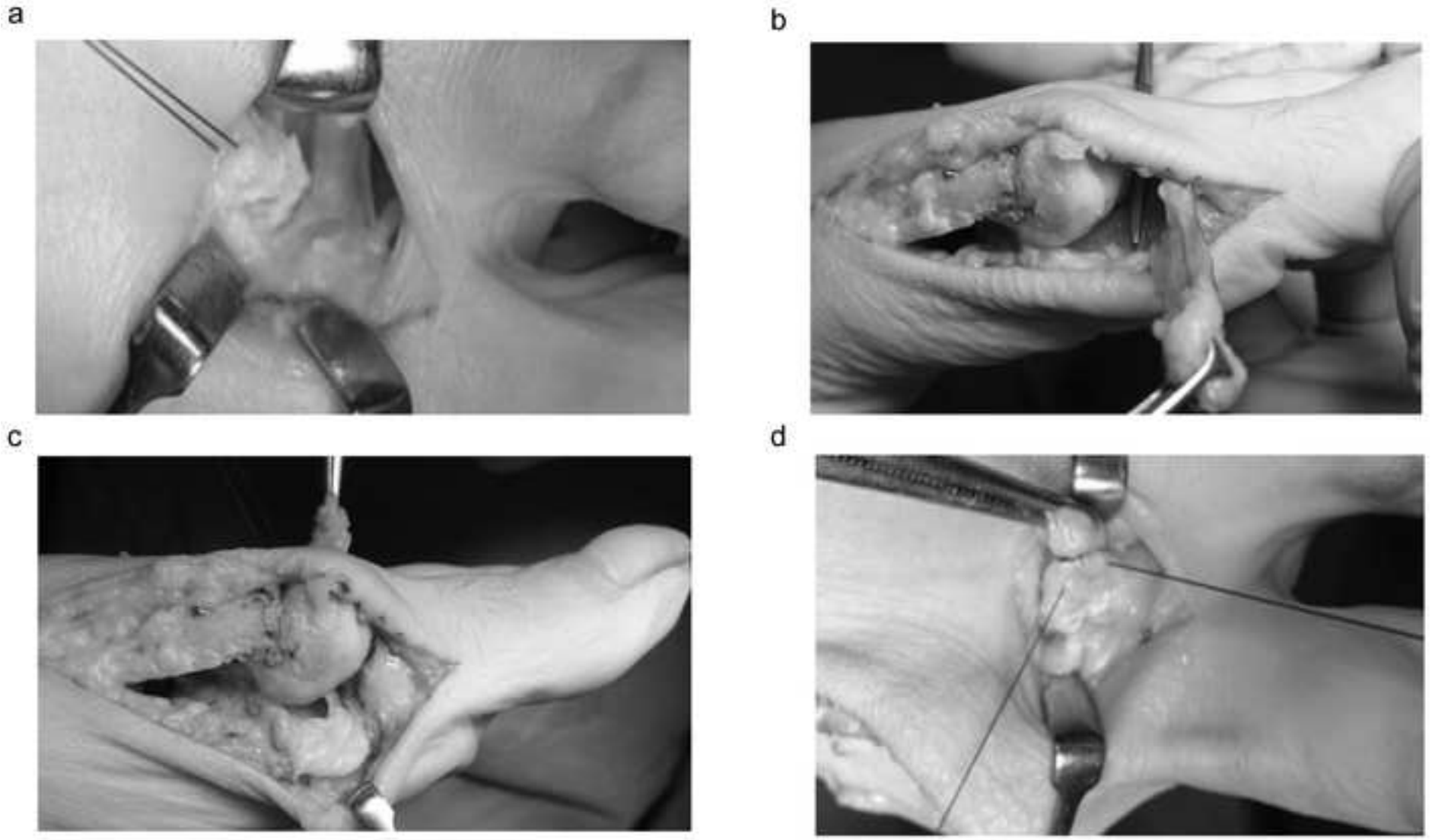

Figure 4

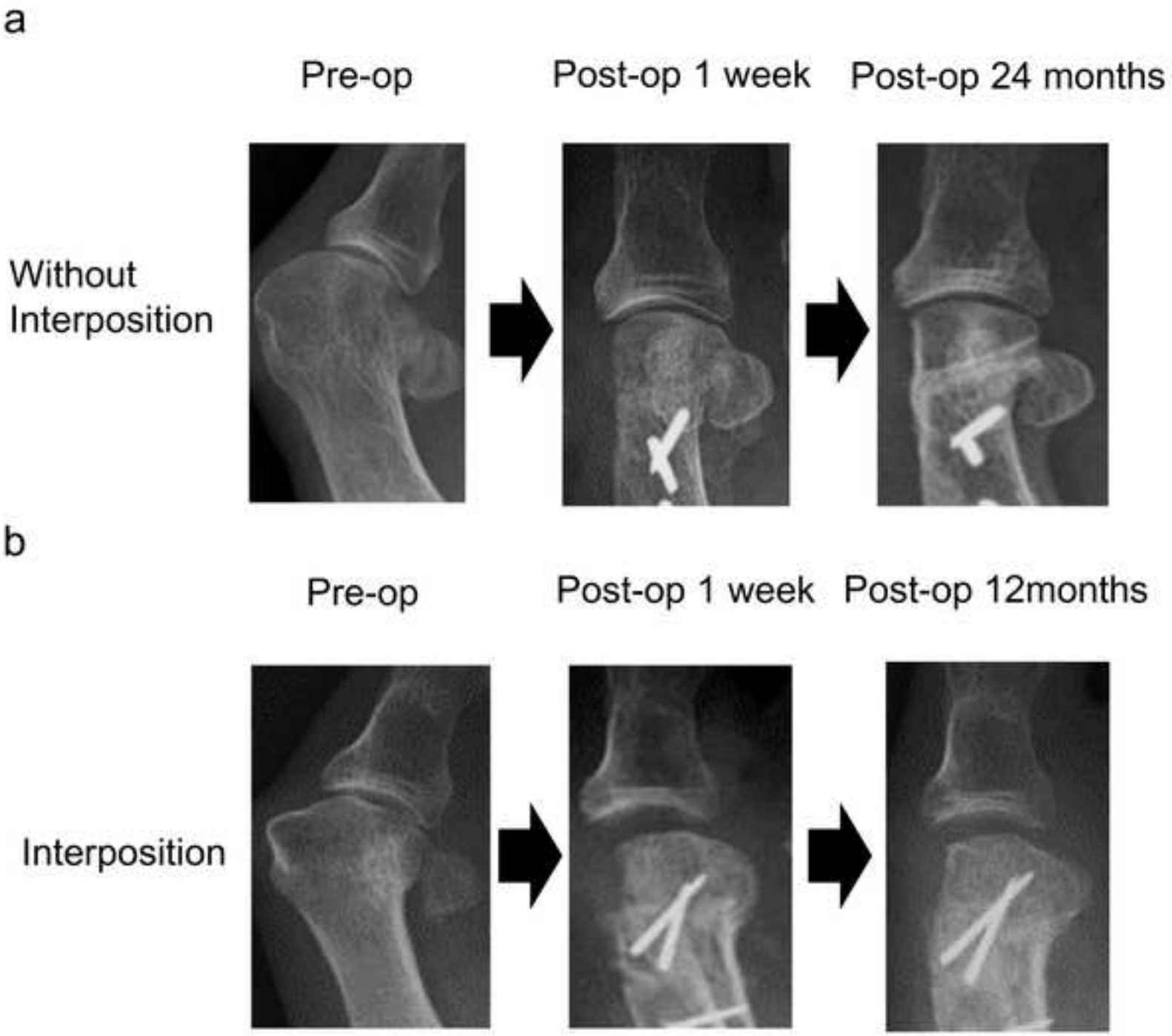
a
Pre-op
Post-op 1 week
Post-op 24 months
Without Interposition
b
Pre-op
Post-op 1 week
Post-op 12months
Interposition

