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Shortening Proximal Chevron Metatarsal Osteotomy for Patients With a Hallux Valgus Deformity With Advanced Arthritis

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ABSTRACT

To correct hallux valgus deformities in patients with advanced arthritis of the first metatarsophalangeal joint, we designed a new reverse chevron-type shortening osteotomy technique that could be used to correct valgus deformities at the proximal metatarsal level, as well as shorten and lower the metatarsal, in a 1-time procedure. Sixteen feet in 16 patients with a minimum of 18 months follow-up who underwent a shortening proximal chevron metatarsal osteotomy for a hallux valgus deformity with advanced arthritic change between January 2014 and March 2016 were reviewed in this study. Double chevron osteotomies with 20° of plantar-ward obliquity at the proximal metatarsal level were made at 5-mm intervals for simultaneous valgus correction and metatarsal shortening. An additional Weil osteotomy of the second metatarsal was performed in all feet. Patients' mean age was 57.88 ± 6.55 years. The deformity was satisfactorily corrected by the operation. The first metatarsal was shortened by approximately 8.75 mm, and the relative length of the second metatarsal did not differ significantly postoperatively ($p = .179$). The relative second metatarsal height, as seen on forefoot axial radiographs, was maintained constantly, with no significant difference ($p = .215$). No painful plantar callosity or transfer metatarsalgia under the second metatarsal head was observed postoperatively. A shortening proximal chevron metatarsal osteotomy for hallux valgus deformities with advanced arthritic change showed a good result with respect to deformity correction and pain relief. Appropriate lowering and an additional Weil osteotomy effectively prevented postoperative pain and painful callosity under the second metatarsal head.

Hallux valgus and rigidus are the 2 most common deformities of the first metatarsophalangeal (MTP) joint. Common causes of hallux rigidus include trauma, use of improper footwear, an excessively long first metatarsal bone, hypermobility or immobility of the first ray, a pronated foot, and microtrauma (1). A few studies have evaluated the use of a concomitant operation to correct hallux valgus deformities in patients with advanced arthritis (2).

To correct hallux valgus deformities in patients with advanced arthritis of the first MTP joint, we designed a new reverse chevron type of shortening osteotomy that could be used to correct valgus deformities at the proximal metatarsal level, as well as shorten and lower the metatarsal, in a 1-time procedure. Double chevron osteotomies with 20° of plantar-ward obliquity were made at 5-mm intervals (Fig. 1). An additional Weil osteotomy of the second metatarsal head was performed to prevent postoperative transfer metatarsalgia that could be affected by shortening of the first metatarsal.

In the present study, we examined the postoperative changes of radiographic and clinical parameters of a shortening proximal chevron metatarsal osteotomy (PCMO). Based on the report of Choi et al (3), which concluded that PCMO induced the greatest change in height of the second metatarsal head by achieving the greatest lowering of the first metatarsal head with the longest lever arm, we hypothesized that our shortening PCMO technique would improve the radiographic and clinical parameters of patients with hallux valgus and advanced arthritis.

Patients and Methods

Ethical Considerations

The patients provided informed consent to undergo a new procedure, and they were also informed about possible complications. Our institution's ethical review committee approved the study.

Patient Selection

Patients with a minimum of 18 months of follow-up who underwent a shortening PCMO for a hallux valgus deformity accompanied by advanced arthritic change (Fig. 2A) between January 2014 and March 2016 were reviewed in this study. Of 20 initially enrolled patients, those with first metatarsocuneiform hypermobility, systemic

