ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Author's translation
Acta Orthop Traumatol Turc 2009;43(6):497-503
doi:10.3944/AOTT.2009.497

Crescentic distal metatarsal osteotomy for the treatment of hallux valgus: a prospective, randomized, controlled study of two different fixation methods

Halluks valgus tedavisinde kresentik distal metatarsal osteotomi: İki farklı tespit yöntemiyle ileriye dönük, randomize, kontrollü bir çalışma

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Amaç: Bu çalışmada, halluks valgus tedavisinde yeterince kullanımda olmayan bir distal metatarsal osteotomi yönteminin tekrar gündeme getirilmesi ve farklı iki tespit yönteminin klinik ve radyografik sonuçlarının karşılaştırılması amaçlandı.

Çalışma planı: Hafif-orta dereceli halluks valgus (<35°) nedeniyle 13 hastanın (11 kadın, 2 erkek) 16 ayağına yeni bir tedavi olan kresentik distal osteotomi uygulandı ve hastalar rastgele iki farklı tespit yöntemine ayrıldı. Grup 1'de (7 hasta, 8 ayak) iki çapraz K-teli, grup 2'de (6 hasta, 8 ayak) ise kompresyon vidası ile tespit uygulandı. Sonuçlar halluks için AOFAS (Amerikan Ortopedik Ayak ve Ayak Bileği Derneği) klinik değerlendirme sistemi ve görsel ağrı skalası ile değerlendirildi. Ameliyat öncesinde ve 12. aydaki radyografik incelemelerde halluks valgus açısı (HVA), birinci/ikinci intermetatarsal açı (İMA), distal metatarsal artiküler açı (DMAA) ölçüldü.

Sonuçlar: Ameliyat öncesi ve sonrası AOFAS skorları ve ağrı skoru açısından iki grup arasında anlamlı fark görülmedi. Bir yıllık takip sonunda AOFAS skoru ve ağrı skoru iki grupta da anlamlı düzelme gösterdi (p<0.001). Ameliyat öncesinde grup 1'de 32° olan HVA ve 12° olan İMA bir yıllık takip sonunda sırasıyla 19° ve 6° ölçüldü; bu açılar grup 2'de sırasıyla HVA için 30° ve 17°, İMA için 12° ve 8° idi (p<0.001). Benzer düzelme DMAA'da da görüldü (p<0.001). Radyografik düzelmeler iki tespit grubunda benzer bulundu. Grup 1'de bir hastada deformite tekrarladı ve aynı yöntemle revizyon uygulandı. Grup 2'de bir hastada kaynama gecikmesi görüldü.

Çıkarımlar: Distal metatarsal kresentik osteotomi yöntemi, hafif-orta dereceli halluks valgus deformitesinin tedavisinde uygun bir yöntemdir.

Anahtar sözcükler: Halluks valgus/cerrahi; metatars/cerrahi; osteotomi/yöntem.

Objectives: This study was designed to draw attention to a distal metatarsal osteotomy technique, which has been somewhat overlooked for the treatment of hallux valgus, and to compare the clinical and radiographic results of two different fixation methods.

Methods: The study included 16 feet of 13 patients (11 women, 2 men) who were treated with crescentic distal metatarsal osteotomy for mild-to-moderate hallux valgus (<35°). The patients were randomized to two fixation methods with two cross K-wires (group 1; 7 patients, 8 feet) and a compressive screw (group 2; 6 patients, 8 feet). The results were evaluated using the AOFAS (American Orthopaedic Foot and Ankle Society) clinical rating scale for hallux, and a visual analog scale for pain. Radiographic measurements included the hallux valgus angle (HVA), first/second intermetatarsal angle (IMA), and distal metatarsal articular angle (DMAA), before and 12 months after surgery.

Results: There were no significant differences between the two groups with regard to pre- and postoperative AOFAS scores and pain scores, which showed significant improvements in both groups at the end of one-year follow-up (p<0.001). The HVA and IMA significantly decreased from 32° to 19° and from 12° to 6° in group 1, and from 30° to 17° and from 12° to 8° in group 2, respectively (p<0.001). A similar improvement was also seen in the DMAA (p<0.001). Postoperative radiographic improvements were similar in both groups. One patient in group 1 underwent revision surgery with the same technique due to recurrence, and one patient in group 2 had delayed union.

