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First Metatarsal Proximal Opening Wedge Osteotomy for Correction of Hallux Valgus Deformity: Comparison of Straight versus Oblique Osteotomy

Seung Hwan Han,[1] Eui Hyun Park,[2] Joon Jo,[3] Yong Gon Koh,[3] Jin Woo Lee,[1] Woo Jin Choi,[1] and Yong Sang Kim[3]

[1]Department of Orthopaedic Surgery, Yonsei University College of Medicine, Seoul;
[2]Department of Orthopaedic Surgery, Yonsei Altair Hospital, Seoul;
[3]Department of Orthopaedic Surgery, Yonsei Sarang Hospital, Seoul, Korea.

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Corresponding author: Dr. Yong Sang Kim, Department of Orthopaedic Surgery, Yonsei Sarang Hospital, 10 Hyoryeong-ro, Seocho-gu, Seoul 137-820, Korea.
Tel: 82-2-2023-5558, Fax: 82-2-2023-5597
E-mail: yskimos@gmail.com

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Purpose: The aim of this study was to compare clinical and radiographic outcomes of proximal opening wedge osteotomy using a straight versus oblique osteotomy. **Materials and Methods:** We retrospectively reviewed 104 consecutive first metatarsal proximal opening wedge osteotomies performed in 95 patients with hallux valgus deformity. Twenty-six feet were treated using straight metatarsal osteotomy (group A), whereas 78 feet were treated using oblique metatarsal osteotomy (group B). The hallux valgus angle (HVA), intermetatarsal angle (IMA), distal metatarsal articular angle, and distance from the first to the second metatarsal (distance) were measured for radiographic evaluation, whereas the American Orthopaedic Foot and Ankle Society (AOFAS) forefoot score was used for clinical evaluation. **Results:** Significant corrections in the HVA, IMA, and distance from the first to the second metatarsal were obtained in both groups at the last follow-up (p<0.001). There was no difference in the mean IMA correction between the 2 groups (6.1±2.7° in group A and 6.0±2.1° in group B). However, a greater correction in the HVA and distance from the first to the second metatarsal were found in group B (HVA, 13.2±8.2°; distance, 25.1±0.2 mm) compared to group A (HVA, 20.9±7.7°; distance, 28.1±0.3 mm; p<0.001). AOFAS scores were improved in both groups. However, group B demonstrated a greater improvement relative to group A (p=0.005). **Conclusion:** Compared with a straight first metatarsal osteotomy, an oblique first metatarsal osteotomy yielded better clinical and radiological outcomes.

Key Words: Hallux valgus, proximal opening wedge osteotomy, straight, oblique, low-profile plate

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INTRODUCTION

For hallux valgus deformity correction, a proximal metatarsal osteotomy is often used for moderate to severe deformity because it allows for greater correction of

an increased intermetatarsal angle (IMA), compared to a distal osteotomy.[1] Numerous proximal osteotomy operative techniques have been described, including crescentic, chevron, Mau, Scarf, Ludloff, and biplanar closing wedge osteotomies, with varying results,[2-7] and the optimal method for osteotomy remains controversial.[8]

First metatarsal proximal opening wedge osteotomy is a proximal corrective osteotomy for hallux valgus deformity that was first described by Trethowan.[9] This original procedure is seldom used because of its technically demanding nature, involving the use of a bone graft wedge, and concerns about nonunion and instability.[10,11] In spite of these concerns, a stable, proximal osteotomy that maintains the relative length of the first metatarsal in relation to the second is needed.[12] Recently, a proximal opening wedge osteotomy using a low-profile wedge plate (Low Profile Plate and Screw System; Arthrex, Naples, FL, USA) was developed, and a few studies have evaluated this procedure.[12-14] According to the guidelines of this surgical procedure, either a straight or oblique first metatarsal osteotomy can be performed based on the surgeons' preference.[12-14] To our best knowledge, however, there are no comparative studies between a straight and oblique first metatarsal osteotomy for proximal opening wedge osteotomy using a low profile wedge plate. Even though previous studies, which used a straight or oblique first metatarsal osteotomy, reported suitable clinical and radiological results, various factors can influence the outcomes of hallux valgus surgery. Park, et al.[15] reported that a larger IMA and wider distance from the first to the second metatarsal contributed to the recurrence of hallux valgus deformity. Therefore, we postulated that two different osteotomy directions could influence the correction of the IMA and distance from the first to the second metatarsus, as well as the postoperative clinical results. The aim of this study was to investigate and compare the clinical and radiographic outcomes of proximal opening wedge osteotomy using a straight versus oblique osteotomy.

