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Original Article

Comparative clinical and radiographic results of three fixation systems for transverse subcapital osteotomy in treating hallux valgus

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Abstract

Objective: Compare three fixation models for Bosch osteotomy both clinically and radiographically.

Methods: A retrospective comparative study was conducted on patients surgically treated for hallux valgus using Bosch osteotomy with three different fixation systems. The first group was treated with a temporary pin for three weeks; the second, received the same pin plus a screw; and the third, used two screws without a pin. Radiographic analysis included the intermetatarsal angle, metatarsophalangeal angle, percentage of lateral shifting of the metatarsal head, dorsal or plantar migration of the metatarsal head, and consolidation time. Clinical evaluation was performed using the American Orthopaedic Foot and Ankle Society (AOFAS) scale. Complications during follow-up were recorded.

Results: Twenty hallux valgus were included in each group. No significant differences were found in radiographic evaluations among groups in the preoperative and final follow-up, except that the third group showed less loss of correction. There were no significant differences in consolidation times. Clinical improvements were observed in all three fixation systems, with no significant differences among them according to the AOFAS scale.

Conclusion: No significant clinical or radiographic differences were observed among the three fixation systems, except that the group using two screws showed less loss of correction.

Level of evidence IV; Therapeutic studies; Case series.

Keywords: Hallux valgus, osteotomy, minimally invasive.

Introduction

Even though more than 130 surgical techniques to treat hallux valgus have been described, there is as yet no consensus on which of these is the most effective. Minimally invasive surgery has gained increasing interest and acceptance in recent decades due to several advantages, including achieving strong corrections, rapid recovery, better cosmetic appearance, a low complication rate, and cost-effectiveness[1,2]. In 1990, Bosch et al. introduced the minimally invasive transverse subcapital osteotomy with temporary fixation using a single Kirschner pin[3]. This technique served as the foundation for subsequent minimally invasive distal techniques, which involved the lateral shifting of the first metatarsal head. While numerous studies have demonstrated favorable clinical and radiographic outcomes using the Bosch osteotomy, some authors have raised concerns regarding the stability provided by the Kirschner pin as the sole fixation system[3-11]. To enhance stability and create a more mechanically robust system, the simple transverse osteotomy has been modified to a chevron-type osteotomy. This modification is primarily in the shape of the osteotomy rather than the fixation method, although the chevron-type osteotomy often includes the addition of one or two screws

Study performed at the Sanatorio Allende, Córdoba, Argentina.

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for improved stability[12]. The concern with this modification is the extent to which the chevron-type osteotomy can provide stability to the plantar limb during extensive lateral shifting, given the minimal bone contact. Although studies have been published comparing different percutaneous techniques, and these with conventional procedures, we have not found studies that assess different fixation methods for Bosch osteotomy[13-20].

The objective of our study is to clinically and radiographically compare and assess three groups of patients diagnosed with hallux valgus who underwent Bosch osteotomy using three different fixation systems, with a minimum follow-up of one year. First group was treated with a temporary pin for three weeks, second group received the same pin plus a screw, and third group was treated with two screws without a pin.

Our hypothesis is that there is no significant differences between the three groups by the end of the minimum one-year follow-up period.

Methods

A retrospective cohort study was designed, which was longitudinal, observational, and with deliberate but not controlled interventions. Sixty hallux valgus cases surgically treated with Bosch osteotomy were included. These were divided into three groups according to the fixation system used: Group 1 (G1) – Bosch osteotomy plus a temporary pin for three weeks plus adductor tenotomy; Group 2 (G2) – Bosch osteotomy plus a temporary pin for three weeks plus a screw with adductor tenotomy; and Group 3 (G3) – Bosch osteotomy plus two screws with no pin plus adductor tenotomy (Figure 1). The sample size of 60 patients was determined based on clinical feasibility and prior similar studies assessing surgical outcomes in hallux valgus surgery.

Inclusion criteria were (1) patients older than 18 years with painful hallux valgus; (2) failure of a more than two-month-long conservative treatment, including oral medications, shoe modification, and physical therapy; (3) mild, moderate, or severe hallux valgus according to the Coughlin classification; and (4) patients operated with Bosch osteotomy[21].

Exclusion criteria were (1) prior hallux valgus surgery; (2) first metatarsophalangeal joint arthritis; (3) additional forefoot procedures; (4) patients with any systemic disease affecting the musculoskeletal system (e.g. gout, systemic lupus erythematosus, rheumatoid arthritis); and (5) incomplete clinical or radiographic follow-up of less than one year.