Conclusion: Crescentic distal metatarsal osteotomy may be an appropriate technique in the treatment of mild-to-moderate hallux valgus.

Key words: Hallux valgus/surgery; metatarsus/surgery; osteotomy/methods.

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Submitted / *Başvuru tarihi:* 04.03.2009 **Accepted / *Kabul tarihi:*** 04.08.2009

Distal first metatarsal osteotomies are well-established techniques for the correction of symptomatic mild to moderate hallux valgus deformity. One such commonly employed osteotomy is the distal chevron osteotomy, which can be used to provide transverse and sagittal plane deformity correction and is accepted as being inherently stable in the sagittal plane but not so in the transverse plane.[1] Various methods of fixation, ranging from Kirschner wires (k-wires), different types of lag screws, including the Herbert-Whipple screw, suture anchors, and bioabsorbable fixation have all been advocated for stabilization of the distal chevron osteotomy.[2, 3, 4] On the other hand, without the use of internal fixation, medial displacement of the capital fragment and loss of correction have been reported with incidences varying from 1.8% to 12.5% in different case series.[4, 5, 6] Overall, k-wire fixation remains a popular method of fixation used to increase stability of the distal chevron osteotomy, primarily due to its low cost and simplicity.

This article describes a relatively simple technique for repair of a moderate hallux valgus deformity by means of a distal crescentic osteotomy of the first metatarsal head. The osteotomy provides deformity correction in the transverse and sagittal planes, and it is stabilized whether with diverging k-wires (Group 1) or cannulated compression screws (Acutrak 2 Mini, Acumed LLC, Hillsboro, OR, USA) (Group 2) for buttressing the capital fragment. This type of osteotomy has been previously described for repair of fifth metatarsal head lesions.[7] Moreover, the use of a distal crescentic first metatarsal osteotomy for the repair of hallux abductovalgus has also been previously described [8] ; however, based on a review of the literature, this technique does not appear to be regularly used by many surgeons. We have found this procedure to be useful for the repair of mild to moderate hallux valgus deformity, wherein the first intermetatarsal angle measures <14º.

Material and methods

Between December of 2005, and February of 2007, 13 referred patients [16 feet) with hallux valgus were included. There were 11 women and two men (seven right-sided). All patients gave voluntary written consent before participating in the study after the surgeon had informed them of the purpose of the study, the methods and risks of the procedure, and the confidentiality of the data to be obtained. Criteria for study entry included age between 15 and 60 years, a hallux valgus angle (HVA) of 20 to 35 degrees, a 1–2 intermetatarsal angle (IMA) up to 14 degrees, a distal metatarsal articular angle (DMAA) up to 25 degrees, no radiographic evidence of degenerative metatarsophalangeal (MTP) arthritis, and persistent symptoms. Patients were excluded if they had had a previous operation on the affected foot or if they had a history of diabetes, peripheral vascular disease, peripheral neuropathy, rheumatoid arthritis, or other inflammatory diseases. Randomization was guaranteed by preparing sealed unmarked envelopes (one for each patient) containing the name of the fixation procedure to be performed (two crossing k-wires or a compressive screw) before the start of the study. After clinical and radiographic examination of the patient, an envelope was drawn. The randomized operation to be performed was communicated to the patient. There were seven patients (8 foot) in group 1 and six patients (8 foot) in group 2.

One physical therapist, who was unaware of the self-reported questionnaire data, examined the patients preoperatively and at followup. Range of motion assessment of the first MTP joint was done with a goniometer. The functional outcome was graded by the American Orthopaedic Foot and Ankle Society's (AOFAS) clinical rating system for the hallux and the physical examination.[9] A visual analogue scale (VAS) was used for the assessment of pain.[10] The measurements were classified into three categories (pain at rest, pain when walking barefoot, and pain at work). A horizontal 100-mm long scale, anchored by "no pain" (0) and "worst pain imaginable" (100) was applied.