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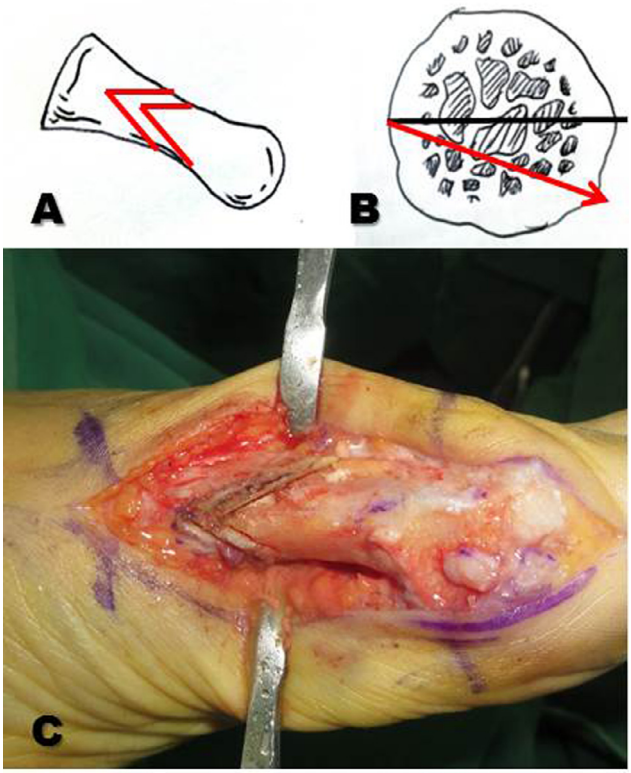

Fig. 1. The chevron-shaped shortening osteotomy technique at the proximal metatarsal level. Double chevron osteotomies (*A*) with 20° of plantar-ward obliquity (*B*) were made at 5-mm intervals. Double osteotomy before removal of the V-shaped fragment (*C*).

inflammatory conditions such as rheumatoid arthritis, and a history of trauma that could have affected the foot's alignment were excluded. Finally, 16 feet in 16 patients were evaluated.

Operative Technique

A single surgeon (J.Y.C) conducted all the operations. The patients were positioned supine on the operating table. Among the 16 feet that were operated on, 12 operations were performed under spinal anesthesia; the others were performed under ultrasound-guided combined sciatic and femoral nerve blocks.

First, a 2-cm vertical incision was made on the dorsum between the first and second metatarsal heads. Adductor tenotomy and extensor hallucis brevis resection from the lateral sesamoid bone were performed along with transverse intermetatarsal ligament and lateral capsule release.

The second medial incision was made longitudinally beyond the bunion. A T-shaped capsular incision, medial eminence resection, and cheilectomy were performed as per our regular protocol. An additional multiple drilling was performed with a 0.9-mm Kirschner wire (K-wire) on the cartilage's denuded surface for all cases (Fig. 2B, 2C). The mean percentage of the denuded cartilage of the metatarsal head was 85.63 ± 8.54 (range 75 to 100).

To conduct the PCMO, the surgeon placed the hindfoot in a neutral position, and a guide wire was inserted at the chevron osteotomy apex 7 mm distal from the first metatarsocuneiform joint with 20° of plantar-ward obliquity. The first chevron osteotomy was performed following the direction of the guide wire, and the second osteotomy was performed in the same manner, 5 mm distal to the first osteotomy (Fig. 2D). Then, a V-shaped fragment was removed. With lateral translation and rotation of the distal fragment to correct the valgus deformity, lowering of the first metatarsal head was achieved by virtue of the obliquely directed metatarsal osteotomy procedure. To fix the osteotomy site firmly, the surgeon fixed two or three 1.4- or 1.6-mm K-wires longitudinally (Fig. 2E, 2F). An additional Akin procedure of the proximal phalanx with 1.2-mm K-wires fixation was performed in 12 feet where the correction was not cosmetically satisfactory.

Next, the dorsal aspect of the second metatarsal head and neck was exposed through the first incision. The guide wire was fixed parallel to the weightbearing surface of the foot, which is generally between 35° and 45° from the long axis of the metatarsal bone. A Weil osteotomy with 5 mm of shortening in the transverse plane was conducted, and two 1.5 miniscrews were fixed in all feet. Extra caution was taken not to make the second metatarsal shorter than the third. Medial joint capsule repair and skin closure were performed. Postoperatively, only heel gait using specially designed shoes with hard outer soles was allowed for 6 weeks. The K-wires were removed under local anesthesia when the postoperative radiographs showed adequate bony union at 6 weeks; weightbearing on the forefoot was permitted afterward.

