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Original Article

Use of Minimally Invasive Distal Metatarsal Osteotomy for Correction of Hallux Valgus
微創遠端蹠骨截骨術矯正拇外翻的應用

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ABSTRACT

Purpose: Minimally invasive surgeries have become increasing popular in Orthopaedics. This study evaluated the clinical and radiographic outcomes of application of the concept for correction of mild-to-moderate hallux valgus deformity.
Methods: From November 2005 to Feb 2010, 20 patients with hallux valgus deformity had distal metatarsal osteotomy performed using the minimally invasive surgical techniques described by P. Bosch. Three patients had bilateral operation done at the same setting. The patient age ranged from 29 years to 75 years (mean 55.1 years) with 2 men and 18 women. One 2 mm Kirschner wire was used to splint the osteotomy site, which was removed after 4 weeks to 5 weeks. The mean follow-up time was 22 months.
Results: All except one foot showed excellent to good grading using the American Orthopaedic Foot and Ankle Society Hallux Scale (total 100 points). The mean score improved from preoperative 53.0 points to postoperative 91.8 points. The hallux valgus angle improved from a preoperative mean of 31.3° to 15.7°, and the first intermetatarsal angle improved from 16.7° to 7.7°. There was no major complication encountered. All patients showed bony union with no avascular necrosis. Three patients had mild pin tract infection. Two patients had backing out of the K-wire and one of them required re-insertion. So far, no patients required reoperation due to recurrence.
Conclusion: Good clinical and radiographic results have been achieved with minimally invasive techniques for treatment of hallux valgus. This is an acceptable alternative operation for mild-to-moderate hallux valgus.

中文摘要

目標：骨科微創手術已日益流行。由於缺乏科學的驗證，這些概念應用在拇趾外翻的情況並不普遍。然而，有最近的研究顯示滿意的結果。本研究評估輕度至中度拇趾外翻畸形經皮遠端蹠骨截骨術治療後的臨床和影像學結果。
方法：自2005年11月至2010年2月，20名有拇趾外翻畸形的病人接受Bosch技術的經皮蹠骨遠端截骨術治療。3名病人接受雙側手術。病人的年齡介於 29至75歲（平均55.1歲），包括2名男性，18名女性。用一支2毫米的克氏針來固定截骨處。克氏針會在4至5週後拆除。平均跟進的時間為 22個月。
結果：根據美國足踝骨科協會拇趾級別，除了一個案例，其餘的病人都達到良好至優異評級，平均得分由手術前平均53.0分改善至91.8分（總分 100分）。拇趾外翻角度由手術前平均為 31.3度改善至15.7度。第一蹠骨間角由手術前平均為16.7度改善至7.7度。我們沒有遇到重大的併發症。所有患者都顯示骨癒合，及沒有缺血性骨壞死。3名病人有輕度針道感染。2名病人有克氏針回退現象，其中一位需要重新插入克氏針。到目前為止，沒有病人因為復發而需要再做手術。
結論：微創治療拇趾外翻技術已經取得了良好的臨床和影像學結果。它提供另一個選擇去治療輕度至中度的拇趾外翻。

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Introduction

Hallux valgus (HV) is a common orthopaedic foot problem affecting the big toe, especially in women. It is characterized by a lateral deviation of hallux and medial deviation of the first metatarsal with subsequent bunion formation. Surgical correction is indicated for failure of nonoperative treatment of painful bunion and progression of hallux deformity affecting shoeing[1–5]. Different open soft tissue and bone surgeries were described with variable successful rate. The application of minimally invasive techniques in HV was not common because of the lack of scientific validation. However, satisfactory results were shown in recent studies. The application of these concepts was reported by P. Bosch et al in 1990 and popularised later by B Magnan & by Giannini et al.

The operation involved a linear osteotomy with precise execution and secure stabilisation of the osteotomy site with one Kirschner wire. Potential advantages include a smaller incision, a cost-effective fixation device, a shorter operating time, and an early weight bearing with little local complications.

