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ORIGINAL STUDY

Early results of distal metatarsal osteotomy through minimally invasive approach for mild-to-moderate hallux valgus

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A prospective study was performed on 24 patients to evaluate the early results of our experience with minimally invasive distal metatarsal osteotomy to treat mild-to-moderate hallux valgus deformities in adults. After failure of conservative treatment and persistence of footwear-related pain, a percutaneous distal first metatarsal osteotomy was performed, stabilized by a Kirschner wire, followed by immediate weight bearing. At final follow-up, clinical assessment showed that 31 of 36 patients were satisfied with their results. At a mean of 21 months, weight-bearing foot radiographs showed significant change compared with the preoperative status : the average corrections of hallux valgus angle and first intermetatarsal angle achieved were 13.1° and 5.4°, respectively ($p < 0.001$). No cases showed nonunion, malunion, overcorrection, transfer metatarsalgia or osteonecrosis. The technique appeared in this study to be an effective , safe and simple option for correction of a painful mild-to-moderate hallux valgus deformity.

Key words : bunion ; hallux valgus ; metatarsalgia ; minimally invasive osteotomy.

INTRODUCTION

Two angles are frequently used to classify hallux valgus (HV) deformities and to evaluate the result of a surgical procedure used for correction : the first intermetatarsal angle (IMA) and the hallux valgus angle (HVA). The deformity is graded as mild with an IMA < 13°, moderate with IMA 13-20°, and severe with IMA > 20°. Generally, HVA > 40° is considered severe *(22)*. Historically, distal metatarsal osteotomies have been performed for mild or moderate HV while moderate-to-severe HV deformities were usually treated with either a proximal metatarsal osteotomy or a metatarso-cuneiform arthrodesis combined with a distal soft tissue procedure *(6)*. In 1983, New reported a percutaneous technique for HV correction. This technique was then used by Bösch *et al* *(9)* who performed a Hohmann-type osteotomy fixed by one K-wire. The advantages of the minimally invasive percutaneous approach are reduced operative time and less surgical dissection, resulting in fewer complications. Early weight bearing allows bilateral surgery under ankle-block anaesthesia. Retrocapital osteotomy should not be considered for HV deformities with an IMA exceeding 16°. A percutaneous distal osteotomy, however, theoretically allows correction of IMA up to 20°. This extended range of indication is attributed to the firmly attached periarticular tissues and the presence of the Kirschner wire, both providing a reliable fixation of the capital fragment *(9)*.

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The purpose of our study was to evaluate our early results with the minimally invasive distal metatarsal osteotomy (MIDMO) to correct mild-to-moderate HV deformities in adult patients.

MATERIAL AND METHODS

Between January 2005 and December 2008, a prospective study involved 26 consecutive patients (40 feet) who underwent MIDMO after approval of the ethics committee and patient's consent for study in Jubail and Qatif Central Hospital, Saoudi Arabia.

Patient selection

The inclusion criterion was a painful primary mild-to-moderate HV with IMA ≤ 18° and HVA more than 17° and less than 40°. Exclusion criteria were patients with metatarso-phalangeal joint (MTPJ) osteoarthritis (Grade II and higher), hallux rigidus, rheumatoid arthritis or a history of previous surgery on the affected hallux.

All patients received conservative treatment (shoe-wear modification) for at least 2 months before surgery. The demographics and baseline characteristics of the study population are summarized in table I.

Table I. — Patients' details

Sex Male Female	 4 (16) 20 (84)
Age	37.8 ± 12.7 (17-52)
Preoperative symptoms Bunion pain due to footwear	 24 (100)
Operation procedure Unilateral Bilateral	 12 (50) 12 (50)

Preoperative Assessment

The patient's complaints of pain, limitation in the use of footwear, and cosmetic concerns were considered. The mobility at the metatarso-phalangeal joint and the reducibility of the deformity was evaluated. Combined rotational deformity of the great toe or callosities under first or second and third metatarsal heads, if present, were considered, as well as any associated deformities of the lesser toes. A standard radiographic examination, including anteroposterior and lateral weight bearing views of the forefoot, allowed assessment of arthritis and congruency of the joint ; measurement of HVA was made with Piggot's method (*18*), and IMA by Coughlin *et al*' s method (*4*) (fig 1). The relative length of the first metatarsal was measured by Morton's method (*15*) (fig 2).