Assessments

First, the mean operation time was investigated. Then, arthritis of the first MTP joint was graded in all patients using 2 different criteria, those from Hattrup and Johnson (4) and also Coughlin and Shurnas (5). The former authors described grade 1 hallux rigidus as mild changes with a maintained joint space and minimal spurring; grade 2 as moderate changes with joint space narrowing, bony proliferation of the metatarsal head, and phalanx, and subchondral sclerosis or cysts; and grade 3 as severe changes with moderate to severe joint space narrowing, extensive bony proliferation, and the presence of loose bodies or a dorsal ossicle. The latter authors proposed a more elaborate classification system based on a combination of range of motion (ROM) and radiographic and clinical findings.

Using standing anteroposterior radiographs of the foot, we measured the hallux valgus angle, first-to-second intermetatarsal angle, and distal metatarsal articular angle preoperatively and postoperatively. The length of the first metatarsal and relative length

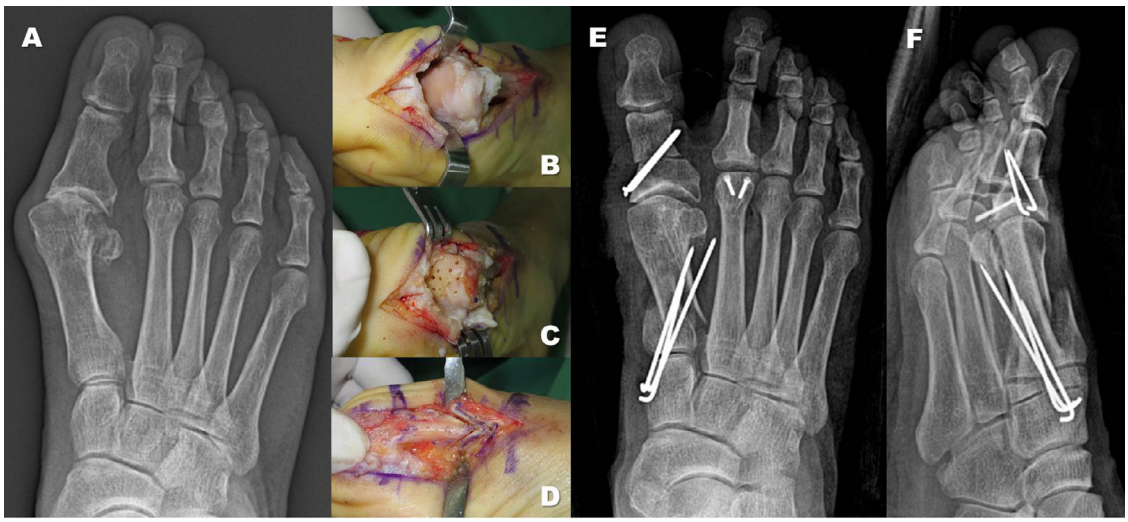

Fig. 2. A female, aged 58 years, with a hallux valgus deformity with advanced arthritic change of the first metatarsophalangeal joint (*A*). Cartilage denuding of the metatarsal head was noted intraoperatively (*B*). After removing the medial eminence, we performed multiple drilling with a 0.9-mm Kirschner wire (*C*). Double chevron osteotomies of the proximal metatarsal were performed (*D*). The immediate postoperative radiographs showed shortening (*E*) and lowering (*F*) of the metatarsal bone.

of the second metatarsal were measured. The length of the first metatarsal was defined as the longitudinal distance between the center of the first metatarsal base and the first metatarsal head (Fig. 3A). The relative length of the second metatarsal was defined as the perpendicular distance from the apex of the second metatarsal head to the line drawn between the apex of the first and third metatarsals (Fig. 3B). The interval between the first MTP joint space and medial sesamoid position according to the protocol of Hardy and Clapham (Fig. 3C) was measured (6).

Plantar offset was measured to determine dorsal or plantar migration of the distal fragment using standing foot lateral radiographs postoperatively (Fig. 3D). A negative value was assigned to dorsal migration of the first metatarsal head.