MATERIALS AND METHODS

A total of 104 consecutive cases in 95 patients with hallux valgus deformity between May 2010 and November 2011 were retrospectively reviewed for this study. All cases received proximal opening wedge osteotomies using a low-profile plate. Twenty-six feet were treated using a straight osteotomy (group A), whereas 78 feet were treated using an oblique osteotomy (group B). Inclusion criteria were symptomatic, moderate-to-severe hallux valgus deformity with a hallux valgus angle (HVA) greater than 20° and an IMA greater than 12°. Fourteen feet in group A and 44 feet in group B had the moderate deformity (HVA of 20° to 40° or IMA of 12° to 15°), and 44 feet in group A and 34 feet in group B had the severe deformity (HVA of greater than 40° or IMA of greater than 15°). All patients had undergone previously failed non-operative treatment consisting of shoe modification and non-steroidal anti-inflammatory medication. Patients with rheumatoid arthritis, failed hallux valgus surgery, symptomatic or radiographic evidence of hallux rigidus, or instability of the first metatarsocuneiform joint were excluded from this study.

The study included 86 women and 9 men with an average age of 45.3 years (range, 21–67 years) at the time of surgery. Among the 104 hallux valgus deformities, 42 occurred in the right foot, 44 in the left foot, and 9 in both feet. The average follow-up period was 24.5 months (range, 19–42 months) in group A and 23.6 months (range, 18–32 months) in group B. There were no significant differences in the patient gender, age, and follow-up period between the groups (Table 1). The study protocols were approved by our ethics committee.

Surgical procedure

Patients were placed in the supine position, and surgery was performed under spinal or general anesthesia. The operative technique consisted of distal soft tissue procedures, excision of the medial eminence, proximal opening wedge osteotomy, and plication of the medial joint capsule. Through a dorsal first web space incision, the transverse metatarsal ligament, adductor hallucis tendon, and lateral capsule were sharply released. A medial longitudinal incision was made over the medial eminence and extended proximally along the first metatarsal shaft to the first metatarsocuneiform joint. A T-shaped medial capsulotomy was performed, and a strip of capsule was excised. The medial eminence of the first metatarsal head was removed 1 mm medial to the sagittal sulcus. Subsequently, metatarsal osteotomy was performed using a small oscillating saw.

In the straight osteotomy group, a straight cut was made into the proximal medial metatarsal base, approximately 1.0 cm from the first metatarsocuneiform joint where the osteotomy was performed, midway between the dorsal and plantar surfaces, leaving the lateral cortex and periosteum intact (Fig. 1). In the oblique osteotomy group, an oblique cut was

Table 1. Demographic Data

Parameters	Group A	Group B	Total	*p* value
Number of patients/feet	24/26	71/78	95/104	
Sex				0.061
Male	2	7	9	
Female	22	64	86	
Mean age, yrs	41.9±12.7	46.4±11.7	45.3±12.0	0.051
Follow-up period, months	24.5±4.7	23.6±3.1	23.8±3.6	0.109

Data are presented as means±standard deviations unless otherwise indicated.

