First metatarsal Chevron osteotomy with minimally invasive surgery

Radiological evaluation

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Received on July 2nd, 2016; accepted after evaluation on July 10th, 2016 • JORGE J. DEL VECCHIO, MD • javierdv@mac.com

Abstract

Introduction: The aim of this study was to analyze X-ray results of Chevron osteotomy in first metatarsal bones using minimally invasive techniques in a uniform patient population (moderate hallux valgus).

Materials and Methods: Between October 2013 and November 2014 we treated hallux valgus with Chevron osteotomy in first metatarsal bones with minimally invasive techniques, in 24 feet in 21 patients, all of them diagnosed moderate hallux valgus.

Results: The average pre-operative inter-metatarsal angle between the first and the second metatarsal bones was 12.46º (11-15º range; standard deviation 1.03). After the surgery, we got average values of 8.13º (5-10º range; standard deviation 1.16º) Average angular correction was 4.33º. The average pre-operative hallux valgus angle was 33.96º (20-40º range; standard deviation 4.93). After the surgery, the average metatarsal-phalangeal angle was 8.16º (3-15º range; standard deviation 2.86). The average improvement of the metatarsal-phalangeal angle was 25.86º.

Conclusions: X-ray correction that we got by Chevron osteotomy using minimally invasive techniques confirm that this is a safe and effective procedure for the treatment of moderate hallux valgus, with satisfactory angular corrections at mid-term follow-up. This procedure resembles reliably open techniques with all its acknowledged advantages, and we have not found any equivalent study in the bibliography.

Key words: Hallux valgus; minimally invasive surgery; Chevron osteotomy.

Level of evidence: IV

Osteotomía en tejadillo (*Chevron*) con técnica mínimamente invasiva en la región distal del primer metatarsiano. Evaluación radiológica

Resumen

Introducción: El objetivo de este estudio fue analizar los resultados radiológicos de una osteotomía en tejadillo (Chevron) del primer metatarsiano, con técnica mínimamente invasiva, en una población uniforme de pacientes (hallux valgus moderado).

Materiales y Métodos: Entre octubre de 2013 y noviembre de 2014, se trató el hallux valgus mediante una osteotomía en tejadillo (Chevron) del primer metatarsiano con técnica mínimamente invasiva, en 24 pies correspondientes a 21 pacientes, todos con diagnóstico de hallux valgus moderado.

Conflict of interests: The authors have reported none.

http://dx.doi.org/10.15417/633

Resultados: El ángulo intermetatarsiano preoperatorio promedio entre el primero y el segundo metatarsiano fue de 12,46° (rango 11-15°; desviación estándar 1,03). En el posoperatorio, se obtuvo un valor promedio de 8,13° (rango 5-10°; desviación estándar 1,16). La corrección angular promedio fue de 4,33°. El ángulo de hallux valgus preoperatorio promedio fue de 33,96° (rango 20-40°; desviación estándar 4,93). En el posoperatorio, el ángulo metatarsofalángico promedio fue de 8,16° (rango 3-15°; desviación estándar 2,86). La mejoría promedio del ángulo metatarsofalángico fue de 25,86°.
Conclusiones: La corrección radiológica obtenida mediante la técnica mínimamente invasiva de la osteotomía en tejadillo confirma que es un procedimiento seguro y eficaz para el tratamiento del hallux valgus moderado, con correcciones angulares satisfactorias a mediano plazo. Este procedimiento remeda, de manera fidedigna, la técnica quirúrgica abierta con todos sus beneficios conocidos y no se encontró un estudio equivalente en la bibliografía.

Palabras clave: Hallux valgus; cirugía mínimamente invasiva; osteotomía en tejadillo.
Nivel de Evidencia: IV

Introduction

According to Kellikian,[1] the term "hallux valgus" was set out by Carl Heuter in 1871. This is the orthopedic disorder that involves the first metatarsal ray most frequently, and the deformity most frequently consulted about at the orthopedist's office. [2-4] According to Myerson[5] it affects 2-4% of the population and consists of the lateral deviation of the hallux associated with the medial displacement of the first metatarsal bone.