Materials and Methods

From November 2005 to February 2010, 20 patients with painful bunion due to mild-to-moderate HV deformity were operated by using mini-incision to perform distal metatarsal osteotomy as described by P. Bosch. Three patients had bilateral operation done, making up a total of 23 feet. All the patients were operated by the same team of surgeons. Standing anteroposterior (AP) and Lateral X-rays were taken for radiological assessment. Radiographic criteria consisted of a HV angle of $\leq 40^\circ$ and a first intermetatarsal (IM) angle of $\leq 20^\circ$. Patients with osteoarthritis of first metatarsophalangeal joint, hallux rigidus, previous surgery, peripheral vascular disease or uncontrolled diabetes were excluded.

Surgical techniques

The operation was performed with a minimally invasive technique under spinal or general anaesthesia. The surgical procedure was facilitated with the use a fluoroscopic image intensifier intraoperatively.[7]

A 1–1.5 cm medial skin incision centred at the intended osteotomy site of the distal part of the first metatarsal bone was made under X-ray guidance (Figure 1). Sub-periosteal dissection was then performed to expose the metatarsal neck. Curve periosteal elevator was used to strip around the intended osteotomy site. A pair of small malleable retractors was inserted to protect the surrounding neuro-vascular bundles and tendons.

A 2.0-mm Kirschner wire (K-wire) was introduced firstly from the incision site in antegrade manner towards big toe pulp by tunnelling in the soft tissue close to the proximal phalanx to exit near the medial nail fold. The K-wire will be withdrawn until the proximal end touching the intended osteotomy site. By using the X-ray screening guidance, a transverse osteotomy was then performed at the metatarsal neck slightly proximal to the sesamoid bones using an oscillating micro-saw. To guide the level and direction of osteotomy, the first metatarsal shaft coronal and sagittal axis were also used as reference for the bone cut. Orientation of osteotomy is perpendicular to the metatarsal shaft in the sagittal plane and parallel to the metatarsal shaft in the frontal plane. The subperiosteal dissection is mainly over dorsal, plantar, and medial side; the main blood supply on lateral side was preserved. The osteotomy was completed laterally by using a small chisel.

The distal bone segment was then laterally displaced with the help of a pair of small artery forceps. The space created during leverage allowed passage of K-wire in retrograde manner. The osteotomy site was then stabilised by means of the K-wire, which was inserted retrogradely up to the base of the medulla canal of the first metatarsal (Figure 2). Derotation of the big toe was also performed manually to correct the pronated hallux.

Special care was taken not to create new fractures at the osteotomy site. We found that the passage of the K-wire was easier by slightly bending the proximal pin tip. We used Jacob chuck to control pin rotation and gently tapped its handle that facilitated the introduction of the intra-medullary K-wire. Additional soft tissue release like modified Mcbride procedure was not performed in our series.

Skin wound was closed with fine suture after confirming the K-wire position radiologically (Figure 3A and B). To maintain the hallux correction, a 2-inch crepe bandage was used to wrap around

Figure 1. Incision (fish-bone marking) & joint line (smooth marking).

Figure 2. Osteotomy followed by insertion of a K-wire to the medullary canal of 1st metatarsal bone.

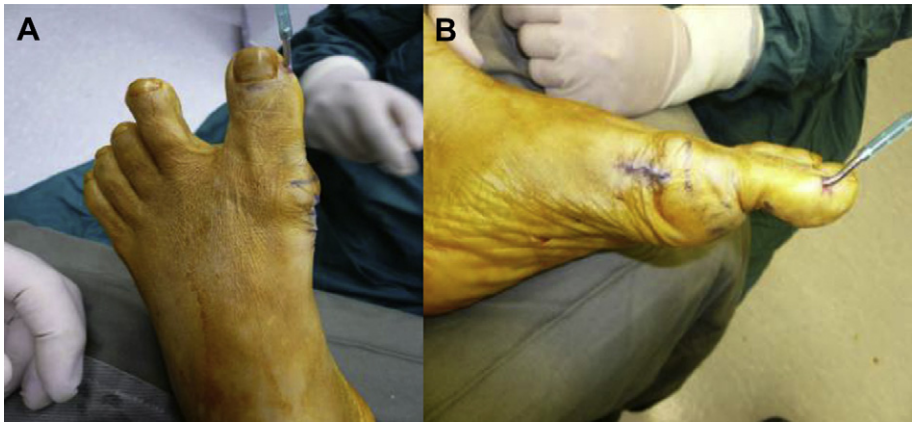

Figure 3. (A & B) Appearance after the operation.

the big toe and the bandage was also strapped around the second toe to give an additional control to the big toe rotation (Figure 4A). The distal tip of the K-wire was cut, bent, and capped.