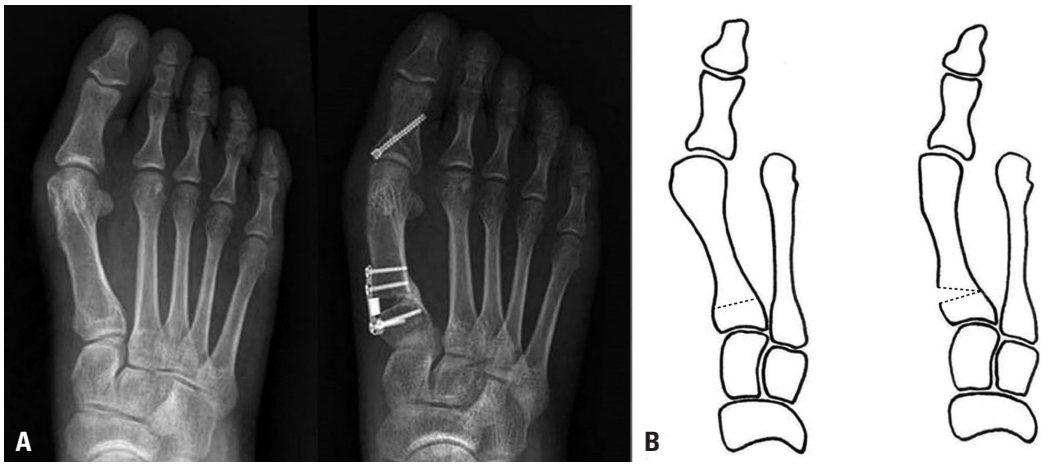

Fig. 1. Preoperative (left) and 3-month postoperative (right) weight-bearing anteroposterior radiographs (A) and schematic drawings (B) of a proximal opening wedge osteotomy utilizing a straight osteotomy. Although the intermetatarsal angle was corrected after surgery, the distance from the first to the second metatarsal was not significantly decreased, and the hallux valgus angle was not corrected.

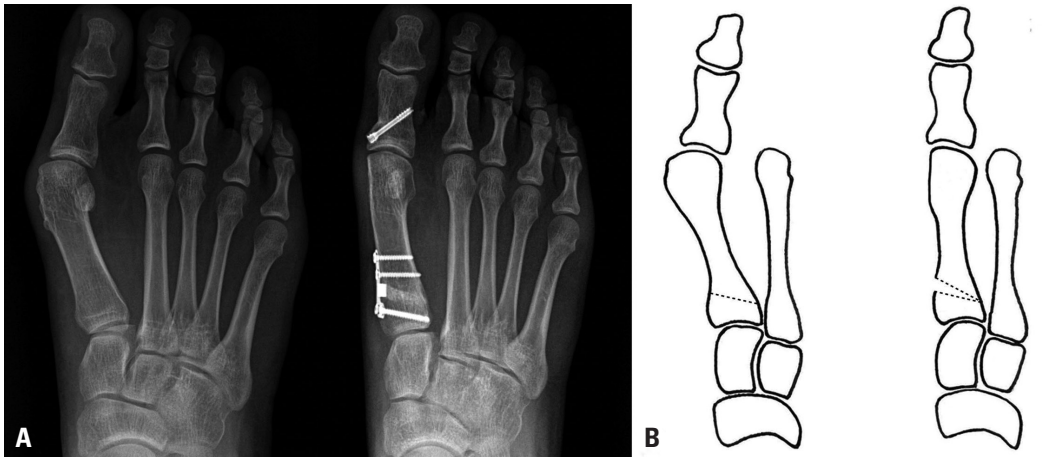

Fig. 2. Preoperative (left) and 12-month postoperative (right) weight-bearing anteroposterior radiographs (A) and schematic drawings (B) of a proximal opening wedge osteotomy utilizing an oblique osteotomy. After surgery, the intermetatarsal angle and hallux valgus angle were corrected, and the distance from the first to the second metatarsal was decreased.

made into the proximal medial metatarsal base, beginning approximately 1.5 cm distal to the first metatarsocuneiform joint, then angled so that the lateral apex was positioned approximately 5 mm distal to the first metatarsocuneiform joint (Fig. 2). Care was taken to avoid breaking the lateral cortex, by performing the osteotomy under direct vision until the sawblade just touched the lateral cortex. The osteotomy was carefully opened to the desired width using an osteotome, and a mini lamina spreader was inserted to hold the desired correction of the IMA under fluoroscopic visualization. The appropriate opening wedge plate (Low Profile Plate and Screw System; Arthrex) was selected based on fluoroscopic visualization of first metatarsal correction (i.e., it was parallel to the second metatarsal). The plate was first secured by screw fixation in the most proximal of the distal screw holes. The two distal screws were always placed

perpendicular to the long axis of the first metatarsal. Both proximal screws were placed parallel to the osteotomy in an oblique fashion. Then, the final distal screw was placed. A similar surgical technique has been previously reported.[12-14] Cancellous bone, obtained from the excised medial eminence or a demineralized bone matrix product (DBM, CG Bio Inc., Seoul, Korea), was packed into the osteotomy site. Then, the medial capsule was repaired using absorbable sutures. An Akin osteotomy was performed at the base of the proximal phalanx when a hallux valgus interphalangeus deformity and/or pronation of the hallux were present. After surgery, a coban strap dressing was applied for the first 2 weeks, and patients were allowed to bear weight as tolerated on their heel and lateral forefoot in an open, hard-soled surgical shoe. Upon radiographic evidence of healing at the osteotomy site, usually 6 weeks later, transfer of weight to the forefoot in a regular shoe was permitted.