Fig. 1. – AP standing radiograph. Illustrates measurement of HVA and first IMA.

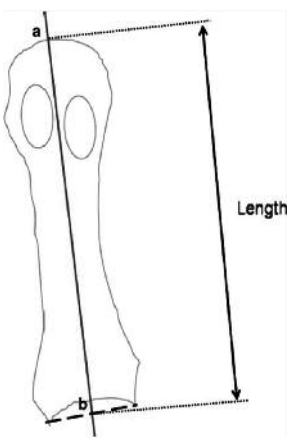

Fig. 2. – Method of measuring the length of the first metatarsal. a) Distal end of the first metatarsal head. (b) Point of intersection of the first metatarsal longitudinal axis with a line connecting the proximal-medial and proximal lateral ends of the metatarsal base.

Fig. 3. — A. Wire insertion.

Fig. 3. — B. Extraperiosteal position of the K-wire.

Fig. 3. — C. Skin incision.

Fig. 3. — D. The level of the cut is checked under fluoroscopy.

Fig. 3. — E. Correction and stabilization.

Fig. 3. — F. The Kirshner wire is driven through the first tarsometatarsal joint for greater stabilization.

Surgical technique

The patient was placed supine, with a below-knee wedge bracket allowing 90° of knee flexion and a plantigrade position of the foot on the operating table. A pneumatic tourniquet was applied in all cases. The operation was performed with either general or ankle-block anaesthesia. The fluoroscopic image intensifier was positioned to the side of the patient while the surgeon stood at the end of the table.

Step 1 : Wire insertion. A 2.0-mm K-wire was inserted starting from the proximal medial corner of the great toe nail and manually driven along the medial border of the proximal phalanx in a distal-to-proximal direction to end just distal to the site of the planned osteotomy (fig 3-A). It is mandatory to place the wire in an extraperiosteal position in order to allow lateral displacement of the capital fragment at the osteotomy site (fig 3-B). The wire was midway between the dorsal and plantar aspect of the great toe in order to engage the metatarsal head correctly.

Step 2 : Incision. A 1.5 cm skin incision centered over the medial aspect of the first metatarsal neck was carried directly to bone, cutting the periosteum, at mid-distance between the dorsal and plantar aspects of the metatarsal neck to avoid injuring the neurovascular bundle (fig 3-C).

Step 3 : The periosteum around the osteotomy site was then detached dorsally and plantarly,

Step 4 : The osteotomy was then performed through the subcapital region of the first metatarsal with an oscillating saw perpendicular to the long axis of the shaft of the first metatarsal in the sagittal plane (fig 3-D). In the frontal plane, the osteotomy was performed with slight mediolateral obliquity to facilitate lengthening or shortening as dictated by the preoperative plan.

Step 5 : Metatarsal displacement and correction. The proximal part of the first metatarsal was then displaced medially with the aid of a small curved artery forceps introduced in the medullary canal in order to facilitate correction and wire insertion. After lateral translation of the metatarsal head, the K-wire was introduced under direct vision into the medullary canal of the metatarsal shaft (fig 3-E). If pronation of the first metatarsal bone was present, correction was obtained with a derotation of the big toe up to neutral position ; the wire was driven through the first tarsometatarsal joint for greater stabilization (fig 3-F).

Step 6 : The skin was sutured. The K-wire distal end was curved and cut. A plantar pad was placed and an elastic bandage was taped in a supination manner to counteract pronation of the big toe. The mean operation time for unilateral MIDMO was 21.4 minutes, and for bilateral MIDMO 40.2 minutes. Postoperatively, patients were allowed to bear weight without shoes on the day after surgery. Stitches were removed two weeks after surgery ; the K-wire was removed 6 weeks postoperatively. Patients were then allowed to bear weight with normal shoes, and range of motion (ROM) exercises of the first MTPJ were carried out from then on.