A questionnaire concerning satisfaction with the outcome of the operative treatment, the patients' perception of the cosmetic appearance, pain relief, and the ability to wear preferred shoes, (all rated as either very satisfied, satisfied, or not satisfied) was administered at each followup assessment. At 14 to 28 (mean 18) months, the patients were asked by an independent examiner whether they would choose the same procedure again (yes, no, or reservation), and whether they would recommend the surgery to a friend (yes, no, or reservation). Standardized anteroposterior and lateral radiographs during weightbearing were made preoperatively, at 12 months, and at the last followup at an

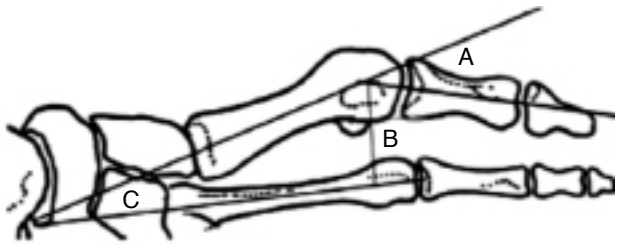

Figure 1. Some of the measurements recorded in this study. **(A)** Hallux valgus angle as reported by Miller (11), **(B)** 1–2 Intermetatarsal distance measured in millimeters (not used in this study). **(C)** currently accepted measurement of 1–2 intermetatarsal angle.

average of 18 months postoperatively. Measurements were performed on all patients at a later date in random order by one trained independent observer with an intra-observer reliability of more than 0.9 for the HVA, and more than 0.9 for the 1–2 intermetatarsal angle. The HVA was determined by two intersecting lines, the first line was drawn from the center of the first metatarsal head through the center of the base of the first metatarsal [11] . The second line was drawn from the center of the proximal articular surface of the proximal phalanx through the center of the distal end of the diaphysis. This method with reference points distal and proximal to the osteotomy site has been shown to have good measurement reproducibility [12] (Figure 1).

To measure the IMA, we used the angle formed by the intersection of the longitudinal axis of the first metatarsal and the second metatarsal (a line drawn through the center of the distal articular surface and the center of the proximal end of the diaphysis) [11] (Figure 1).

For the determination of joint congruency, we considered the relationship between the articular surface of the base of the proximal phalanx and the metatarsal head articular surface.[13] A line was drawn at the base of the proximal phalanx, and a second line was drawn through the margins of the articular surface of the first metatarsal. If these lines were parallel, the joint was congruent.[14] The DMAA was determined according to Richardson et al [15] . Six degrees or less was defined as a normal DMAA. From preoperative and postoperative radiographs, the lengths of the first and second metatarsals were measured, and the percentage shortening of the first metatarsal was expressed as a/b before operation, divided by a'/b' at review X 100, according to Klosok et al.[16] This ratio was used in all linear measurements.

Operative technique

All the operative procedures were carried out by one experienced surgeon. The distal aspect of the first metatarsal is approached through a medial, midline longitudinal incision, extending from base of the proximal phalanx to the distal metaphysis of the metatarsal. The capsule is incised in a Y-shape and reflected, after which the medial eminence is excised. A crescentic osteotomy is then made in a through-and-through fashion from medial to lateral, orienting the blade parallel to the articular cartilage and perpendi-