Figure 5

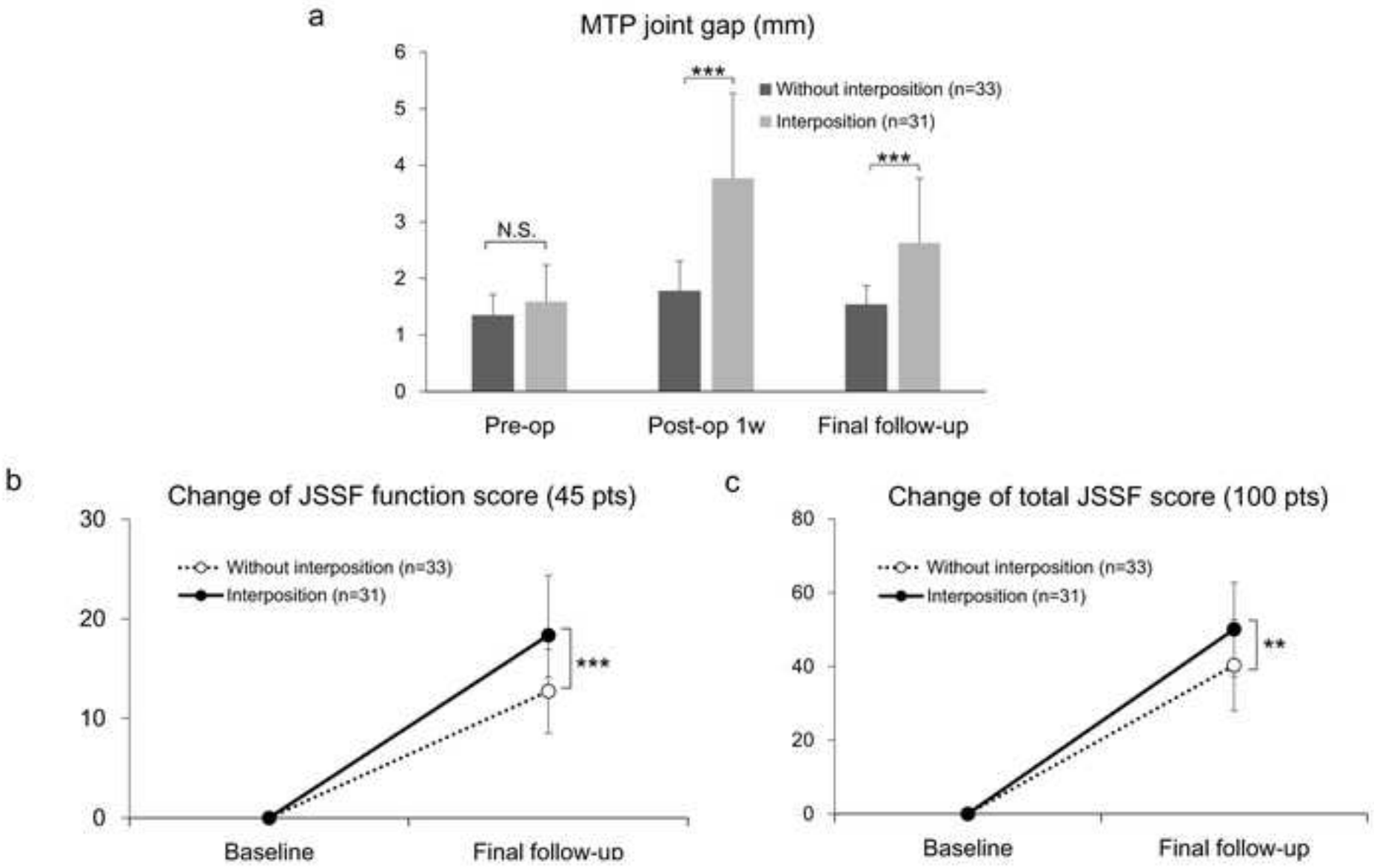
a
MTP joint gap (mm)
6
5
4
3
2
1
0
***
***
N.S.
Without interposition (n=33)
Interposition (n=31)
Pre-op
Post-op 1w
Final follow-up
b
Change of JSSF function score (45 pts)
30
20
10
0
Without interposition (n=33)
Interposition (n=31)
***
Baseline
Final follow-up
c
Change of total JSSF score (100 pts)
80
60
40
20
0
Without interposition (n=33)
Interposition (n=31)
**
Baseline
Final follow-up