Figure 4 presents a case example in our series.

Documentation and follow-up

For every patient, we recorded name, age, gender, complaints and their duration and any previous treatment. Radiological evaluation included radiographs on the following day, six weeks and then between two and three months postoperatively. The subsequent follow-up frequency was variable, usually every 6 months. Clinically the patients were questioned on each follow-up about cosmetic appearance of the foot, pain over the metatarsal head and shoe-wear problems. Thorough clinical examination was done looking for appearance, calluses under second and third metatarsal heads (transfer lesions), sensory abnormalities, and ROM of first MTPJ. Furthermore, the clinical rating system for foot and ankle function, established by Kitaoka *et al* (*8*) (American Orthopedic Foot and Ankle Society (AOFAS) Hallux-Metatarsophalangeal-Interphalangeal Score) was used as a quan-

Fig. 4. — A & B. Clinical and radiological preoperative appearance in 45 -year-old. female with moderate hallux valgus.

Fig. 4. — C & D. Clinical and radiological appearance after 18 months follow-up.

tification of the clinical and subjective evaluation at follow-up. Additionally patients were asked whether they were satisfied with the result of the operation. Assessment of passive ROM of first MTPJ was performed according to Okuda *et al* (*17*).

Statistical analysis

Data were analyzed using SPSS software V. 16.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Twenty-six patients with symptomatic mild-to-moderate HV deformities were operated using MIDMO. Two patients were lost to follow-up and did not complete the minimum follow-up period of 12 months. We report the results of 36 feet in 24 patients (20 females and 4 males). Twelve patients had bilateral surgery. Patients' age ranged from 17 to 52 years, with a mean age of 37.8 years. The average follow-up period was 21 months (range 12-36 months).

Clinical results

At final follow-up, no patient had worsening of pain and no patient who presented with shoe-wear restriction as a primary symptom had such complaints after surgery. Eighteen patients reported total disappearance of pain, four had mild occasional pain and two had daily moderate pain, (table II). The mean pain score was 37.3 ± 4.7 points. The functional capacity of the hallux (table III) averaged 40.9 ± 3.6 points. The maximum score for hallux alignment was recorded for 30 feet in 20 patients ; mild, asymptomatic malalignment (a score of 8 points) was recorded for 6 feet in 4 patients ; symptomatic malalignment (a score of 0 points) was not recorded in our study (table II). The overall mean score for hallux alignment was 12.9 ± 4.2 points. The total scores at the time of final follow-up was 91.1 ± 6.8 points (table IV). Motion of first MTPJ was limited to $< 30°$ in three feet. Patients were satisfied with the results of 31 of the 36 procedures. Satisfaction was evaluated as the patient's willingness to undergo surgery again or not.

Table II. — AOFAS scores for pain at the time of final follow-up

Pain	Score (points)	No. (%) of Feet (N = 36)	No. of Patients
None	40	30 (83.3)	18
Mild, occasional	30	4 (11.1)	4
Moderate	20	2 (5.6)	2
Severe, constant	0	0	0

Table III. — AOFAS scores for functional capability at the time of final follow-up.

Functional Capability	Score (points)	No. (%) of Feet (N = 36)	No. of Patients
Activity limitation			
None	10	33 (91.7)	21
No limitation of daily activity, limitation of recreational activity	7		3
Limitation of daily and recreational activity	4	0	0
Severe limitation of all activity	0	0	0
Footwear			
Normal	10	30 (83.3)	l20
Comfortable and/or insole	5	6 (16.7)	4
Orthopaedic	0	0	
Metatarsophalangeal joint motion			
> 75°	10	10 (27.8)	6
30°-74°	5	23 (63.9)	15
< 30°	0	3 (8.3!	3
Interphalangeal joint motion			
Normal	5	34 (94.4)	22
< 10°	0	2 (5.6)	2
Joint stability			0
Stable	5	36 (100)	24
Unstable	0	0	0
Callus			
None or asymptomatic	5	34 (94.4)	22
Symptomatic	0	2 (5.6)	2