Radiographic evaluation

To measure the HVA, IMA, distal metatarsal articular angle (DMAA), the degree of lateral translation of the first metatarsal head, and the congruency of the first metatarsophalangeal joint, standing weight-bearing anteroposterior and lateral radiographs were obtained before surgery, 1 day, 6 weeks, 3 and 6 months after surgery, and at the final follow-up. To avoid potential bias, an independent observer, who was a musculoskeletal-trained radiologist not involved in the care of the patients and blinded to the intention of this study, evaluated the radiographs. The HVA was measured as the angle between a line from the center of the metatarsal base to the center of the first metatarsal head and a line connecting the midpoints of the proximal and distal articular surfaces of the proximal phalanx. The IMA was measured as the angle between a line of the first metatarsal and a line bisecting the diaphyseal portions of the second metatarsal bone.[16] The DMAA was measured on anteroposterior radiograph. To measure the DMAA, a line was drawn from the most medial extent of the metatarsal articular surface to its most lateral extent. A perpendicular line was then drawn to this articular line. The angle between this perpendicular line and the long axis of the metatarsal was determined as the DMAA.[17] To determine the degree of lateral translation of the first metatarsal head, the distance from the first to the second metatarsal was measured on anteroposterior radiographs as the shortest distance between the center of the first metatarsal head and the longitudinal axis of the second metatarsal, as described by Park, et al.[15]

Clinical evaluation

For clinical evaluation, the American Orthopaedic Foot and Ankle Society (AOFAS) forefoot score for the hallux[18] was used. All patients were evaluated before surgery and as part of the follow-up. Furthermore, patients rated their overall satisfaction with the operation as excellent, good, fair, or poor, and were asked whether they would undergo the procedure again under similar circumstances.

Statistical analysis

To evaluate changes between preoperative and final follow-up values, a Wilcoxon signed-rank test was used for group A and the paired t test was used for group B. The Mann-Whitney U test was performed to compare the outcomes between groups A and B. All continuous data were expressed as mean±standard deviation. The Spearman rank-order correlation test was used to analyze the correlation between the congruency of the first metatarsophalangeal joint and performance of the Akin osteotomy in both groups. To analyze the association between clinical and radiographic outcomes at the final follow-up in each group, we used stepwise multivariate linear regression to assess the correlation between the AOFAS score and radiographic outcomes, including HVA, IMA, DMAA, and the distance from the first to the second metatarsal. We used SPSS version 15.0 (IBM Corporation, Armonk, NY, USA) for all analyses, and statistical significance was accepted for p values less than 0.05.

RESULTS

Radiographic outcomes

Radiographic outcomes are summarized in Table 2. There were no significant differences between the groups in the preoperative HVA, IMA, DMAA, and distance from the first to the second metatarsal. Significant corrections in the HVA, IMA, and distance from the first to the second metatarsal were obtained in both groups at the final follow-up (p<0.001). The HVA decreased from 34.6±6.4° to 20.9±7.7° in group A and from 33.7±8.4° to 13.2±8.2° in group B. Mean HVA correction was 13.6±6.9° in group A and 20.6±8.1° in group B, with a significant difference between the 2 groups at the final follow-up (p<0.001). The IMA improved from 17.5±3.0° to 6.1±2.7° in group A and from 16.7±1.5° to 6.0±2.1° in group B. The mean IMA correction was 11.4±4.0° in group A and 10.7±2.4° in group B. No difference was detected in the mean IMA correction between the

Table 2. Comparison of Clinical and Radiographic Outcomes between the Groups

Parameter	Group A	Group B	*p* value*
AOFAS score			
Preoperative	51.5±6.1	50.3±6.0	0.326
Last follow-up	79.0±6.8	83.5±7.0	0.005
p value†	<0.001	<0.001	
Hallux valgus angle, °			
Preoperative	34.6±6.4	33.7±8.4	0.724
Last follow-up	20.9±7.7	13.2±8.2	<0.001
p value†	<0.001	<0.001	
Intermetatarsal angle, °			
Preoperative	17.5±3.0	16.7±1.5	0.112
Last follow-up	6.1±2.7	6.0±2.1	0.883
p value†	<0.001	<0.001	
Distal metatarsal articular angle, °			
Preoperative	3.2±1.4	2.9±1.3	0.365
Last follow-up	7.8±2.9	7.4±3.5	0.509
p value†	<0.001	<0.001	
Distance from the first to second metatarsal, mm			
Preoperative	29.9±0.3	30.2±0.3	0.751
Last follow-up	28.1±0.3	25.1±0.2	<0.001
p value†	0.036	<0.001	