Postoperatively, the patients were allowed to walk with a rigid sole short leg boot. The patients were discharged within 1–3 days postoperatively and followed up weekly. Heel walking was allowed in the first 2 weeks. When the pain was gradually reduced, forefoot partial weight-bearing walking was allowed. The K-wire was removed in 4–5 weeks, when clinical union had occurred. After the K-wire had been removed, full weight bearing walking exercise as tolerated was allowed. The patients were subsequently referred for mobilisation exercises of the big toe and were taught to perform bandaging to maintain the corrected position for 2–3 months (Figure 4B). Normal shoe wear could be used 6–8 weeks after the operation.

Clinical and radiological assessment

The Hallux-Metatarsophalangeal-Interphalangeal Scale and grading system proposed by the American Orthopaedic Foot and Ankle Society (AOFAS) was used to assess the result[8] (Table 1). The scoring system ranged from 0 to 100 points, incorporating both subjective and objective factors into numerical scales to describe pain, functional capacity, and hallux alignment.

All the patients had pre- and postoperative standing anteroposterior (AP) and lateral radiographs of the foot taken. The HV angle, first IM angle, tibial sesamoid position (TSP), and distal metatarsal articular angle (DMAA)[6] were measured to assess the correction of the deformities. The HV angle was defined as the angle formed by the bisection of 1st metatarsal axis and proximal phalanx axis (Figure 5A). Normal value was less than 15°. The first IM angle was defined as the line joining bisection of the first and the second metatarsal axis. The mean value was 8°.[9]

"Haas" presented a classification scheme to quantify the degree of lateral movement of sesamoid apparatus. The TSP is determined by the location of tibial sesamoid relative to the bisection of the first metatarsal. The TSP was graded in 1–7 from medial to lateral positions. TSP 1 = Sesamoid rests medially clear of the first metatarsal bisector; TSP 2 = Sesamoid (lateral edge) touches the first metatarsal bisector; TSP 3 = Sesamoid (lateral edge) overlaps the first metatarsal bisector; TSP 4 = Sesamoid equally halved by the first metatarsal bisector; TSP 5 = Sesamoid (medial edge) overlaps the first metatarsal bisector; TSP 6 = Sesamoid (medial edge) touches the first metatarsal bisector; TSP 7 = Sesamoid rests laterally clear of first metatarsal bisector. A normal TSP is position 3 and will increase with HV progression.

Because the distal segment was lateralised after osteotomy, the reference points to define the longitudinal axis need to be adjusted. To assess the correction of the HV angle and IM angle, the method described by Hiroski at el[10] was used in our review. In this method, a line drawn joining the centre of the first metatarsal head to the central proximal articular surface of the first metatarsal was used to define its longitudinal axis of the first metatarsal bone (Figure 5B).

Statistical analysis

Comparison of preoperative HV angle, first IM angle, and DMAA with those at the final follow-up was made with use of the paired Student *t* test. P value less than 0.05 was set as the cut off for the level of significance (Figure 6).

Figure 4. (A & B) Dressing and subsequent bandaging to maintain corrective position.

Table 1
AOFAS Hallux Scale & grading

Hallux Metatarsophalangeal-Interphalangeal Scale	
Pain (40 points)	
None	40
Mild, occasional	30
Moderate, daily	20
Severe, almost always present	0
Function (45 points)	
Activity limitations	
No limitations	10
No limitations of daily activities such as employment	7
Limited daily and recreational activities	4
Severe limitation of daily and recreational activities	0
Footwear requirements	
Fashionable, conventional shoes, no insert required	5
Comfort footwear, shoe insert	3
Modified shoes or brace	0
MTP joint motion (dorsiflexion plus plantarflexion)	
Normal or mild restriction (75° or more)	10
Moderate restriction (30°–74°)	5
Severe restriction (less than 30°)	0
IP joint motion (plantarflexion)	
No restriction	5
Severe restriction (<10°)	0
MTP-IP stability (all direstions)	
Stable	5
Definitely unstable or able to disiocate	0
Callus related to hallux MTP-IP	
No callus or asymptomatic callus	5
Callus, symptomatic	0
Alignment (15 points)	
Good, hallux well aligned	15
Fair, some degree of hallux malalignment observed, no symptoms	8
Poor, obvious symptomatic malalignment	0
Total	100