Table IV. — AOFAS scores for hallux alignment at the time of final follow-up

Alignment	Score (points)	No. (%) of Feet (N = 36)
Excellent/good	15	30 (83.3)
Mild asymptomatic misalignment	8	6 (16.7)
Symptomatic misalignmen	0	0

Table V. — Overall AOFAS scores at the time of final follow-up

Pain (0-40 points)	37.3 ± 4.7
Functional capability (0-45 points)	40.9 ± 3.6
Activity limitation	11.2 ± 1.3
Footwear	9.7 ± 2.1
Metatarsophalangeal joint motion	5.9 ± 3.4
Interphalangeal joint motion	3.6 ± 0.5
Joint stability	5.7 ± 0.4
Callus	4.8± 1.6
Alignment (0-15 points)	12.9 ± 4.2
Total (0-100 points)	91.1 ± 6.8

Table VI. — Radiographic results of 36 consecutive minimally invasive distal metatarsal osteotomies

	Preoperative	Follow-up	Correction
Hallux valgus angle	27.7° ± 3.8 (18-36.8)	14.6° ±5.8 (8-25.4)	13.1° ± 4.6 (3.8-23.7)
First intermetatarsal angle	11.2° ± 1.8 (9.8-18)	5.8° ± 2.4 (4-11.6)	5.4° ± 2.2 (2.4-11.6)

Radiographic results

The radiological results of the 36 consecutive MIDMOs are presented in table VI. The mean HVA decreased from 27.7° preoperatively to 14.6° at final follow-up ($p < 0.001$). The first IMA decreased from an average of 11.2° preoperatively to 5.8° at final follow-up ($p < 0.001$). Plantar displacement of the first metatarsal head (mainly a plantar translation, with some degree of plantar angulation) was found at the time of follow-up in 17 (47.3%) of

the 36 feet, dorsal displacement of the head (mainly angular deformity) was seen in 3 feet (8.3%), and the position defined as neutral was observed in 16 feet (44.4%). The extent of lateral displacement of the first metatarsal head was 56.2% ± 18.4% of the diameter of the first metatarsal shaft in the immediate postoperative period and 36.1% ± 15.9% at follow-up. Relative shortening of the first metatarsal was noted in 11 feet (30.6%), with a mean shortening of 2.2 ± 2.8 mm (range : -8 to 3.4 mm). All the osteotomies healed well, with evidence of callus after an average of 3 months. Consolidation of the osteotomy site was confirmed radiologically in all patients within six months.

Complications

No intraoperative complications occurred except for some comminution at the osteotomy site in one foot but this did not affect either the stability of fixation or the union of the osteotomy. In 3 feet, mild skin inflammatory reaction was present around the outlet of the K-wire at the tip of the toe. There was no need to remove the K-wire before the scheduled time. There were no instances of nonunion, malunion, transfer metatarsalgia or avascular necrosis of the metatarsal head. No cases of secondary hallux varus were observed despite the slight overcorrection consistently achieved at the time of stabilization of the osteotomy site.