AOFAS, American Orthopaedic Foot and Ankle Society.
Data are presented as means±standard deviations.
*Mann-Whitney U test.
†Wilcoxon signed-rank test for group A and paired t-test for group B.

groups (p=0.883). The distance from the first to the second metatarsal decreased from 29.9±0.3 mm to 28.1±0.3 mm in group A and from 30.2±0.3 mm to 25.1±0.2 mm in group B. The mean change in the distance from the first to the second metatarsal was 1.8±0.4 mm in group A and 4.9±0.2 mm in group B, and was significantly different between the two groups at the final follow-up (p<0.001). The mean DMAA was significantly increased from 3.2±1.4° preoperatively to 7.8±2.9° at last follow-up in group A, and from 2.9±1.3° to 7.4±3.5° in group B. There were no significant differences in the DMAA at last-follow-up (p=0.509) between the groups. We compared the HVA and distance from the first to the second metatarsal at the final follow-up in both groups, and a good correlation was found by linear regression analysis in group B (r=0.844, p<0.001). However, no significant correlation was found in group A (r=0.134, p=0.480). The Akin osteotomies were performed in 18 cases of group A (69.2%) and 57 of group B (73.1%). Congruencies of the first metatarsophalangeal joint were observed in all cases of both groups on the immediate postoperative radiographs. However, at the final follow-up, incongruences of the first metatarsophalangeal joint were observed in 10 group A (38.5%) and 11 group B (14.1%) cases. According to the Spearman rank-order correlation test, there was no significant correlation between the first metatarsophalangeal joint congruency and performance of the Akin osteotomy in both groups (Table 3).

Clinical outcomes

The AOFAS score showed a significant improvement in both groups, from 51.5±6.1 to 79.0±6.8 in group A and from 50.3±6.0 to 83.5±7.0 in group B (p<0.001). There was a significant difference in the mean AOFAS score at the final follow-up between groups (p=0.005) (Table 2). As for the overall patient satisfaction with the operation, 9 patients (38%) reported their satisfaction as excellent, 6 (25%) as good, 5 (20%) as fair, and 4 (17%) as poor in group A, and 44 (62%) as excellent, 24 (34%) as good, 2 (3%) as fair, and 1 (1%) as poor in group B. The satisfaction rate of group B was higher than group A (p<0.001). The 4 patients in group A and 1 in group B who graded their satisfaction as poor stated that they would not be willing to undergo the same operation again. The remaining 20 patients (83%) in group A and 70 (99%) in group B stated that they would be willing to undergo the same foot operation again.

Table 3. Correlation between the Congruency of the First Metatarsophalangeal Joint and Performance of the Akin Osteotomy in Both Groups

	Group A, No. (%)				Group B, No. (%)			
	Akin (+)	Akin (-)	CC	*p* value	Akin (+)	Akin (-)	CC	*p* value
Preoperative			-	-			-	-
Congruent	4 (15.4)				11 (14.1)			
Incongruent	22 (84.6)				67 (85.9)			
Postoperative								
Congruent	18 (100)	8 (100)	-	-	57 (100)	21 (100)	-	-
Incongruent	0 (0)	0 (0)			0 (0)	0 (0)		
Last follow-up			0.013	0.95			0.080	0.49
Congruent	11 (55.6)	5 (62.5)			48 (84.2)	19 (90.5)		
Incongruent	7 (44.4)	3 (37.5)			9 (15.8)	2 (9.5)		

Akin (+), performance of Akin osteotomy; Akin (-), nonperformance of Akin osteotomy; CC, correlation coefficient according to the Spearman rank-order correlation test.