In order to solve this problem, adult patients have to undergo surgical treatment. Among surgical approaches, bone correction and alignment play a key role and avoid most cases of recurrence. There are several kinds of osteotomies for hallux valgus correction, and the most frequently used are the distal ones, such as the Chevron osteotomy.

The Chevron osteotomy was described by Corless in 1976 as a modification of Mitchell's osteotomy. [6] In 1981 Austin [7] published his osteotomy (a chevron shaped osteotomy), that consisted of osteotomy and 60º-angled "V" lateral displacement of the head of the first metatarsal bone to correct the abnormal varum of the first metatarsal bone in hallux valgus conditions.

In 1994, Johnson et al. modified the orientation of the dorsal branch so as to get a 90º angle and decrease the risk of avascular necrosis.[8,9]

Nowadays, the Chevron osteotomy is indicated to correct mild or moderate hallux valus.

This technique offers stability, allows the patient fast recovery, results in minimal shortening of the first metatarsal bone and is associated with low complication rates.[10-12]

Percutaneous metatarsal osteotomies have made progress as of traditional open techniques and have been progressively acknowledged, with short- and mid-term success; [13-17] moreover, they are safe techniques that can be reproduced in corpses.[18]

Bearing in mind the indications and the potential advantages of the minimally invasive techniques, some authors started experimenting with osteotomies similar to open Chevron osteotomies, although with some conceptual differences—one of them is the so called "Minimally Invasive Chevron-Akin technique",[19,20] which is carried out at the level of the neck of the first metatarsal bone (extra-articular) and requires two screws as stabilization method and, in other cases, the so called "third generation osteotomies", also at the level of the neck of the fist metatarsal bone.[21]

The aim of this study was to analyze the X-ray results of Chevron osteotomy in the first metatarsal bone with minimally invasive techniques in a uniform patient population (diagnosed moderate hallux valgus).

Materials and Methods

This consecutive-case prospective cohort study was approved by the Educational Committee of the Fundación Favaloro. Every patient gave the necessary and proper consent for the study. Between October 2013 and November 2014, 24 feet in 21 patients were subject to surgical treatment of hallux valgus by Chevron osteotomy using minimally invasive techniques in the first metatarsal bone. Surgeries were carried out by a sole surgeon (J.d.V). All the patients had been diagnosed moderate hallux valgus.

Indications to these patients of surgical treatment were isolated and resistant pain at the level of the first metatarsal-phalangeal joint or pain at the level of the medial exostosis associated with the hallux valgus deformity resistant to medical and orthoses treatment (changes in shoes or plantar orthoses), or changes in daily or entertaining activities.

Patients with severe degenerative disorders at the level of the first metatarsal-phalangeal joint, rheumatoid arthritis and hallux rigidus were not included. One patient was subject to distal percutaneous minimally invasive osteotomy of the smaller metatarsal bones due to metatarsal pain resistant to orthoses treatment (Case # 16).

X-ray evaluation

We made patients take both feet anterior-posterior and lateral X-rays in a weight-bearing bipodal-stance with no shoes, before the surgery and, at least, six months after the surgey.[22] Angles between the fist and the second meta-

tarsal rays were determined on the basis of the recommendations by the *American Orthopaedic Foot and Ankle Society (AOFAS) ad hoc Committee on Angular Measurements*.[23] We measured the hallux valgus or metatarsal-phalangeal angle (normal up to 15º), the inter-metatarsal angle (normal ≤9º), and the distal metatarsal joint angle (normal ≤6).

Hallux-valgus moderate deformity is defined as that with a metatarsal-phalangeal angle between 20º and 40º, an inter-metatarsal angle between 12º and 15º, and lateral sesamoid sub-luxation of 50-75%.[4]

For angular gauge we used the rotation center landmark of the head of the first metatarsal bone as described by Miller et al.[24] in 1974, what allowed us to get a correct and consistent pre-operative and post-operative evaluation of the patients' inter-metatarsal and metatarsal-phalangeal angles. This method has recently been described as the most accurate for the post-operative evaluation of distal osteotomies of the first metatarsal bone.[25]

The evaluation and registration of the distal metatarsal joint angle was made using the aforementioned conventional gauge technique.[26] Joints were classified as suggested by Piggott[27] as congruent or incongruent on the basis of the relationship between joint aspects.