To evaluate the risk of postoperative transfer metatarsalgia or plantar callosity under the second metatarsal head more precisely, we measured the relative height of the second metatarsal head on forefoot axial radiographs, following the method of Suzuki et al (7). This procedure required a specially designed standing apparatus in

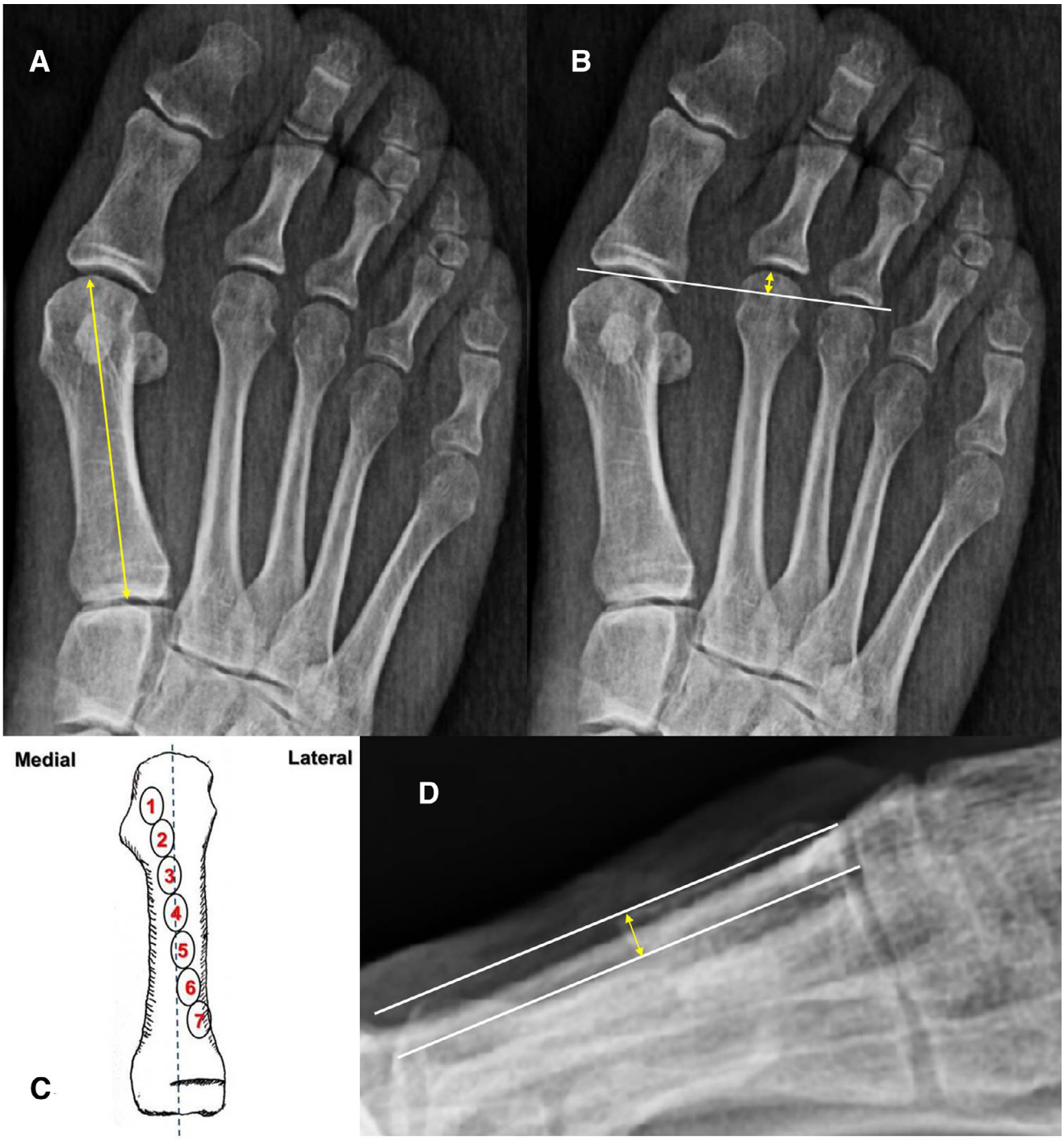

Fig. 3. The length of the first metatarsal was defined as the longitudinal distance between the center of the first metatarsal base and the first metatarsal head (*A*). The relative length of the second metatarsal was defined as the perpendicular distance from the apex of the second metatarsal head to the line drawn between the apex of the first and third metatarsals (*B*). Hardy and Clapham's medial sesamoid location numbering system (*C*) was based on the relationship to the longitudinal midline of the first metatarsal bone. Plantar offset was measured to determine dorsal or plantar migration of the distal fragment using standing lateral radiographs of the foot postoperatively (*D*).