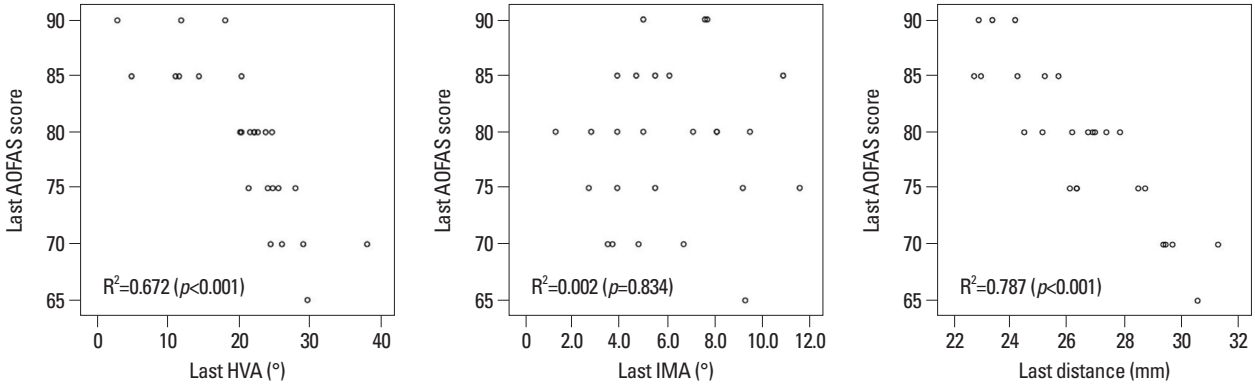

Fig. 3. Associations between the American Orthopaedic Foot and Ankle Society (AOFAS) score and final follow-up radiographic outcomes, including the hallux valgus angle (HVA), intermetatarsal angle (IMA), and distance from the first to the second metatarsal (distance), in group A.

Association between clinical and radiographic outcomes

In multivariate analyses, final follow-up AOFAS score, HVA, IMA, and distance from the first to the second metatarsal accounted for 67.2%, 0.2%, and 78.7% of the variability, respectively, in group A (Fig. 3) and for 2.2%, 2.0%, and 0.2% of the variability, respectively, in group B (Fig. 4). As illustrated in the scatter plots, the HVA and distance from the first to the second metatarsal significantly influenced the AOFAS score at the final follow-up (p<0.001), whereas the IMA did not influence the AOFAS score at the final follow-up (p=0.834) in group A. However, no radiographic outcome influenced the AOFAS score at the final follow-up in group B (p>0.05).

Complications

One patient in group A and 3 in group B developed superficial wound infections, which were treated successfully with antibiotics. Five patients each in both groups rated their satisfaction as poor. Four patients in group A complained of uncorrected HVA despite undergoing an Akin procedure at the time of the index surgery. Three patients in group A and 10 in group B had symptoms of plate irritation; the plates were removed after radiographic confirmation of union at the osteotomy site. There were no other complications such as sensory loss of the great toe, nonunion at the osteotomy site, recurrence of deformity, or development of hallux varus during the follow-up period.

DISCUSSION

A few retrospective studies have assessed the effectiveness of proximal opening wedge osteotomy using a low-profile plate.[12-14] In these studies, only a single osteotomy, either straight or oblique osteotomies, was utilized, based on the surgeons' preference. In the present study, we performed a proximal opening wedge osteotomy using both osteotomies. To our knowledge, this is the first study to compare the outcomes of hallux valgus correction utilizing a straight versus an oblique osteotomy.

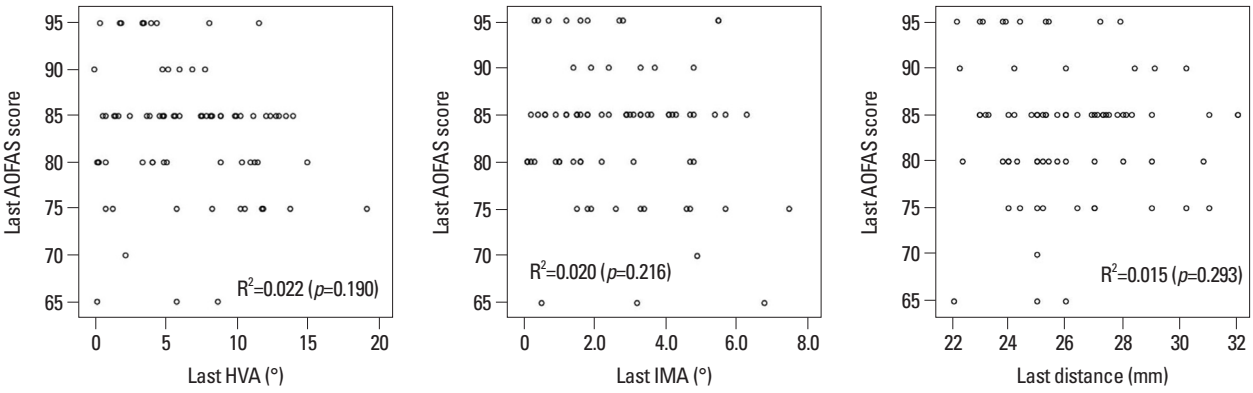

Fig. 4. Associations between the American Orthopaedic Foot and Ankle Society (AOFAS) score and final follow-up radiographic outcomes, including the hallux valgus angle (HVA), intermetatarsal angle (IMA), and distance from the first to the second metatarsal (distance), in group B.

