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Original Article

High intermetatarsal angle hallux valgus: does modified chevron osteotomy solve the problem?

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Abstract: An evaluation was made to introduce the efficacy of modified chevron osteotomy, in which extended plantar limb osteotomy was applied to hallux valgus cases with a high intermetatarsal angle and no hypermobility of the 1st metatarsocuneiform and hallux interphalangeus. A total of 21 patients and 34 feet were examined. The mean age of the patients was 47.3 ± 13.4 years (range, 20-74 years). The surgery was performed on 19 (55%) right feet and 15 (45%) left feet. Extended plantar limb osteotomy and soft tissue procedures were performed on all patients from a single dorsomedial incision. Fifteen-degree angle anterior-posterior, full lateral radiographs and photographs were taken preoperatively and at 6 weeks, 6 months, 12 months and at a final postoperative follow-up examination. The hallux valgus, intermetatarsal and distal metatarsal articular angles were determined, and the HV-foot-AOFAS values showing clinical satisfaction were calculated. The mean follow-up period was 12 months, (range, 11-22 months). At the final follow-up examination, the hallux valgus angle had decreased from 37.9° to 17.2° on the right foot and from 32.2° to 11.9° on the left foot; the intermetatarsal angle had decreased from 16° to 6.6° on the right and from 15.1° to 6.6° on the left; and the distal metatarsal articular angle had decreased from 21.1° to 11.4° on the right and from 18.8° to 6.4° on the left. The mean AOFAS-HV score increased from 63 to 83.8 on the right and from 64.3 to 88.2 on the left. A statistically significant improvement was determined in all the angle values at the final follow-up examination. The AOFAS scales showing clinical satisfaction were determined as 'good'. It was concluded that the extended plantar limb modified chevron osteotomy is an effective surgical treatment option for adult cases of hallux valgus with a high intermetatarsal angle, with no 1st metatarsal hypermobility or hallux interphalangeus and no history of recent foot surgery.

Keywords: Chevron, distal, hallux valgus, intermetatarsal, osteotomy

Introduction

Hallux valgus is described by Carl Hueter as a static subluxation characterized by deviation of the first metatarsal medially and the first toe laterally at the same time [1]. The desire to increase life quality [2] and the ongoing pain that has not responded to conservative treatment methods are the primary indications for surgical treatment of hallux valgus [3]. Although proximal metatarsal osteotomies are the most important choice for severe hallux valgus deformities with a high intermetatarsal angle, no significant difference has been reported in the radiological and clinical results of the distal chevron osteotomy and its modifications; this procedure is popular due to its simplicity, low invasiveness, lower complication rate and shorter rehabilitation period [3-6].

We hypothesized that extended plantar limb modified chevron osteotomy is an effective surgical treatment for cases of hallux valgus with high intermetatarsal angle. The aim of this study was to evaluate the efficacy of the modified chevron osteotomy applied to hallux valgus cases with no hypermobility of the 1st metatarsocuneiform and no hallux interphalangeus.

Material and methods

Between January 2014 and July 2015, a total of 54 feet from 31 HV participants were operated on with a modified chevron osteotomy in addi-

Figure 1. Preoperative radiographic and clinical appearance of the foot of case No: 1.

Figure 2. Radiographic and clinical appearance of the foot at the final follow-up of case No: 1.

tion to soft tissue loosening. A retrospective evaluation was made into 34 of the feet from 21 participants who met the inclusion criteria of age >18 years, no history of foot surgery, with a preoperative intermetatarsal angle [IMA] >11° and moderate or high pain according to the Coughlin classification (**Figure 1**). The 21 participants comprised 81% females and 19% males with a mean age of 47.3 ± 13.4 years [range, 20-74 years]. Nineteen [55%] patients had right-sided operations, and 15 [45%] patients had left-sided operations, with bilateral operations performed in 13 [61%] cases.