AOFAS = American Orthopaedic Foot and Ankle Society.
Grading: Excellent = 90–100 points; Good = 75–89 points; Fair = 60–74 points; Poor = <60 points.

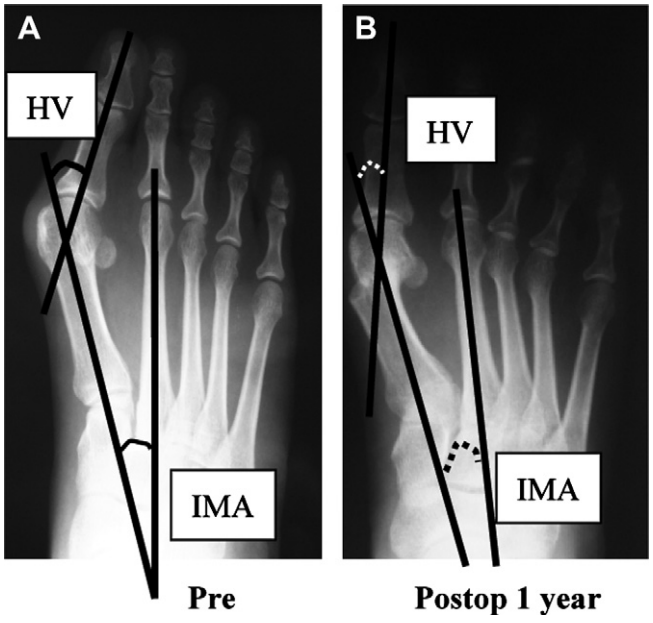

Figure 5. (A & B) Pre & post op X-ray measurement (by Hiroski method). PrePostop 1 year.

Results

There were a total of 20 patients (male: 2; female: 18) with 3 cases of bilateral involvement (Table 2). Thus 23 feet were available for the analysis. The mean age of the patients at the time of operation was 55.1 years (ranged 29–75 years) with male-to-female ratio was 1:9. The average follow-up time was 22 months (ranged 12–60 months).

For the bunion pain, all patients reported the disappearance or reduction of pain over the first metatarsal (MT) heads after the operation. Sixteen patients (18 feet; 78%) reported total disappearance of the pain, whereas eight patients (5 feet; 22%) had occasional pain. The mean overall pain score was 38 points of the 40-point maximum on the AOFAS Hallux-Metatarsophalangeal-Interphalangeal scale. The scoring for the functional capacity of the hallux (which assesses the activity limitation, footwear, metatarsophalangeal (MTP) joint motion, interphalangeal (IP) joint motion, joint stability, and callus) was averaged to 41 points. Eighteen of 23 patients can achieve 75° of the first MTP joint motion (from dorsiflexion to plantarflexion). In terms of the hallux alignment, 16 patients (17 feet) gained full marks. Mild asymptomatic mal-alignment was noted in 6 patients (6 feet). There was no patient with recurrence of HV. The overall mean score for hallux alignment was 13.0 points.

Using the AOFAS Hallux Scale (total 100 points), a mean improvement of total score from 53 points to 92 points was achieved in the 23 feet operated. Except one foot with fair result, all the rest of the patients (95.7%) had excellent to good to excellent result.

Radiologically, the mean HV angle improved from 31° preoperatively to 16° postoperatively ($p < 0.05$). The mean first IM angle improved from 17° to 7.7° ($p < 0.05$). The mean DMAA decreased from 16° to 9.7° ($p < 0.05$). The results were statistically significant according to the paired Student *t* test (Table 3). Concerning the TSP, 11 patients were found to have improvement. Nine patients had no change in TSP. We cannot draw conclusive results on 3 patients (Patient 6, Patient 14, and Patient 15) whose TSPs were deviated from one extreme position to other postoperatively.