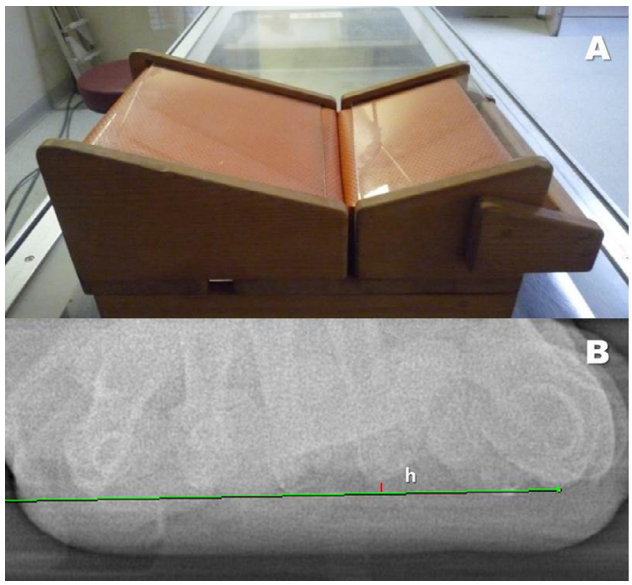

Fig. 4. A specially designed standing apparatus was used for axial radiography of the forefoot (*A*). The relative height of the second metatarsal head was defined as the perpendicular height of the second metatarsal head from the baseline, drawn from the lowest point of the first metatarsal head to the lowest point of the fifth metatarsal head (*B*).

which the patients' feet were adjusted to raise the hindfoot by 20° and the forefoot by 10°, thus positioning the MTP joint at the lowest point (Fig. 4A). The relative height of the second metatarsal head was defined as the perpendicular height of the second metatarsal head from the baseline, drawn from the lowest point of the first metatarsal head to the lowest point of the fifth metatarsal head (Fig. 4B).

Functional outcomes were evaluated using the American Orthopaedic Foot and Ankle Society hallux MTP interphalangeal scale (8,9), which is used to assess pain (40 points), function (45 points), and alignment (15 points). The standardized mean was calculated as a score between 0 and 100, with 100 representing the best possible outcome. ROM in both the first and second MTP joints (dorsiflexion and plantar flexion) was measured preoperatively and at the final follow-up visit. Complications related to the operation were also evaluated during the follow-up period.

Statistical Analyses

The means and standard deviations of all the dependent parameters were calculated using SPSS version 19 (SPSS, Inc., IBM Corp., Chicago, IL). Wilcoxon's signed rank test was used to assess the pre-operative and postoperative radiographic and clinical parameters. Statistical significance was determined as a p value of $<.05$ for all analyses.

Results

The patients' demographic data are shown in Table 1. The mean operation time was 45.38 ± 4.65 (range 40 to 55) minutes. The preoperative and postoperative radiographic parameters are presented in Table 2. The hallux valgus angle, intermetatarsal angle, and distal metatarsal articular angle were significantly improved postoperatively ($p = .001$, $<.0005$, and .005, respectively) (Fig. 5A). The first metatarsal was shortened by approximately 8.75 mm, whereas the relative length of the second metatarsal did not differ significantly postoperatively ($p = .179$). The medial sesamoid was decreased with statistical significance ($p = .0001$), and the first MTP joint space interval was increased by 3.37 mm. The mean postoperative plantar offset was 3.21 ± 0.42 (range 2.56 to 3.93) mm (Fig. 5B). The relative second metatarsal height, as seen on forefoot axial radiographs, was maintained constantly ($p = .215$).

Table 1
Demographic data of the patients (N = 16 feet* in 16 patients†)

Parameter	Mean ± SD (Range)
Mean age (y)	57.88 ± 6.55 (53 to 65)
Mean follow-up duration (mo)	22.19 ± 2.86 (19 to 27)
Mean preoperative Hattrup and Johnson hallux rigidus grade	2.69 ± 0.48 (2 to 3)
Mean preoperative Coughlin and Shurnas hallux rigidus grade	2.75 ± 0.58 (2 to 4)

* Eleven (68.75%) right and 5 (31.25%) left.
† All females.