The first metatarsophalangeal joint dorsiflexion and plantar flexion were measured with a goniometer. The preoperative angles were determined as right mean hallux valgus angle [HVA]: 37.9°, left hallux valgus angle [HVA]: 32.2°, right intermetatarsal angle [IMA]: 16.0°, left intermetatarsal angle [IMA]: 15.1°, right distal metatarsal articular angle [DMAA]: 21.1°, and left distal metatarsal articular angle [DMAA] 18.8°. The mean HVAOFAS scale values, which express clinical satisfaction, were 63 on the right side and 64.3 on the left side, preoperatively.

Approval for the study was granted by the Ethics Committee with decision no. 367, dated 17.11.2015.

Standing 15° angle AP and lateral radiographs were taken of all patients preoperatively and at the final followup examination (**Figure 2**). Measurements were taken for the HVA, IMA and DMAA on the preoperative and postoperative radiographs. In the clinical evaluation, the AOFAS hallux metatarsophalangeal-interphalangeal and the AOFAS ankle-rear foot scales were used [7, 8].

Surgical technique

Under appropriate anesthesia, a dorsomedial incision was made on all patients. The dorsal cutaneous nerve was dissected.

The M. abductor hallucis tendon in the 1st intermetatarsal space was cut from the proximal phalanx attachment point. The lateral capsule was perforated at the joint level. Then, the big toe was taken into varus position until the capsule ruptured.

Following lateral loosening, the capsule was incised longitudinally at the same level without touching the proximal and distal connection

Table 1. The preoperative and final follow-up angle values of the foot

	Preoperative left foot	Final follow-up left foot
HVA	28°	12°
IMA	16°	7°
DMAA	25°	8°
AOFAS HV	73	95
AOFAS ankle-foot	-	100

Mann-Whitney U test/Wilcoxon test.

Table 2. The preoperative and final follow-up Hv Angle values of the right foot Right side

HV ANGLE	Mean ± SD	Med [Min - Max]	P
Preop	33.1 ± 10.1	30 22 - 45	0.157
Postop	15.3 ± 6.6	14 6 - 23	0.338
Change p	0.000		

Mann-Whitney U test/Wilcoxon test.

Table 3. The preoperative and final follow-up IMA values of the right foot

IMA			
Preop	15.9 ± 4.9	14 11 - 25	0.435
Postop	5.2 ± 2.7	5 2 - 9	0.061
Change p	0.000		

Mann-Whitney U test/Wilcoxon test.

Table 4. The preoperative and final follow-up DMMA values of the right foot

DMMA			
Preop	13.1 ± 6.0	15 3 - 20	0.014
Postop	10.2 ± 5.0	10 3 - 18	0.440
Change p	0.000		

Mann-Whitney U test/Wilcoxon test.

Table 5. The preoperative and final follow-up HV-AOFAS values of the right foot

HV-AOFAS			
Preop	65.6 ± 10.2	65 47 - 78	0.155
Postop	86.9 ± 7.6	85 78 - 100	0.220
Change p	0.008		
Foot AOFAS	93.9 ± 6.5	90 87 - 105	0.638

Mann-Whitney U test/Wilcoxon test.

points. Then, the medial eminence was partially excised parallel to the medial metatarsal shaft while remaining medial to the sagittal groove. After excision of the medial eminence, the surface of the metatarsal head was marked to create an extended plantar limb V-shaped chevron osteotomy. With the apex of the cut at least 1 cm proximal to the joint, the osteotomy was separated into 2 layers in the middle of the plantar foot and the dorsal foot. After adjusting the appropriate angles, the head was osteotomized.

While stabilizing the metatarsal head after osteotomy, the shaft was medialized using a clothes-peg clamp. Drilling was performed to the dorsal cortex over the K-wire that had been advanced in a dorsomedial-plantarolateral direction for fixation of the 2 parts. An appropriately sized headless, cannulated screw was placed under fluoroscopy guidance to provide fixation in this position.

After fixation, the soft tissue procedures were continued with the application of capsulotomy and plication. The layers were then closed in the appropriate manner.