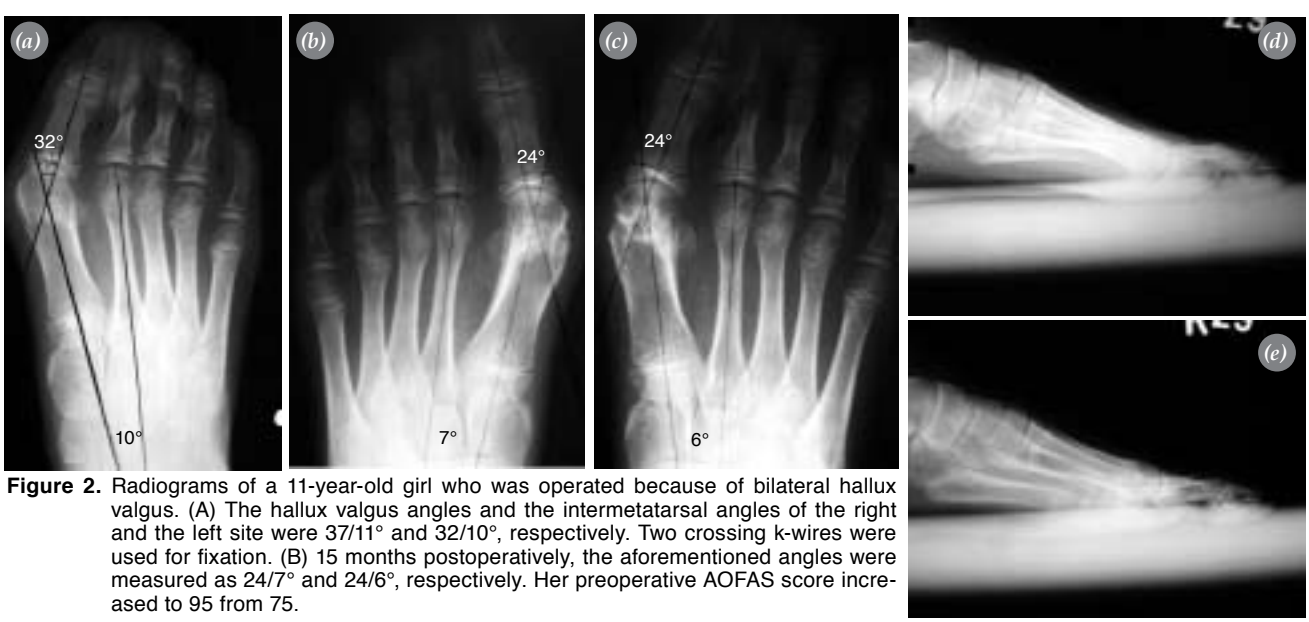

Figure 2. Radiograms of a 11-year-old girl who was operated because of bilateral hallux valgus. (A) The hallux valgus angles and the intermetatarsal angles of the right and the left site were 37/11° and 32/10°, respectively. Two crossing k-wires were used for fixation. (B) 15 months postoperatively, the aforementioned angles were measured as 24/7° and 24/6°, respectively. Her preoperative AOFAS score increased to 95 from 75.

Figure 3. X-rays of a 52-year-old female who was operated because of left hallux valgus with **(A)** a hallux valgus angle of 35° and an intermetatarsal angle of 13°. A 28 mm cannulated compression screw was used for fixation. **(B)** 22 months postoperatively, the aforementioned angles were measured as 18° and 4°, respectively. Her preoperative AOFAS score increased to 90 from 75.

cular to the longitudinal axis of the metatarsal in the sagittal plane. The osteotomy is made using a power crescentic oscillating osteotome that has a thickness of 1 mm, and a 10 mm radius (Aesculap GC 554 Inox 16, Aesculap-Werke AG, Tuttlingen, Germany). We do not routinely release the plantarlateral soft tissue contracture in the first intermetatarsal space. After completion of the distal crescentic osteotomy, the metatarsal head is displaced laterally while the metatarsal shaft is pulled medially under fluoroscopic guidance. Attention is paid to correct the deformity in both the transverse and, if necessary, sagittal planes. Once a satisfactory structural realignment has been made; in Group 1, two 0.062-inch diameter crossing k-wires are used to stabilize the capital fragment. The first k-wire is inserted into the dorsal aspect of the proximal segment of the first metatarsal percutaneously, and directed into the capital fragment taking care to avoid violation of the articular surface. A second k-wire is then similarly directed through the medial side of the metatarsal shaft, traversing the osteotomy and seating in the subchondral bone of the metatarsal head. Direct operative visualization and, if desired, image intensification fluoroscopy are used to assess final pin placement; and the first metatarsophalangeal joint is manipulated to assure that the range of motion is satisfactory and that the sesamoids and phalangeal base move freely about the metatarsal head. The outer (proximal) end of the first k-wire exits through the dorsal surface of the metatarsal shaft, and that of the second k-wire exits through the proximal end of the surgical wound. The sharp ends of the k-wires are