Complications

There were 3 cases of mild pin tract infection, which resolved with a course of oral antibiotics. Two patients had accidentally pulled out the K-wire during sleeping and one of them required revision operation. The other patient had backed out the K-wire at the 3rd week postoperatively that was removed without revision surgery. Strapping was used to hold and maintain the correction. The osteotomy was transverse and had some intrinsic stability. There was uneventful bone healing and re-displacement did not occur. Two patients had transient mild reflex sympathetic dystrophy of the feet during the early follow-up and it resolved with rehabilitation training. There was no non-union or avascular necrosis of the metatarsal head noted. Up to the latest follow-up, there was no case with overcorrection or recurrence of the HV beyond the normal limit (i.e. HV angle > 15–20°).

Discussion

Percutaneous distal first metatarsal osteotomy was first introduced by Bösch et al in 1984.[7] A long-term follow-up report of 114 patients showed satisfactory correction of the HV and the IM angles without complications like hallux varus, pseudoarthrosis or orosteonecrosis. Portaluri[11] used the method of Bösch to correct HV and reported 89% patients were fully satisfied with their results. Several features of this procedure were highlighted which including short operating time, low incidence of complications, and high patient compliance. Magnan et al[12] also found 91% patient-satisfaction rate

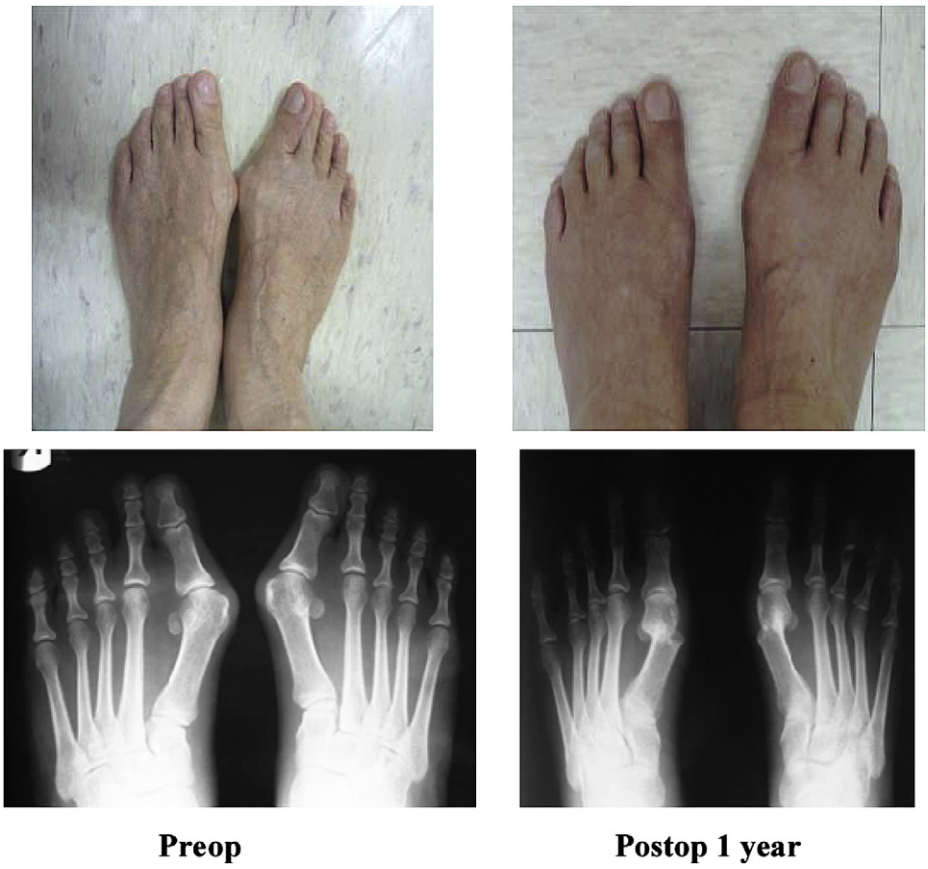

Figure 6. Case illustration. Pre- & Postop 1 year.

in 118 similar procedures. The clinical results were also comparable with those obtainable with traditional open techniques.