Likewise, the patients' metatarsal and digital equations were taken into account.

So as to determine if there were degenerative joint disorders, we searched the patients' anterior-posterior X-rays for joint space narrowing, osteophytes or osteochondral lesions. Only two feet showed mild oseteoarthritic changes before the surgical procedure.

General X-ray assessment was undertaken by two of the authors (N.R and M.E.G., orthopedic surgeons experienced in leg, ankle and foot surgery).

Surgical technique

All the patients were subject to first metatarsal bone Chevron osteotomy with minimally invasive techniques in association with lateral release by lateral approach plus percutaneous Akin osteotomy when it was worth doing it. What follows is the descripiton of the procedure stages:

- *Anesthesia* (regional nerve blockade). Digital nerves block of the first ray with 0.5% 20 ml-bupivacaine without epinephrine (May's blockade).

- *Minimally invasive surgery.* Three-mm medial approach on the limit between the proximal and the middle thirds of the head of the first metatarsal bone located under fluoroscopic control, with scalpel for minimally invasive surgery (SM69, Swann-Morton®) (Figure 1), followed by percutaneous dorsal-medial capsulotomy for head mobilization. Chevron osteotomy with 80-100º angle using 2 x 12.0 mm Isham Straight Flute Shannon drill (Vilex®) associated with specific instruments for percutaneous surgery (Osada® Pedo Podiatry Unit). Lateral displacement of the head of the first metatarsal bone up to 50%, using intramedullary 2-mm Kirschner pin and fluted probe (Bosch's method) (Figure 2). When there was abnormal

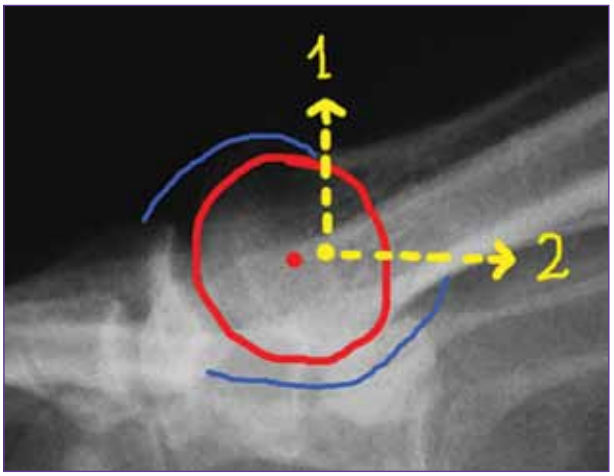

Figure 1. Approach orientation and opening for the drill in minimally invasive Chevron osteotomy (limit between proximal and middle thirds of the head of the first metatarsal bone). 1. Direction of the vertical branch. 2. Direction of the horizontal branch.

Figure 2. Technique of head displacement. Sub-cutaneous 2-mm Kirschner pin. Using the intramedullary fluted probe and putting forward the pin it is possible to get lateral displacement of the head of the first metatarsal bone.

distal metatarsal joint angle associated, we carried out a medially based larger "wedge" removal at the level of the upper branch of the osteotomy. Head displacement of 3 or 5 mm to the side as required (<50%). Osteosynthesis with made in Argentina 2.7-mm grooved double thread screw, or —preferably— 3.0-mm conical screwing (Miniacutrak II, Acumed®) from the dorsal-medial area in the lateral-plantar direction (Figure 3). Finally, removal of remaining medial exostosis using delicate drill (Wedge Burr 3.1, 3.1 x 10 mm,Vilex®).

-*Lateral release* (lateral approach). By 5-mm dorsal-lateral approach, full release of the hallux abductor tendon plus exclusive lateral-plantar capsulotomy (Figure 4).