Results

The mean follow-up period was 12 months, [range, 11-22 months]. At the final follow-up examination, the HVA was determined to have decreased from 37.9° to 17.2° on the right foot and from 32.2° to 11.9° on the left foot; the IMA decreased from 16° to 6.6° on the right and from 15.1° to 6.6° on the left; and the DMAA decreased from 21.1° to 11.4° on the right and from 18.8° to 6.4° on the left. The mean AOFAS-HV score increased from 63 to 83.8 on the right and from 64.3 to 88.2 on the left. The participants returned to normal daily activities at mean 1.7 months (**Table 1**).

Statistical analysis

Analysis of the study data was made using SPSS 22.0 software. In the descriptive statistics of the data, mean, standard deviation, median, minimum, maximum, frequency and percentage values were used. The distribution of variables was assessed with the Kolmogorov-Smirnov test. In the analysis of quantitative data, the Mann-Whitney U test was used. In the analysis of repeated measurements, the Wilcoxon test was used. The chi-square test, or the Fisher test when the chi-square test conditions were not met, was used in the analysis of qualitative data.

Table 6. The preoperative and final follow-up HV Angle values of the left foot Left Side

HV ANGLE	Mean ± SD	Med [Min - Max]	P
Preop	31.5 ± 7.5	29 25 - 45	0.097
Postop	13.7 ± 4.2	13 9 - 20	0.595
Change p	0.000		

Mann-Whitney U test/Wilcoxon test.

Table 7. The preoperative and final follow-up IMA values of the left foot

IMA			
Preop	13.0 ± 2.4	14 10 - 15	0.051
Postop	7.5 ± 1.2	7 6 - 9	0.706
Change p	0.000		

Mann-Whitney U test/Wilcoxon test.

Table 8. The preoperative and final follow-up DMMA values of the left foot

DMMA			
Preop	15.3 ± 6.6	18 6 - 22	0.063
Postop	7.2 ± 4.3	6 3 - 15	0.632
Change p	0.000		

Mann-Whitney U test/Wilcoxon test.

Table 9. The preoperative and final follow-up HV-AOFAS values of the left foot

HV-AOFAS			
Preop	64.8 ± 6.8	65 55 - 76	0.623
Postop	86.7 ± 5.7	86 78 - 95	0.442
Change p	0.028		
Foot AOFAS	94.2 ± 4.9	93 90 - 100	0.455

Mann-Whitney U test/Wilcoxon test.

The preoperative to final follow-up decrease in the HVA, IMA and DMAA values of the left and right sides and the increase in the HV-AOFAS values were found to be statistically significant ($P<0.05$).

The mean values of the clinical evaluations are shown in **Tables 2** to **9**.

When the HV-AOFAS evaluation criteria were examined, there was a loss of points to below the normal level because of pain, restricted activity, MTP joint restriction, misalignment and shoe selection. While the greatest loss of points was in the parameter of 'pain' [total 170 points], the parameter which affected the most patients was 'shoe selection' [total 24 patients]. Pain was determined as 'mild and normal pain' and shoe selection as 'the selection of comfortable shoes'. In the AOFAS scale, a loss of points to a level below normal was seen in the parameter evaluations of pain in 17 feet, restricted activity in 11 feet, MTP joint restriction in 13 feet, misalignment in 11 feet, and shoe selection in 24 feet.

At the final follow-up examination, the 21 participants were questioned about their satisfaction with the outcome of the operation. Ninety percent of the patients were satisfied. Of the participants who underwent bilateral surgery, only 1 patient was not satisfied with 1 foot. Another participant who reported dissatisfaction because of pain had undergone surgery on 1 foot.

Discussion

There are several metatarsal osteotomies and soft tissue procedures indicated for symptomatic HV deformity. It may be hard to pick the correct surgery technique because many unsuccessful surgeries have been reported in the literature [9, 10]. More than 130 techniques are reported for restoring deformities [11-13].