cut, bent to a right angle, then covered with a smooth ball or cap (Figure 2). In Group 2, a temporary k-wire is directed through the medial side of the metatarsal shaft, traversing the osteotomy and seating in the subchondral bone of the metatarsal head. Lenght of the desired screw is measured and introduced over that k-wire and tightened causing compression on the osteotomy site. The k-wire is taken off and direct operative visualization and, if desired, image intensification fluoroscopy are used to assess final screw placement; and the first metatarsophalangeal joint is manipulated to assure that the range of motion is satisfactory and that the sesamoids and phalangeal base move freely about the metatarsal head (Figure 3). Thereafter, in both groups, the capsule is plicated in a V-shape and the wound is closed in layers.[17]

The postoperative treatment was identical in both groups. All patients received a standard bunion dressing with supported strapping of the hallux for 3 weeks. Then a new dressing was applied and worn for 2 weeks. Patients were allowed full weightbearing as tolerated in a postoperative shoe.

Table 1. AOFAS scores of both groups preoperatively and 1 year follow-up.

	K-wire (7 patients, 8 foot)		Compression screw (6 patients, 8 foot)	
	Preop	Postop	Preop	Postop
Pain	11	34	16	34
Function	29	38	30	38
Alignment	1	13	1	13
Total	31	85	47	85

AOFAS: American Orthopedic Foot and Ankle Society; Decided best total score 100 (Pain 40, Function 45, Alignment 15).

Statistical analysis

Power analysis was performed so that for continuous variables there was an 80% chance of detecting an effect size of approximately 0.60 when the significance level was 0.05. We used SPSS version 11.0 (SPSS, Inc, Chicago, IL) for all statistical analyses. Normally distributed independent samples were tested for differences with the Student t test and non-normally distributed continuous data with

Table 2. Clinical and radiographic data.

	K-wire (7 patients, 8 foot)			Compression screw (6 patients, 8 foot)		
	Amount	Percentage	Average	Amount	Percentage	Average
Age			37			36
Metatarsalgia						
Preoperatively	1	12.5		2	25.0	
Postoperatively	–			–		
Metatarsophalangeal (MTP) joint						
Passive plantarflexion (°)						
Preop/Postop first year			29/28			28/24
Range of Motion						
Good (Pre/postop)*	7/6	87.5/75.0		7/7	87.5/87.5	
Mild restricted (Pre/postop)	1/1	12.5/14.3		1/1	12.5/12.5	
Pain (1st year) (Ext./Flex)*	1/1	14.3/14.3		1/1	12.5/ 12.5	
Treatment satisfaction						
Patients would reop	6	85.7		5	83.3	
Patients would advise	6	85.7		6	100.0	
Hallux valgus angle (°)						
Preop/Postop 1st year			32/19			30/17
Congruent/Subluxed joint			26/32			27/33
Intermetatarsal angle (°)						
Preop/Postop 1st year				12/6		12/8
Distal metatarsal articular angle (°)						
Preop/Postop 1st year				15/8		15/10
Postop MT shortening (mm)				1.4		1.2

*1 patient in K-wire group who was revised has not been included.

the Mann-Whitney U test, which also was used for ordered categorical data. Paired t-tests and Wilcoxon signed-rank test (for nonparametric variables) were used to compare preoperative and postoperative data within the groups. Categorical variables were compared with the chi-square test. The reported p values are two-sided. $p < 0.05$ was considered as statistically significant.

Results

American Orthopaedic Foot and Ankle Society (AOFAS) scores and sub-scores are shown in Table 1. The results of the clinical and radiological data are presented in Table 2. The VAS values for pain demonstrated significant improvement in both groups ($p<0.001$) at a minimum 1-year followup. Statistical analysis failed to demonstrate any significant difference between the two groups. The HVA, and IMA were significantly reduced ($p < 0.001$) in both groups (Table 2).