DISCUSSION

Hallux valgus is a common deformity. HVA > 15° and first IMA more than 9° is regarded as hallux valgus (*20*). Pain over the medial eminence and problem in shoe wear are the major reasons for seeking treatment. The management of HV aims at restoring a well-aligned and painless first MTPJ with preservation of dorsiflexion, allowing normal progression in the gait cycle (*13*). Till the late 19th century, hallux valgus was managed conservatively. More than 130 procedures have subsequently been described for correction (*21*). For a long time, bunion surgery had a reputation for being very painful with a lengthy recovery period. Indeed, many people put up with their bunions for years rather than face surgery as older techniques involved cutting the bone and not using any form of fixation. During the past decade newer techniques were developed, which made it possible to fix the bones into correct position, reducing pain and promoting better and more controlled recovery. However, we are constantly exploring ways of moving from open surgery to minimally invasive techniques, replacing large incisions with small 'ports' through which the surgeon works. This may offer important benefits for the patient, removing or damaging less tissue, reducing scarring and the risk of infection. Minimally invasive distal first metatarsal osteotomy with a percutaneous technique was first described by Bösch *et al* in 1990 (*1*), with satisfactory results (*2*). Portaluri (*19*) achieved 89% satisfaction rate using Bösch's method and stated that the advantages of this technique included short operation time and a low incidence of complications. Sanna and Ruiu (*23*) reported excellent results in a long-term follow-up study of percutaneous distal first metatarsal osteotomies. Magnan *et al* (*11*) reported that the patients were satisfied following 107 (91%) of 118 percutaneous distal first metatarsal osteotomies. Numerous studies have revealed that minimally invasive hallux valgus surgery can achieve a good satisfaction rate similar to other open techniques (*24,25*). The distal metatarsal osteotomy in our study was a minimally invasive, simple bony procedure without other specific soft tissue procedures. We did not perform bunion resection, formal capsulorrhaphy, lateral release or capsulotomy. We used a fluoroscopic image intensifier to ensure accurate extraperiosteal position of the K-wire, check the osteotomy level, check that the wire was midway between the dorsal and plantar aspects of the great toe in order to engage the metatarsal head correctly and to control driving of the wire through the first tarsometatarsal joint for greater stabilisation. Our study involved 24 adult patients including 12 with bilateral HV deformity (36 feet) managed with MIDMO. Their ages ranged from 17 to 52 years with mild-to-moderate HV. All patients presented with pain over the bunion as their primary complaint. In our study, patients reported complete disappearance of pain for 83.3% of the operated feet, occasional pain for 11.1%, and daily moderate

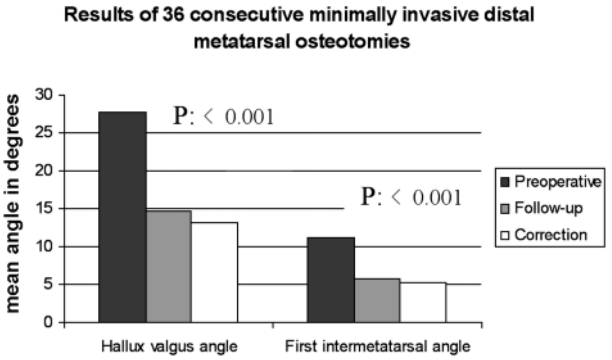

Fig. 5.— Radiographic results of 36 consecutive minimally invasive distal metatarsal osteotomies.