Thordson showed that increased quality of life was in direct proportion to satisfaction with the surgery but was not always associated with the rate of correction [14]. In the current study, distal soft tissue loosening was applied together with a modified chevron osteotomy. Satisfaction was determined to be related to the functional score measured with AOFAS values and angle. The HV-AOFAS scores of the patients in the current study were determined to have a mean of 63.3 in the right foot and 64.3 in the left foot, preoperatively, and 83.8 in the right foot and 88.2 in the left foot, postoperatively.

Chou applied biplanar chevron osteotomy in their study because of increased DMAA and reported mean correction of 7° in the DMAA. In the current study, after application of plantar extended limb osteotomy to the patients [44%] with high [>10°] DMAA, correction was obtained with a 3 mm closed wedge osteotomy from the dorsal aspect, which was consistent with literature.

Mahavedan used 2 Barouk® screws in scarf osteotomy and 1 in modified chevron osteoto-

my, and no malunion was observed associated with fixation failure. Therefore, they reported that the modified chevron osteotomy was more stable. The modified chevron osteotomy was also found to be superior in terms of cost of the implant that was used [2]. Andrews compared fixation with a single screw, axial loading 2 screws and a locking plate with 1 interfragmentary screw following chevron osteotomy. The recovery time and incidence of main fragment displacement were found to be the same in all 3 groups, but in terms of the possibility of displacement, the locking plate with interfragmentary screw was found to be superior [15]. In the current study, fixation during metatarsal osteosynthesis was achieved with 2 screws in 10 feet [29%] and with 1 screw in 22 feet [64%].

When applying chevron osteotomy, it is very important to keep the limbs away from the osteotomy site, especially the plantar side, outside the joint. Otherwise, sesamoid damage, adhesion between the metatarsal head and the sesamoid in the MTP joint and restricted movement in the MTP joint may develop. Trnka reported that preoperative movement of 72° was reduced to 62° at 2 years postoperatively [6]. Consistent with these results in the literature, MTP joint movement restriction was determined in 13 [34%] of 34 feet in the postoperative period of the current study. Movement in the range of 30°-75° was determined in these patients in the postoperative period which was evaluated as moderate restriction, according to AOFAS. It was observed that these patients had not performed the recommended exercises postoperatively.

By keeping the plantar limb extended in the modified chevron in this study, translation was applied up to 2/3 of the metatarsal width and sufficient correction was achieved during the operation. As opposed to other reports in the literature, additional deformity correction was obtained with repositioning of the sesamoids and capsule plication with the distal soft tissue procedure [4].

Chen reported low AVN incidence and high patient satisfaction, even in severe HV patients, by adding intra-articular lateral soft tissue loosening to a distal chevron osteotomy [5, 16]. In the current study, the modified chevron osteotomy combined with the soft tissue procedure performed on participants with moderate and severe HVA and IMA, was observed to have a potentiating effect on the deformity correction.

In an examination of radiological results of modified chevron osteotomy, Suk reported a mean HVA and IMA as 34.1° and 14.4°, respectively, in the preoperative period and as 11.1° and 7.9°, respectively, in the postoperative period [9]. In regards to the distal soft tissue loosening applied in the current study to patients with high IMA compared to previous reports in the literature, the HVA was determined to have decreased from 37.9° to 17.2° for the right foot and from 32.2° to 11.9° for the left foot; the IMA decreased from 16° to 6.6° for the right and from 15.1° to 6.6° for the left; and the DMAA decreased from 21.1° to 11.4° for the right and from 18.8° to 6.4° for the left.

In a study by Kurklu, the preoperative HV-AOFAS with a mean of 44.2 increased to 89 postoperatively [17]. Trnka reported a mean HV-AOFAS of 91.6 in the postoperative period of patients who received the modified chevron technique [6]. In the current study, the mean HV-AOFAS increased from 63 to 83.8 for the right foot and from 64.3 to 88.2 for the left foot, which was a lower point increase compared to that in the literature but was still within a good limit according to the Trnka classification. In the AOFAS scale in the current study, the loss of points was in the parameters of pain in 17 feet, restricted activity in 11 feet, MTP joint restriction in 13 feet, misalignment in 11 feet, and shoe selection in 24 feet. There was a loss of points to a level below normal in all the parameters evaluated.