- *Postoperative care.* Patients should be allowed full weight-bearing between 12 and 24 hours after the surgery, as tolerated by pain. Neutral heel rigid sole shoes for four weeks are recommended. By this moment, passive range of motion (ROM) exercises for metatarsal-phalangeal and inter-phalangeal joints and physiokinesis in case the patient has made little progress in ROM throughout. Then, two weeks of semi-rigid sole casual shoes wearing are recommended. Usual shoes at week six. Contact and launch sports or multiple jumping as from the three or four months following the surgery, depending on metatarsal-phalangegal mobility and symptoms.

Statistical analysis

Data were analyzed with the IBM's SPSS 20 statistical package. We used a mixed lineal model analysis to compare data (for example, hallux valgus angle, inter-metatarsal angle and distal metatarsal joint angle) got at different times (before and after the surgery). We considerate as significant a $p < 0.0001$ difference (Mann-Whitney's test).

Results

Demographic data

The patients' average age at the time of the surgery was 48 years old (ranging from 24 to70, standard deviation [SD] 13.37), 19 patients were females (90.4%) and two, males (9.6%). These figures were higher when all the feet were considered bilaterally—91.6% of the patients were females. Eleven feet were right, and 13, left. In three patients we took bilateral standards into account. Average follow-up was 11.59 months (ranging from 6 to 18, SD 4.67) (Table 1).

X-ray evaluation

X-rays were taken pre-operatively, and between 6 and 18 months after the surgery right as we carried out the patients' follow-up.

Figure 3. Lateral release by dorsal-lateral approach; hallux abductor tendon and lateral-plantar capsule section.

Figure 4. Definite correction. Bicortical stabilization.

The average pre-operative inter-metatarsal angle between the first and the second rays was 12.46º (ranging from 11º to 15º; SD 1.03). After the surgery, the average value was 8.13º (ranging from 5º to 10º; SD 1.16). So, this average decrease (angular correction) was 4.33º, on average.

The pre-operative average hallux-valgus angle was 33.96º (ranging from 20º to 40º; SD 4.93).

After the surgery, the average metatarsal-phalangeal angle was 8.16º (ranging from 3º to 15º; SD 2.86). Average improvement in the metatarsal-phalangeal angle was 25.86º (Table 1).

Table 1. X-ray results

X-ray evaluation		Average	SD	p
Intermetatarsal angle (º)	Pre-operative	12.46	1.06	
	Post-operative	8.13	1.19	
	Difference	4.33		<0.0001
Hallux valgus (°)	Pre-operative	33.96	5.04	
	Post-operative	8.17	2.93	
	Difference	25.8		<0.0001
Distal metatarsal joint angle (°)	Pre-operative	9.92	3.48	
	Post-operative	4.96	2.85	
	Differnce	4.96		<0.0001

SD = standard deviation.

With respect to the distal metatarsal joint angle, we got the following results: before the surgery, 9.91º (SD 3.4) and, after the surgery, 4.95º (SD 2.79) (Figures 5-7).

We got full bone healing in all Chevron osteotomies. We found a case of incongruent joint due to hyper-correction of the distal metatarsal joint bone (-3º), in Case # 13. In four patients who were previously incongruent, we got joint parallelism (Cases # 5, 11, 20 and 22). In one patient, we had to remove the screw (3 mm) due to protrusion on skin and symptomatic difficulty to wear shoes.

We did not register any case of avascular necrosis, hallux varus, (dorsal or plantar) mal-union or hallux valgus recurrence.

Discusion

A number of studies based on the surgical treatment of the hallux valgus report that more than 90% of the patients are women.[28] In our series, 90.4% of the feet operated on were female.

There is a correlation between the increase of the hallux valgus angle and that of the inter-metatarsal angle,[4] what we confirm in this study.

Chevron osteotomy is indicated for the treatment of mild and moderate hallux valgus with sub-luxation of the metatarsal-phalangeal joint.[9-12] Since such procedure gets intra-articular correction, it can be carried out in congruent hallux valgus with non-severe distal metatarsal joint angle (≤15°). In the patients of our series, with such angle altered, we chose to perform a 1-3 mm medially based wedge by drilling repeatedly at the level of the upper branch of the osteotomy (minimally invasive triplanar osteotomy). The removal of osteosynthesis material (Case # 1) due to intolerance is similar to that reported in other series.[21]