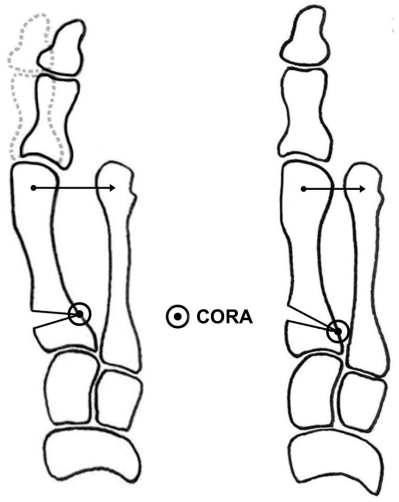

Fig. 5. In an oblique osteotomy (right), the center of rotation of angulation (CORA) is located more proximally and closer to the second metatarsal base than in a straight osteotomy (left). Thus, the distance from the first to the second metatarsal decreases more in an oblique osteotomy than in a straight osteotomy. In a straight osteotomy, correction of the hallux valgus angle (dotted line) is decreased because of the wide distance from the first to the second metatarsal.

Proximal opening wedge osteotomy using a low-profile plate is a straightforward procedure yielding excellent and reliable correction of hallux valgus deformity.[12-14] Randhawa and Pepper[14] reported that the mean HVA and IMA decreased significantly from 31.1° to 17.4° and from 18.4° to 8.1°, respectively, Shurnas, et al.[12] reported that the mean HVA improved from 30° to 10° and that the mean IMA also improved from 14.5° to 4.6°, Saragas[13] reported that the HVA and IMA improved by a mean of 14.7° and 6.4°, respectively. In the present study, significant corrections in the HVA and IMA were obtained in both groups. Although no difference between groups was detected in the mean IMA correction at the final follow-up (p=0.883), there was a significant difference in the mean HVA correction between groups (p<0.001) (Table 2). We believe that the mean preoperative HVA in this study was relatively larger than that in previous studies. Thus, correction of the HVA was not sufficient, especially in group A.

We also measured the distance from the first to the second metatarsal preoperatively and at the final follow-up. This distance was improved significantly in both groups (p=0.036 for group A and p<0.001 for group B), but there was also a significant difference in the mean change in distance between groups (p<0.001) (Table 2). Park, et al.[15] compared the results of hallux valgus surgery between feet fixed with Kirschner wires and those fixed with a plate, and reported that, although the immediate postoperative HVA was not different between the 2 groups, the plate group had a larger IMA and wider distance from the first to the second metatarsal. They concluded that a larger IMA and wider distance from the first to the second metatarsal attributed to the recurrence of hallux valgus. In the current study, the IMA was decreased similarly at the final follow-up in both groups, but the distance from the first to the second metatarsal was improved more in group B. We believe that the significant difference in the distance from the first to the second metatarsal between the groups at the final follow-up was due to a difference in the center of rotation of angulation (CORA) at the osteotomy site. When performing an oblique osteotomy, the CORA is located more proximally and closer to the second metatarsal base than in a straight osteotomy. Thus, the distance from the first to the second metatarsal decreases to a greater extent in an oblique osteotomy than in a straight osteotomy (Fig. 5). Moreover, by linear regression analysis, we found a good correlation between the last follow-up HVA and distance from the first to the second metatarsal in group A (r=0.844, p<0.001). This correlation was not observed in group B. Furthermore, we investigated if performance of an Akin osteotomy influ-

enced congruency of the first metatarsophalangeal joint at the final follow-up. According to a Spearman rank-order correlation test revealed no significant correlation between congruency of the first metatarsophalangeal joint and performance of an Akin osteotomy in both groups (Table 3). In addition, incongruences of the first metatarsophalangeal joint were observed in 7 cases despite the performance of 18 Akin osteotomies in group A. Therefore, we believe that a decreased distance from the first to the second metatarsal has more influence on HVA correction than an Akin osteotomy. Interestingly, the radiographic outcomes, which demonstrated significant improvements in the HVA and distance from the first to the second metatarsal between groups, support the significant differences in clinical outcomes between groups. In multivariate analyses, the HVA and distance from the first to the second metatarsal significantly influenced the AOFAS score at the final follow-up (p<0.001), whereas the IMA did not influence the AOFAS score at the final follow-up (p=0.834) in group A (Fig. 3). However, no radiographic outcome influenced the AOFAS score at the final follow-up in group B (p>0.05) (Fig. 4). These findings indicate that, in proximal opening wedge osteotomy using a low-profile plate, an oblique osteotomy is a more useful method than a straight osteotomy to obtain better clinical and radiographic outcomes.