Avascular necrosis [AVN] is the most serious complication which may be seen after chevron osteotomy. Complications of AVN, distal fragment displacement and nonunion have been reported in modified chevron osteotomy [6, 9]. Consistent with reports in the literature, AVN was not observed in any patient in the current study which included a single dorsomedial incision followed by controlled soft tissue dissection with lateral loosening followed by the chevron modified with the plantar extended limb osteotomy distanced from the metatarsal head. The careful application of the chevron and modifications is considered to have preserved the dorsal and plantar blood circulation. The lateral capsular and adductor loosening

applied proximal to the sesamoids did not impair circulation.

In a study by Coughlin evaluating the intraobserver reliability of mean HVA measurements, it was reported that mistakes of ≤3° were made by 61% of doctors, 4°-5° by 25.2%, 6°-8° by 10.5%, and >8° by 2.9% [19]. In the current study, a 35% difference was determined in HVA measured preoperatively, postoperatively, and at the final follow-up. When intraobserver measurement margin of error was applied, this rate was found to be consistent with that reported in the literature at 16% [18, 19].

Recurrence reasons are multifactorial [16%], with the most important reason being insufficient initial correction [18]. Another important cause of recurrence is ankle equinus contracture, which occurs when the hallux is exposed to hyperpronation force. The identification and treatment of ankle equinus contracture related to HV procedures is important [18]. Consistent with the literature is the finding that in 1 case of the current study, recurrence developed over time due to a deforming force of hyperpronation on the hallux because the patient had hip dysplasia and a short lower extremity and therefore walked on tiptoe with the ankle in equinus. Thus, it can be considered that HV surgery should be performed after removal of limb length discrepancy or that the use of shoes to redress the limb length imbalance would be appropriate after surgery.

In addition to HVA and IMA, MTP joint's congruency is an important factor in the selection of surgery [19]. In the current study where osteotomy was performed together with lateral loosening, the joint incongruency rate was determined to be 88% preoperatively and 8% postoperatively.

Suk reported that patients were not permitted any weight-bearing in the first week, then a brace was applied, and weight-bearing was permitted as tolerated [9]. In various internal fixation procedures, the mean time to weight-bearing varies from 6 to 8 weeks [17, 20]. In a study by Kurklu, internal fixation was applied with a Stofella pin and weight-bearing was reported to be within 2 weeks with the return to work and social life in 4-5 weeks [17]. In the current study, patients were given a special open-toed sandal-type shoe and full weight-bearing was encouraged in 2-7 days. The return to normal living activities was determined to take a mean 1.7 months. Recovery was determined to be more rapid in the patients who underwent surgery on one foot and those who needed to return to work as soon as possible compared to those who underwent bilateral surgery and those with a more sedentary lifestyle.

Although proximal chevron osteotomy is an important option in severe HV deformity and has been reported to provide the possibility of greater correction compared to distal osteotomy, the radiological and clinical results of distal chevron osteotomy surgical modification are no different [4]. In regard to osteotomies that extend to the metatarsal shaft, the modified chevron has been found to be superior to Scarf osteotomy in respect to IMA correction [2]. In the current study, taking into consideration the advantages that it could be applied bilaterally, that there could be early weight-bearing with postoperative footwear, that there was a provision of stable fixation, that >40% shift could be made and that DMAA could be corrected at the same time, it was considered that the modified chevron osteotomy could give satisfactory results in HV deformities with moderate and severe IMA of >11°. However, loss of joint range of movement by not starting MTP joint range of movement exercises in the early period, not using the toe separator for a period of 6 months postoperatively, and not taking comorbidities such as limb length inequality into consideration can cause recurrence of the deformity and dissatisfaction.

We concluded from the functional and radiological results of this study that the extended plantar limb modified chevron osteotomy was a good treatment option for adult cases of hallux valgus with a high intermetatarsal angle, with no 1st metatarsal hypermobility or hallux interphalangeus and with no history of foot surgery.

Disclosure of conflict of interest

None.

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