pain for 5.6% ; no patient reported severe or constant pain. The mean overall pain score was 37.3 ± 4.7 points of the 40 point maximum on the AOFAS. These results are comparable to other series that have reported satisfactory improvement in pain in 80-95% patients using open techniques. In a study of 91 Mitchell osteotomies, Desjardins *et al* (*5*) achieved satisfactory improvement of pain in 92% of patients. Johnson *et al* (*7*) retrospectively compared their results with distal chevron osteotomy and a modified McBride bunionectomy. Ninety-two percent of patients in the chevron group and 88% of patients in the modified McBride group were totally satisfied or improved regarding pain relief. The results of other series using minimally invasive techniques also reported comparable results to our study: the mean overall pain score reported by Magnan *et al* (*11*) was 36.3 ± 6.2 and that reported by Yu-Chuan Lin *et al* (*10*) was 35.7 ± 5 points. In our study, the mean HVA and first IMA corrections were 13.1° and 5.4° respectively compared with 17.8° and 5.1° in Magnan *et al*'s (*11*) study and 11.8° and 6.3° in the study by Lin *et al* (*10*). Our results indicate that this minimally invasive technique can achieve angular correction as good as that achieved using traditional techniques. Using open techniques, the mean HVA correction reportedly ranged from 8.8° to 26°, and the mean first IMA correction from 3.8° to 11° (*3,24*). A limitation of this minimally invasive approach is that we were unable to control the magnitude of lateral translation. This method simply relied on the stiffness of the K-wire and the size of the capital fragment to achieve lateral translation. We believe that the magnitude of the angular correction needed might limit the use of our approach to treat more severe hallux valgus deformities. This explains why a first intermetatarsal angle < 18° was used as an inclusion criterion in our study. The absence of lateral release or formal capsulorrhaphy may explain the absence of hallux varus after surgery. In Magnan *et al*'s study (*11*) and in ours, there were no instances of overcorrection into hallux varus. The valgus deformity recurrence rate reported by Magnan *et al* (*11*) was 2.5%. In our study there were no cases of recurrence, which may be explained by the smaller number of cases in our series (36 feet) compared with the series of Magnan *et al* (118 feet) (*11*) : good selection of the cases according to the inclusion criterion may also be an explanation. Absence of any specific action on the soft tissues did not appear to affect the occurrence of recurrent hallux valgus deformity, perhaps because reorientation of the metatarsal head and reduction of the head on the sesamoids were consistently achieved. In other studies that used open techniques in association with soft tissue procedures, the recurrence rate ranged from 0% to 10% (*9,14,16,24*). Although some of our cases had an increase in HVA after K-wire removal, the HVA and first IMA were significantly decreased at final follow-up. The Kirschner wire insertion level in the study of Lin *et al* (*10*) was at the middle of the proximal phalanx. In our study and in the study of Magnan *et al* (*11*) the more distal percutaneous insertion level of the K-wire, may have achieved a greater correction of the hallux valgus angle because of a longer level arm to abduct the big toe. The mean extent of lateral displacement of the first metatarsal head in our study was 56.2% of the diameter of the first metatarsal shaft in the immediate postoperative period and 36.1% at the time of full consolidation of the osteotomy ; similar values have been reported by Magnan *et al* (*11*) (52.6%, 32.8% respectively). The action of the long extensor and long flexor tendons on the hallux during the plasticity phase of the healing callus probably offset the slight hypercorrection obtained intraoperatively. In our study the relative length of the first metatarsal was measured by the method of Morton (*15*). Morton's method has two advantages :

First, it detects the ''biomechanical length'' of the first metatarsal (medial deviation of the first metatarsal leads to a functional shortening). Second, the probability of a measuring error caused by perspective distortion of the radiographs is reduced. In our study the relative shortening of the first metatarsal was measured in 11 feet (30.6%). The mean first metatarsal shortening was 2.2 ± 2.8 mm (range : -8 to 3.4 mm). The measured lengthening in some cases can be explained by the reduction of the first IMA and the resulting functional lengthening of the first metatarsal. Transfer metatarsalgia, which may affect clinical outcomes, is a serious complication after first metatarsal osteotomy. Transfer metatarsalgia occurred with a range from 0% to 40% in studies that used open techniques (*9*). This may be as a result of dorsalisation of the first metatarsal head or significant shortening of the first metatarsal. Transfer metatarsalgia was not noted in our series, and was not mentioned by Magnan *et al* (*11*). This may be because the osteotomy performed in MIDMO was in a single perpendicular plane, which was unable to cause overshortening of the first metatarsal. Also there was mild dorsiflexion of the capital fragment in the lateral radiograph after surgery in only 3 feet out of the 36 feet in our study. Stiffness of the first MTP joint has been reported to occur in 0% to 37.8% of cases using open techniques with capsulotomy (*9*). This may be from lengthening of the first metatarsal through an oblique distally oriented osteotomy (dorsal arm) and excessive medial capsular tightening. However, this can be overcome by early passive mobilization of the MPI joint. The incidence of postoperative stiffness of the first MTP joint in our study was 8.3% ; it was 6.8% in Magnan *et al*'s series (*11*) and 4.26% in that of Lin *et al* (*10*). This was attrituted to poor mobilisation of the hallux following removal of the tape. However, these patients did not regard the joint motion deficit as disabling, and did not report pain during walking. We had no case of postoperative avascular necrosis of the first metatarsal head, presumably due to the preservation of soft tissues on the lateral side of the metatarsal. These structures are important for the blood supply of the distal fragment. In our study, there were also no instances of nonunion, malunion or deep infection.

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