Figure 6

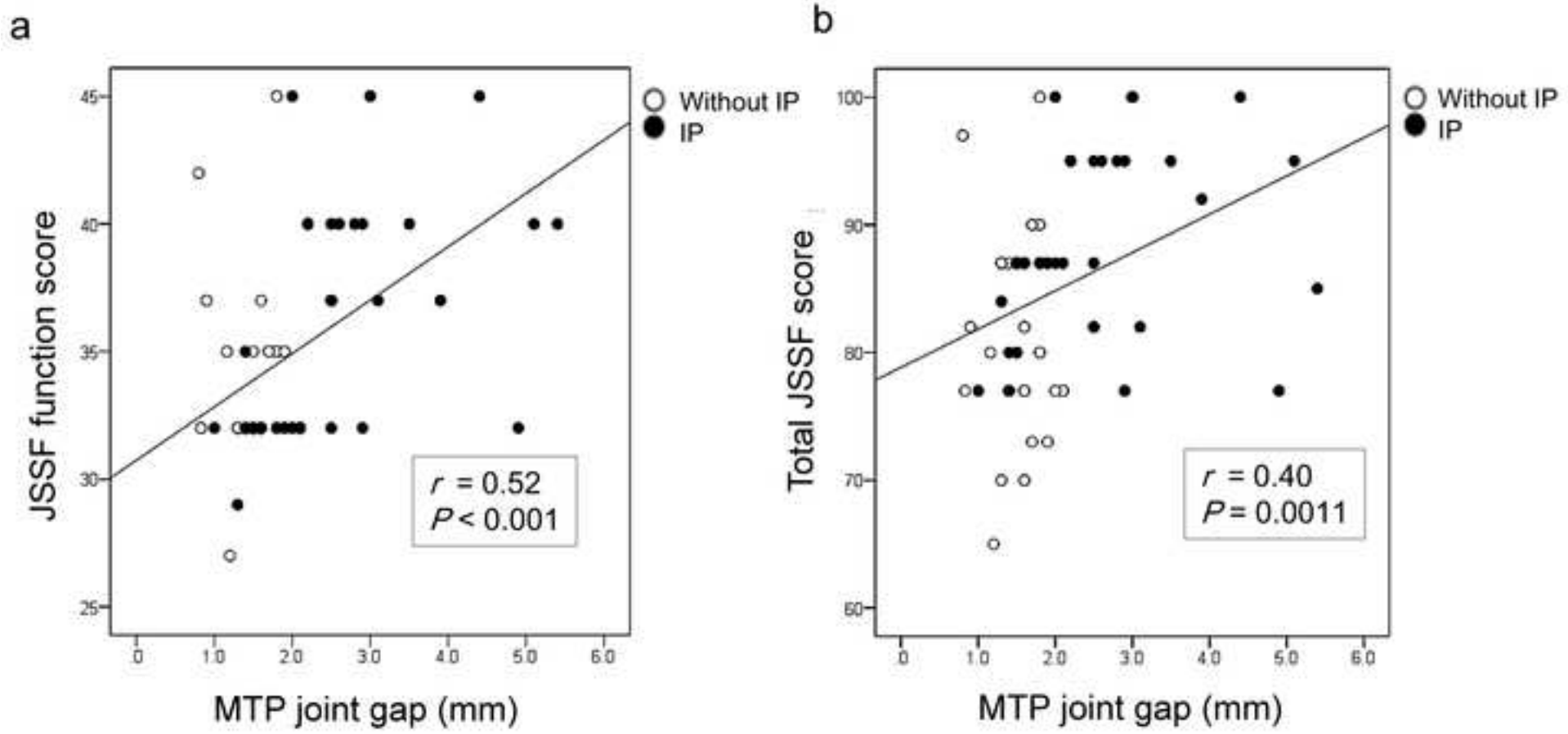
a
JSSF function score
MTP joint gap (mm)
Without IP
IP
r = 0.52
P < 0.001
b
Total JSSF score
MTP joint gap (mm)
Without IP
IP
r = 0.40
P = 0.0011