Regarding clinical parameters, the American Orthopaedic Foot and Ankle Society hallux MTP interphalangeal score was significantly improved postoperatively ($p < .0005$) (Table 3). All patients were satisfied with the cosmetic appearance of their foot (Fig. 5C). In terms of passive ROM of the first MTP joint, postoperative dorsiflexion was significantly increased ($p = .013$) and plantar flexion was decreased, without a significant difference ($p = .211$) (Fig. 5D, 5E). Both passive dorsiflexion and plantar flexion of the second MTP joint were decreased postoperatively.

The complications that were observed during follow-up included postoperative hallux varus deformities, including a 17° deformity after an excessive medial eminence resection in 1 (6.25%) foot. We did not observe loss of correction, postoperative superficial or deep infection, or delayed union or nonunion of the osteotomy site during the follow-up period.

Persistent painful plantar callosity under the second metatarsal head was observed in 4 (25%) feet preoperatively. However, painful plantar callosity or transfer metatarsalgia was not observed postoperatively. Painful plantar callosity or transfer metatarsalgia under the third metatarsal head was also not noted postoperatively.

Discussion

Traditionally, joint arthrodesis has been thought to be the best option to treat advanced arthritis of the first MTP joint compared with total arthroplasty (10), hemiarthroplasty (11), and interpositional arthroplasty (12). However, joint-preserving options are still being reported because arthrodesis can be performed, even if the operation fails. Joint-preserving operations have some advantages, including the ability to wear various types of shoes, fewer limitations with activities/sports, and perhaps also a psychological benefit.

The concept of proximal phalangeal osteotomy, which was introduced by Moberg (13), was to place the great toe into a more dorsiflexed position using a dorsal closing wedge osteotomy, because painful limited dorsiflexion is a main clinical finding of hallux rigidus. As a distal metatarsal osteotomy option, Watermann (14) presented a dorsal closing wedge osteotomy technique to relocate intact articular cartilage on the plantar side of the metatarsal head to a functional position. Youngswick (15) reported using a chevron-type distal metatarsal osteotomy to fix the first metatarsal head into a plantar-flexed position. He made the second osteotomy proximally parallel to the dorsal side osteotomy to translate the metatarsal head. However, he also reported that excessive shortening occurred postoperatively. Ronconi et al (16) and Derner et al (17) reported the oblique and perpendicular osteotomy techniques, respectively, as alternate options to achieve plantar flexion with shortening of the first metatarsal head. Recently, Cho et al (18) described that a distal metatarsal dorsiflexion osteotomy using biocompression screws seems to be effective to treat advanced hallux rigidus with viable cartilage on >50% of the first metatarsal articular surface. Although the degree of shortening varied, several reports have revealed that distal chevron metatarsal osteotomy caused shortening of the metatarsal bone (6,19).

Several authors found that scarf osteotomy was another option to treat advanced hallux rigidus (20–22). Lee et al (21) insisted that shortening scarf osteotomy decreased joint pain and increased ROM owing to decompression of the first MTP joint pressure. However, Kilmartin (23) insisted that a great number of patients suffered from transfer metatarsalgia after undergoing shortening scarf osteotomy. Although

Table 2
Preoperative and postoperative radiographic parameters (N = 16 feet in 16 patients)

	Preoperative	Postoperative	*p* Value
HVA (°)	30.79 ± 12.32 (22.48 to 64.5)	5.37 ± 3.45 (1.37 to 12.09)*	.001
IMA (°)	13.24 ± 2.80 (10.48 to 19.39)	5.21 ± 2.50 (0.81 to 9.88)	<.0005
DMAA (°)	10.32 ± 10.64 (1.50 to 31.42)	4.25 ± 5.18 (0 to 18.65)	.005
First metatarsal length (mm)	58.31 ± 5.71 (51.31~70.05)	49.56 ± 5.18 (41.41 to 59.00)	.001
Relative second metatarsal length (mm)	3.91 ± 1.18 (2.28 to 6.67)	4.53 ± 1.78 (0.94 to 7.18)	.179
Relative second metatarsal height (mm)	0.39 ± 1.88 (-5.70 to 2.14)	0.43 ± 0.29 (0.11 to 0.90)	.215
Medial sesamoid position, as described by Hardy and Clapham (9)	5.25 ± 1.18 (4 to 7)	2.81 ± 0.98 (1 to 5)	.0001
First MTP joint space interval (mm)	0.63 ± 0.21 (0.32 to 0.95)	4.00 ± 0.38 (3.32 to 4.73)	.0001