The DMAA averaged 16.4 degrees (4.5 degrees) for congruent joints and 10.4 degrees (3.2 degrees), with subluxation of the first MTP joint ($p < 0.001$). The average preoperative HVA in the patients with congruent joints was 25 degrees (±4 degrees), and 31 degrees (±5 degrees) for the subgroup with incongruent joints ($p < 0.001$).

There were no serious complications. One patient in the k-wire group had recurrence of the deformity and required a revision procedure at 6 months. The same method was used as the revision procedure. At 12-month followup no further problems were noted. Only the preoperative data of this patient were included in the study. One patient in the compressive screw group had an asymptomatic delayed union at 6-months followup. It healed spontaneously before the 1-year examination. At the final followup, there was no evidence of hallux varus, nonunion, or osteonecrosis in either of the groups.

Discussion

The strength of this study is its prospective and randomized design and the inclusion of only patients who had no history of previous foot surgery or a history of systemic illnesses that could affect the final result. There was high level of participation (all patients could be reached at the followup). One experienced surgeon performed all operations, and the followup measurements were done by unbiased observers not involved in the treatment of the patients. On the other hand, the major limitation of this study is its period of followup, and number of patients. Longer followup and large patient sample results may courage the reader to perform such an osteotomy. Moreover, there is only one series in the literature reporting the results of such a distal metatarsal crescentic osteotomy, making difficult to compare our results objectively. Unfortunately, we could not reach the full text of that article, even its abstract. The only source of that article was our pubmed search.[8] The only article other than this is the one that we previously published as a technical note.[17]

So, we chose to compare our results with the literature based on the distal chevron osteotomy.

No significant differences were noted between the two procedures regarding the AOFAS score for the hallux. The comparison of preoperative and postoperative pain during different activities demonstrated obvious improvement in both groups but no difference between the groups. We found a statistically significant reduction ($p<0.001$) in the degree of passive plantarflexion at 1-year follow-up in the compressive screw group. Although, neither the configuration of the osteotomy, nor the method of fixation are similar, we had to compare our results with the literature and we took the case series of Trnka et al. and Saro et al [18, 19] . Our findings about the passive plantarflexion of the MTP joint were in accordance with that of Trnka et al and Saro et al [18, 19] .

Regardless of the method of fixation, the correction of the HVA, and the IMA was statistically significant ($p<0.01$) in both groups. Statistical analyses failed to demonstrate any significant difference between the two groups regarding the preoperative values of these variables ($p=0.2$).

At 1 year after surgery, 11 (85%) patients stated that they would have the same procedure again, and were satisfied with the procedure. All of these patients had decreased total range of motion in the first MTP joint (average 45 degrees), suggesting some degree of joint disease. We expect this will improve with time. Reasons given for the lack of satisfaction in two patients, were failure to meet preoperative cosmetic expectations and continued limitations in the choice of shoes.

This new technique is adequate for mild and moderate hallux valgus deformities (20-35 dergrees), with

an intermetatarsal angle of less than 14 degrees. It also provides the advantage of preserving the lenght of the first metatarsal. The configuration and the simplicity of the osteotomy provides correction in both the coronal and sagittal planes. Comparable sagittal instability may take more attention while radiographic evaluation in suspecting malunion. However, it may be difficult to perform such an osteotomy without the crescenting osteotome. Unless the formentioned osteome is not at reach, we advise to perform the operation with usual techniques. The Kirschner wires are driven distally into the metatarsal head of the first metatarsal in the sagittal plane and at a 30 degree angle, therefore this technique is less demanding and can be done under direct vision with minimal use of fluoroscopy. In compression screw technique specialized k-wires, cannulated drill tips and cannulated taps are crucial. The crossing Kirschner wires provide a stable fixation and adequate compression in two planes against medial displacement of the metatarsal head, and are much more cost effective than compressive screws (compression screw/k-wire=550/1 $). We also want to mention that, this technique can be used in revision cases securely, as we did in one of our cases.

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