Table 1. Baseline clinical characteristics by group

Variable		Without interposition (n=33)	Interposition (n=31)	*P* value
Operation methods (n)	Hallux	Modified Scarf (n=33)	Modified Scarf (n=31) Akin osteotomy (n=1)	
	Lesser toes	Off-set osteotomy (n=16)	Off-set osteotomy (n=20)	0.20
Age, (years)		65.5±12.0 (40-87)	72.3±9.4 (48-93)	0.014
Gender, Females (%)		93.9	87.1	0.63
Body mass index (kg/m^2)		22.5±3.1 (18.1-30.1)	23.1±2.4 (19.0-28.5)	0.39
Clinical scores				
Total JSSF score (100 points)		41.5±1.9 (15-65)	38.5±1.9 (14-65)	0.27
Pain score (40 points)		19.4±7.0 (0-30)	18.4±6.9 (0-30)	0.57
Function score (45 points)		20.8±5.4 (14-35)	18.3±5.4 (10-32)	0.063
Alignment score (15 points)		1.2±2.9 (0-8)	1.8±3.4 (0-8)	0.46
Radiographic assessment				
HV angle (°)		45.4±7.7 (30-65)	41.9±8.3 (28-57)	0.084
M1M2 angle (°)		16.0±3.9 (2-22)	16.3±4.3 (10-29)	0.83
M1M5 angle (°)		36.2±5.3 (26-50)	37.3±5.9 (21-47)	0.43
Sesamoid Hardy grade (1-7)		6.5±0.8 (4-7)	6.6±0.7 (5-7)	0.86
Hallux MTP joint gap (mm)		1.4±0.4 (1.0-2.1)	1.6±0.7 (0.9-3.2)	0.092

Mean ± Standard Deviation (range). JSSF, Japanese Society of Surgery of the Foot; HV, Hallux valgus; M1M2, first metatarsal and second metatarsal; M1M5, first metatarsal and fifth metatarsal; MTP, metatarsophalangeal. Differences between the groups were determined by the Mann-Whitney U test or the chi-squared test.

Table 2. Operation-related outcomes by group

Variable	Without interposition (n=33)	Interposition (n=31)	*P* value
Follow-up duration (months)	25.7±2.0 (13-50)	27.5±1.7 (13-45)	0.49
Clinical scores of final follow-up			
Total JSSF score (100 points)	81.8±7.7 (65-100)	88.5±7.6 (77-100)	<0.001
Change of total JSSF score	40.3±12.4 (20-75)	50.0±12.7 (22-81)	0.0029
Pain score (40 points)	34.2±5.0 (30-40)	37.1±4.6 (30-40)	0.021
Change of pain score	14.8±8.3 (0-40)	18.7±8.8 (10-40)	0.078
Function score (45 points)	33.6±3.2 (27-45)	36.6±4.8 (29-40)	0.0045
Change of function score	12.7±4.2 (0-20)	18.4±6.0 (5-30)	<0.001
Alignment score (15 points)	13.9±2.5 (8-15)	14.8±1.3 (8-15)	0.10
Change of alignment score	12.7±3.5 (7-15)	13.0±3.5 (7-15)	0.79
Radiographic assessment			
Post-op 1 week			
HV angle (°)	6.3±6.6 (-4-19)	6.8±6.1 (-12-18)	0.79
M1M2 angle (°)	4.2±3.1 (-5-10)	5.1±2.4 (1-9)	0.16
M1M5 angle (°)	18.4±4.9 (9-29)	19.0±5.1 (7-27)	0.62
Sesamoid Hardy grade (1-7)	2.9±1.3 (1-6)	2.5±0.9 (1-4)	0.17
Hallux MTP joint gap (mm)	1.8±0.5 (0.6-3.1)	3.8±1.5 (1.0-8.1)	<0.001
Change of hallux MTP joint gap	0.4±0.5 (-0.2-1.7)	2.1±1.5 (0-6.8)	<0.001
Final follow-up			
HV angle (°)	13.7±6.4 (2-26)	10.7±8.8 (-10-26)	0.13
M1M2 angle (°)	6.8±2.7 (2-14)	7.6±3.3 (1-14)	0.29
M1M5 angle (°)	24.6±4.8 (17-36)	25.6±5.1 (12-41)	0.42
Sesamoid Hardy grade (1-7)	3.2±1.4 (1-6)	3.1±1.0 (1-5)	0.79
Hallux MTP joint gap (mm)	1.5±0.3 (0.8-2.1)	2.6±1.1 (1.0-5.4)	<0.001
Change of hallux MTP joint gap	0.2±0.4 (-0.9-1.2)	1.0±1.1 (-0.3-4.1)	<0.001

Mean ± Standard Deviation (range). JSSF, Japanese Society of Surgery of the Foot; Post-op, postoperation; HV, Hallux valgus; M1M2, first metatarsal and second metatarsal; M1M5, first metatarsal and fifth metatarsal; MTP, metatarsophalangeal. Differences between the groups were determined by the Mann-Whitney U test.