The merit of the procedure was small incision with minimal soft tissue dissection, shorter operation time, and no major complication. By lateral translation of the osteotomised distal metatarsal bone segment helps to reduce the adductor hallucis pull and thus save additional soft tissue rebalance procedure like the modified Mcbride procedures. Bunion resection was also spared. Because the MT joint capsule was not disturbed in this extra-articular procedure, the chance of joint stiffness was reduced.

Table 2
Results

Patient	Sex	Age	Side	Follow-up (FU)s	AOFAS		Grade	Final			Pre X-ray				Final				Remarks
				Mon	Pre	Final		Pain	Funct	Align	HV	IM	DMA	TSP	HV	IM	DMA	TSP	
1	F	75	L	60	60	92	E	40	37	15	20	10	6	4	18	8	4	4	Pin infection, RDS
2	M	61	L	54	44	93	E	40	45	8	30	18	14	2	22	8	12	4	Pin infection
3	F	60	R	52	34	100	E	40	45	15	36	16	14	2	22	4	10	4	Pin infection
4	F	47	L	28	37	90	E	40	40	15	36	18	30	3	14	14	8	3	
5			R	28	37	88	G	40	40	8	36	18	30	3	16	14	14	3	
6	F	31	R	42	47	93	E	40	45	8	30	12	16	2	20	10	14	5	
7	F	52	R	24	37	93	E	40	45	8	30	16	18	3	24	8	10	4	
8	F	75	L	36	62	68	F	30	35	8	38	16	18	3	2	4	4	4	Fair result
9			R		62	95	E	40	35	15	38	18	12	6	12	10	4	4	
10	F	62	L	36	75	100	E	40	45	15	30	20	24	3	8	4	8	2	
11	F	48	R	36	60	95	E	40	40	15	25	15	8	6	16	6	16	4	
12	F	29	L	28	44	100	E	40	45	15	30	15	14	3	20	4	2	3	RDS
13	F	69	L	24	52	85	G	30	40	15	25	18	16	4	10	10	16	4	
14	F	65	L	20	47	100	E	40	45	15	32	18	24	1	18	4	16	4	
15			R		47	100	E	40	45	15	38	20	14	1	22	12	10	5	
16	M	53	L	24	39	100	E	40	45	15	30	20	12	2	18	14	14	4	
17	F	52	L	17	47	85	G	30	40	15	30	13	10	2	16	4	2	4	
18	F	62	R	14	67	80	G	30	42	8	26	20	18	2	14	14	16	3	
19	F	35	R	13	60	90	E	40	35	15	32	18	16	4	16	6	12	4	
20	F	59	R	13	70	85	G	30	40	15	32	17	6	4	8	4	6	4	Back out & re-insertion
21	F	54	L	12	60	90	E	40	40	15	35	13	25	5	10	4	14	3	Back out 3 wk
22	F	54	L	12	60	100	E	40	45	15	40	16	4	6	20	6	4	3	
23	F	60	R	12	70	90	E	40	35	15	22	20	20	5	14	6	6	3	

AOFAS = American Orthopaedic Foot and Ankle Society; DMA = distal metatarsal articular; F = female; HV = hallux valgus; L = left; M = male; R = right; RDS = reflex sympathetic dystrophy; TSP = tibial sesamoid position.

Table 3
Radiological and functional results

Radiological results				
Angle	Preoperative	Follow-up	Correction	*p*
HV	31.3 ± 5.3 (20–38)	15.7 ± 5.4 (2–24)	15.0 ± 7.7 (2–36)	<0.05
First IM	16.7 ± 2.8 (10–20)	7.7 ± 3.8 (4–14)	9.0 ± 3.8 (2–16)	<0.05
DMA	16.0 ± 7.1 (4–30)	9.7 ± 4.9 (2–16)	6.4 ± 7.1 (−8 to 22)	<0.05
Functional results				
Pain (40 points)			37.8 ± 4.2 (30–40)	
Function (45 points)			41.3 ± 3.9 (35–45)	
Alignment (15 points)			13.2 ± 3.1 (8–15)	
Total (100 points)			91.8 ± 7.9 (68–100)	

DMA = distal metatarsal articular; HV = hallux valgus.