Abbreviations: DMAA, distal metatarsal articular angle; HVA, hallux valgus angle; IMA, first to second intermetatarsal angle; MTP, metatarsophalangeal joint.
Values are mean ± standard deviation (range).
* Excluding 1 case with postoperative hallux varus.

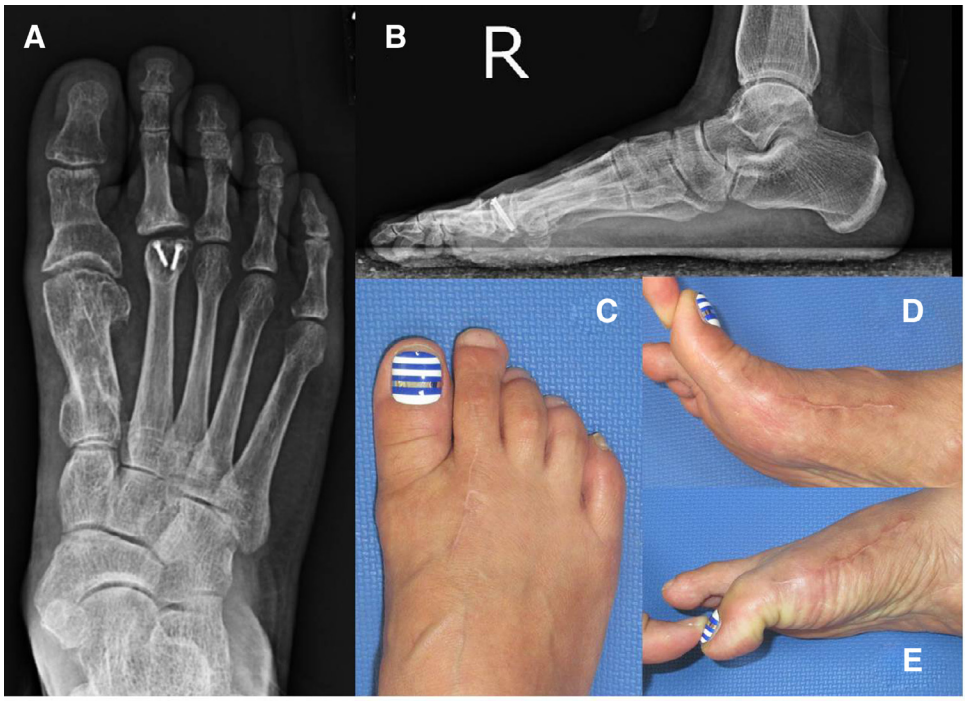

Fig. 5. Radiographs at 20 months postoperatively show shortening (*A*) and lowering (*B*) of the first metatarsal. The patient was cosmetically satisfied with the result (*C*), with increased dorsiflexion (*D*) and constant plantar flexion (*E*).

scarf osteotomy has several advantages, such as firm fixation and a low rate of nonunion, we concluded that its effects on lowering of the metatarsal head could be less than those with proximal level osteotomy, referring to the research by Choi et al (3).

Regarding osteotomy that is performed at the proximal metatarsal level, Drago et al (24) presented combined distal closing wedge osteotomy using the technique of Watermann (14) with proximal opening wedge plantar-flexed osteotomy. They aimed to shift the location of the distal articular cartilage from the plantar side to the dorsal side and simultaneously correct metatarsus primus elevatus.