The most severe complication following a distal Chevron osteotomy combined with procedures on soft tissues release is the avascular necrosis of the head of the metatarsal bone, with a reported incidence of 4-20%.[29-31] So, although by soft tissues release it is possible to get greater correction, if such release is extensive the risk of avascular necrosis can increase up to 40%. However, in other studies, they did not find this complication[32] and nor did we find it. We believe that this is because we carried out soft tissues release by a minimally invasive surgery approach and we only severed the hallux abductor tendon and a small portion of the capsule (lateral-plantar); this way, we avoided vascular injuries. Anyway, we are aware of the fact that sometimes this complication arises at mid-term follow-up (near 12 months after the surgery).

Figure 5. Case # 24. Anterior-posterior X-ray with weight-bearing.

Figure 6. Case # 24. Six months after the surgery. Anterior-posterior X-ray with weight-bearing.

Figure 7. Case # 24. Six months after the surgery. Lateral X-ray.

After carrying out distal percutaneous osteotomy, Kadakia et al.[33] reported high complication rates, such as dorsal mal-union (69%) and hallux valgus recurrence (38%).[34] In our series, there was no recurrence of the deformity, although we did find one case of mal-union (internal rotation of the head of the first metatarsal bone, -3º distal metatarsal joint angle).

With respect to the angular corrections gotten and while comparing our study with others on open Chevron osteotomy[11,12,35] and minimally invasive surgery, analyzing this patient population we found that this technique can correct axial and sagittal planes just as well. We corrected the hallux valgus deformity to a lesser extent, though, but we should bear in mind that the other studies included patients with greater angles (severe hallux valgus), and ours is a series of consistent patients (moderate hallux valgus) (Table 2). One advantage of this study is that it is based on a uniform patient population, all of them diagnosed as moderate hallux valgus.

In order to carry on with the validation of this technique, we should incorporate medical data (valuation and life-quality scales) and carry out comparative studies (control group, greater level of evidence), apart from security and reproducibility tests included in corpses studies.

Table 2. Comparison between studies (X-ray correction)

Chevron. Open surgery						
Publication	Average pre-operative inter-metatarsal angle (º)	Average post-operative inter-metatarsal angle (°)	Difference (°)	Average pre-operative hallux valgus angle (°)	Average post-operative hallux valgus angle (°)	Difference (°)
Pochatko & cols. (1994)	13	8	5	31	17.5	13,5
Potenza & cols. (2009)	13	7	6	28	16	12
Bai & cols. (2010)	17.1	7.3	9.8	36.2	12.4	23.8
Average	14.36666667		6.933333333			16.43333333
Minimally invasive chevron. Extra-articular						
Publication	Average pre-operative inter-metatarsal angle (º)	Average post-operative inter-metatarsal angle (°)	Difference (°)	Average pre-operative hallux valgus angle (°)	Average post-operative hallux valgus angle (°)	Difference (°)
Vernois & Redfern (2013)	14.5	5.5	9	33.7	7.3	26,4
Brogan & cols. (2014)	14.55	7.11	7.44	30.54	10.41	20.13
Average	14.525		8.22			23.265
Minimally invasive chevron. Intra-articular						
Publication	Average pre-operative inter-metatarsal angle (º)	Average post-operative inter-metatarsal angle (°)	Difference (°)	Average pre-operative hallux valgus angle (°)	Average post-operative hallux valgus angle (°)	Difference (°)
Our series (2015)	12.46	8.13	4.33	33.96	8.17	25.8

Conclusions

The results of hallux valgus X-ray correction by Chevron osteotomy using minimally invasive techniques confirm that this is a safe and effective procedure for the treatment of moderate hallux valgus, with satisfactory angular corrections at mid-term follow-up. This procedure resembles reliably open surgical techniques with all its acknowledged advantages, and we have not found any equivalent study in the bibliography. It is worth mentioning that minimally invasive surgery has an extensive learning curve associated and, therefore, at the beginning it can be difficult to reproduce our results. We recommend initiating the experience in this type of surgeries with procedures on soft tissues and osteotomies technically easier, with more predictable results.

Acknowledgment
To Débora Chan, for her assistance with the statistical analysis.

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