The risk of avascular necrosis was not high if one followed the proper surgical technique. Using small malleable retractors, the surrounding periosteal soft tissue was protected. Because the lateral release was not done, the blood supplied to the metatarsal head would be preserved.

Pronation of the hallux was indirectly corrected manually using this procedure. The sesamoid position also indirectly restored during derotation of the pronated hallux and lateral displacement of the distal metatarsal head segment after the osteotomy. The use of bandaging was also helpful to maintain the hallux correction.

Being a transverse osteotomy with little soft tissue dissection, the osteotomy site is intrinsically stable. Thus a less rigid fixation device would suffice to maintain the correction. The application of Kapandji intra-focal type of K-wire fixation in this study was able to maintain the bony alignment, while permitting early protective walking. The other advantages of the procedure include the fixation implant, which is less costly and can be removed in outpatient setting.

The possible reasons for correction of DMAA are due to rotation of the distal MT head segment in the frontal plane by a couple of forces created during the surgical procedure. While attempting to insert the K-wire in retrograde manner, we have to deviate the big toe to varus position. As the lateral collateral ligament was intact and not disturbed by surgery, an indirect couplying force will be generated to derotate the MT head. Derotation effect of the lateral force will be facilitated by relaxation of the adductor muscle pull secondary to lateral translation of the osteotomy MT head segment. The derotated distal segment will be maintained by the splintage of the K-wire on the medial side.

AOFAS Hallux Scale was commonly used to evaluate clinical outcome of HV surgery. Grading was based on the total score on pain, functional capacity, and hallux alignment. The mean scores after open techniques range from 83 points to 93 points[13–15]. Magnan et al reported the mean score of 88.2 points[12]. The average score for the twenty patients in our study was 91.8 points. Ninety-six percent of our series had good-excellent result. One foot with fair result (Patient 8) may be because of a combination of factors including pain from mild degenerative changes over the first metatarsophalangeal joint (MTPJ) and postoperative joint stiffness with loss of joint motion.

Magnan et al observed 2.5% recurrence rate and no hallux varus. Bosch did not encounter recurrence. In contrast, recurrence rate in open techniques with soft tissue procedures was up to 10%[14,16,17]. In our study, there was no overcorrection or recurrence of the HV deformity.

We agreed that the HV and IM angle improvement was not universally good in this series when compared with the functional scores. The main advantage of this operation was minimal soft-tissue trauma and extra-articular osteotomy without bunionectomy. The pain relief and joint mobility were much better when compared with open surgery. This may explain why there was discrepancy in X-ray improvement and functional results.

Because for the radiological improvement, we admitted that there was no good way to predict the exact correction that could be achieved after the transverse osteotomy. Further study to find a more predictable radiological correction can be obtained intra-operatively in future.

Concerning radiological parameters, inter and intra observer variances are quite common in the measurement of HV angle and IM angle. This is especially true when the X-ray film taking was not truly standardized. Some literature would take the upper limit of normal HV angle as 15–20° instead of strictly 15°.

Although there was not much controversy on the method of measurement of preoperative HV angle and IM angle, no consensus could be made on the radiological measurement on postoperative radiological measurement after distal metatarsal osteotomy. Inter and intra observer differences were much higher compared with preoperative X-ray measurement. A figure of ±5° for the HV angle and ±4° for the IM angle was being quoted. For the above reasons, we accepted the normal limit of the HV angle up to 15–20° and IM angle 9–13°.

One drawback of this procedure was that the exact degree of correction could not be precisely determined preoperatively when compared with other distal metatarsal osteotomy techniques. Furthermore, there is concern of the maintenance of correction by single K-wire. From this retrospective review, it showed that our clinical results were comparable with other series. The result of this operation is reproducible.

In conclusion, this study demonstrated that minimal invasive distal metatarsal osteotomy with K-wire stabilisation under fluoroscopic guidance offered a reliable, reproducible, simple, safe, and cost-effective way of treating mild-to-moderate HV deformity.

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