As a newly designed osteotomy option for the proximal metatarsal level, our procedure has the advantage of easy correction of even a highly deformed hallux valgus, while simultaneously shortening and lowering the metatarsal bone, using a long lever arm. In addition, an advantage of the PCMO technique is the potential benefit of placing fixation in the proximal portion of the metatarsal. In advanced arthritis,

Table 3
Preoperative and postoperative clinical parameters (n = 16 feet in 16 patients)

	Preoperative	Postoperative	*p* Value
AOFAS hallux MTP interphalangeal score	37.38 ± 10.02 (17 to 52)	84.63 ± 2.97 (79 to 89)	<.0005
Passive range of motion of the first MTP joint: dorsiflexion (°)	16.50 ± 6.43 (10 to 30)	25.88 ± 7.76 (10 to 40)	.013
Passive range of motion of the first MTP joint: plantarflexion (°)	27.63 ± 7.50 (20 to 40)	23.75 ± 10.41 (0 to 40)	.211
Passive range of motion of the second MTP joint: dorsiflexion (°)	31.25 ± 6.45 (20 to 40)	23.69 ± 6.18 (15 to 35)	.001
Passive range of motion of the second MTP joint: plantarflexion (°)	31.88 ± 6.29 (25 to 40)	22.06 ± 5.14 (15 to 35)	.001

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; MTP, metatarsophalangeal joint.
Values are mean ± standard deviation (range).

where there may be cystic erosions around the first MTP joint or an aggressive cheilectomy may be necessary, the cortical integrity of the metatarsal head may be compromised, rendering the distal metatarsal a suboptimal location for placement of fixation.

Although the interval between the chevron osteotomies was 5 mm, the actual mean shortening of the first metatarsal was 8.75 mm, because the width of the oscillating saw was included twice. Each osteotomy procedure provided an additional 1- to 2-mm shortening increment. However, this additional, excessive shortening did not lead to an increase in the joint space (3.37 mm).

Excessive shortening of the first metatarsal can cause pain or painful callosity under the second metatarsal head. In contrast, excessive lowering of the first metatarsal head can increase the joint pressure between the first metatarsal and medial sesamoid bone so that pain or arthritis can occur postoperatively. Ahn et al (25) reported that transfer lesions under the second metatarsal did not appear in patients with <5.8 mm of shortening. In our study, none of the patients complained of pain or a painful callosity under the medial sesamoid bone or second metatarsal head postoperatively. A further study using computed tomographic scanning or magnetic resonance imaging would reveal the postoperative arthritic changes more precisely. We concluded that the balance between shortening and lowering was the most important. Therefore, we do not recommend this procedure for patients with excessively shortened first metatarsal bone such as brachymetatarsia. In such cases, the first MTP arthrodesis with a proper lengthening of the first metatarsal bone would be strongly recommended. Other potential complications related to shortening of the first metatarsal include a floating toe deformity, soft tissue redundancy, and decreased great toe dorsiflexion power.

In this study, clinically, passive dorsiflexion of the first MTP joint was significantly improved and plantar flexion was not changed. This finding could be a result of the cheilectomy or the widening of the joint space. However, we also experienced an unwanted decrease in the passive ROM (both dorsiflexion and plantar flexion) of the second MTP joint.

The present study has certain limitations, including a relatively short mean follow-up duration (<2 years) and a small sample size. Another limitation is that we did not compare shortening PCMO with previously reported joint preserving techniques or arthrodesis. Because the shortening PCMO was combined with additional multiple drilling on the denuded cartilage surface, it might be confusing to judge the decompressive effect of osteotomy without comparing it with the solitary shortening osteotomy or multiple drilling group. A further study with a larger sample size and longer follow-up or a comparative study is required.

There remains debate on the effects of a joint preserving procedure compared with arthrodesis to treat advanced hallux rigidus in elderly people and those with lower physical demands (22). However, we believe that a joint-preserving operation will provide benefits for younger and highly physically active patients. Therefore, even though the evidence that is currently available on joint-preserving procedures, including osteotomy, is poor, the attempts to preserve the joint are worthwhile.

In conclusion, a shortening PCMO for patients with a hallux valgus deformity accompanied by advanced arthritic change of the first MTP joint showed a good result in terms of deformity correction and pain relief, with a significant postoperative increase of dorsiflexion. Appropriate lowering and an additional Weil osteotomy effectively prevented postoperative pain or painful callosity under the second metatarsal head.

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