Recent studies have reported suitable overall clinical outcomes of proximal opening wedge osteotomy using a low-profile plate.[12,13] Saragas[13] retrospectively evaluated 46 patients (64 feet) with hallux valgus deformity who underwent proximal opening wedge osteotomy using a low-profile plate, and reported significant improvement in the AOFAS score (from 51.3 to 86.8; p<0.0001). Similarly, Shurnas, et al.[12] retrospectively evaluated 78 patients (84 feet) and reported that 70 patients (89.7%) noted good to excellent subjective satisfaction after the surgery. In our study, similar postoperative clinical results were found in group B. However, the mean AOFAS score was significantly increased from 51.5 to 79.0 in group A and from 50.3 to 83.5 in group B (p=0.005) (Table 2). As for the overall patient satisfaction, 15 patients (63%) in group A and 68 (96%) in group B reported their satisfaction as good to excellent. We believe that the differences in patient satisfaction between the 2 groups were due to cosmetic demands of patients. As mentioned above, significant improvements in the HVA and distance from the first to the second metatarsal were achieved in group B, and these improvements might have contributed to a better appearance of the patient's feet, and consequently, better patient satisfaction. According to the linear regression analyses, good correlations of the HVA and distance from the first to second metatarsal with the patient satisfaction were found (r=0.724, p<0.001 for HVA and r=0.811, p<0.001 for distance, respectively).

The disadvantages of proximal opening wedge osteotomy using a low-profile plate include nonunion at the osteotomy site and lengthening of the first metatarsal by the opening wedge, which can result in tightening of the soft tissue and a higher rate of recurrence.[11,13,19] Shurnas, et al.[12] reported 1 case of nonunion in 78 patients (84 feet); revision with a Lapidus procedure was performed in that patient. They reported that even with nonunion, the plate and screws did not break, but the wedge became dissociated from the bone and recurrence of a widened IMA was evident. Fortunately, we found no nonunion. With regards to lengthening of the first metatarsal, Saragas[13] reported that despite a mean increase in the first metatarsal length of 2.3 mm, no complications were found due to this lengthening, and Shurnas, et al.[12] also reported a mean increase in the first metatarsal length of 1.9 mm, and found that the effect of lengthening was minimal and not statistically significant. In the current study, a mean increase in the first metatarsal length of 1.4 mm was observed, but no complications were found. Although we did not statistically compare the correlation between the lengthening of the first metatarsal and width of the open wedge, we believe that the amount of lengthening in the current study was relatively minimal compared to that in previous studies because of the narrow opening wedges used.

The present study had some limitations. First, the number of patients was small, especially in group A, and the relatively short follow-up period. In addition, the data were retrospectively collected. For more accurate evaluation of the outcomes of hallux valgus correction using straight versus oblique osteotomy, a prospective randomized study and a larger series of cases with a longer follow-up period are required. Second, we found that the distance from the first to the second metatarsal decreased to a greater extent in an oblique osteotomy than in a straight osteotomy because the CORA is located more proximally and closer to the second metatarsal base in an oblique osteotomy than in a straight osteotomy. However, we cannot quantify the exact association between the amount of the decreases of the distance from the first to the second metatarsal achieved by two different osteotomies and location of CORA. Cadaveric study with precise measurements is required to compare the difference in magnitude of correction between the two osteot-

omies. Lastly, it is important to note potential long term effects of 'jamming' in the first metatarsopahalangeal joint from the lengthening of the first metatarsal. Therefore, a prospective study with a longer follow-up period is required to specifically look into this potential problem, and it is prudent for the authors to consider a distal shortening osteotomy of the first metatarsal.

In conclusion, this study shows satisfactory clinical and radiographic outcomes of proximal opening wedge osteotomy using a low-profile plate for correction of hallux valgus deformity. According to radiographic outcomes (including the HVA and distance from the first to the second metatarsal) and the associated clinical outcomes, the oblique osteotomy group had better results than the straight osteotomy group. Therefore, we recommend oblique osteotomy, rather than straight osteotomy, when performing proximal wedge osteotomy using a low-profile plate.

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