All patients were followed up for at least one year. Groups 1 and 2, being the initial techniques implemented, were followed up for an extended period of two years. Group 3, representing the newer approach, also had a follow-up period exceeding one year.

Patients were functionally assessed using the scale from the American Orthopaedic Foot and Ankle Society (AOFAS)[22].

Weight-bearing digital X-rays were obtained in the anteroposterior and lateral projections. They were taken preoperatively and immediately postoperatively, at 6 weeks, 12 weeks, and at the end of follow-up. The intermetatarsal angle (IMA) was measured between the longitudinal axis and first and second metatarsal, while the metatarsophalangeal angle (MTPA) was assessed between the longitudinal axes of the first metatarsal and first phalanx. The lateral shifting percentage of the first metatarsal head (LSP-1M) was assessed to determine the correction maintenance, defined as the lateral shifting distance divided by the total width of the metatarsal in weight-bearing anteroposterior X-rays taken at six weeks and at the end of follow-up (Figure 2)[23,24]. Dorsal and plantar migration were studied in millimeters of the metatarsal head

Figure 1. Group 1: Bosch osteotomy plus one temporary pin (A); Group 2: Bosch osteotomy plus one temporary pin and one screw (B); Group 3: Bosch osteotomy plus two screws (C).

(Mgr-DP) with weight-bearing lateral X-rays at six weeks and at the end of follow-up. Dorsal migrations were recorded using negative values and plantar migrations, using positive values (Figure 3). Consolidation time was studied, occurring when a bony bridge was observed in all four cortical regions in obtained projections[25]. Complications were recorded until the end of follow-up. All clinical and radiographic assessments were made by the author.

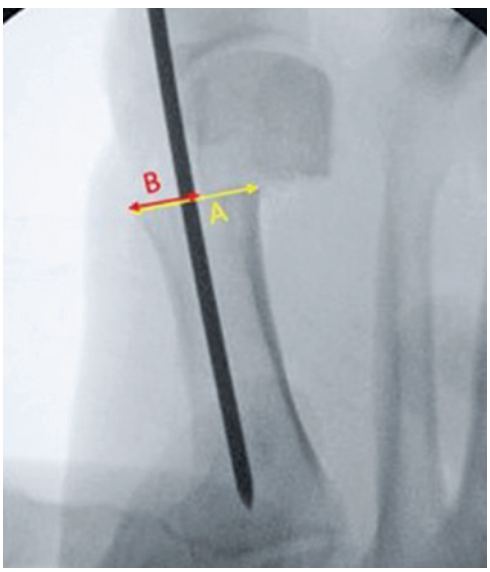

Figure 2. Lateral shifting percentage of the metatarsal head. Lateral shifting distance (B) divided by total width of the metatarsal (A).

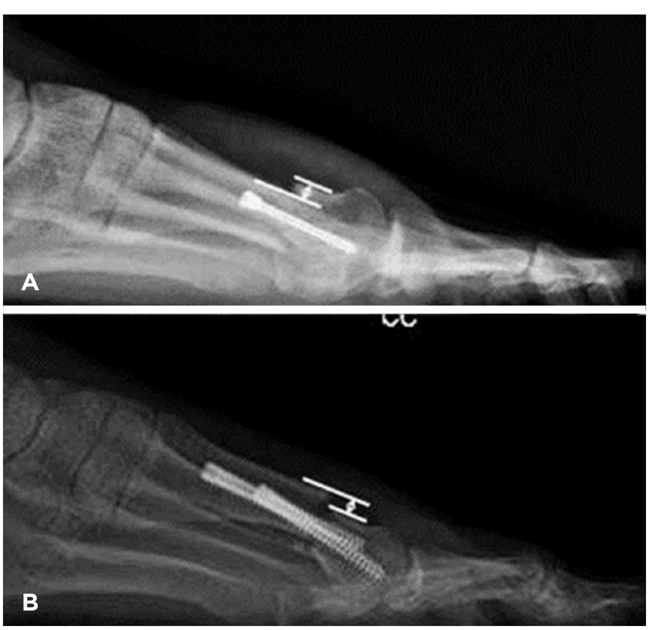

Figure 3. Dorsal-plantar migration of the metatarsal (in mm). Dorsal migrations recorded with negative values (A) and plantar migrations, with positive values (B).

Surgical Technique

All patients were operated on in the supine position, under regional anesthesia guided by ultrasound. A 5 cm Esmarch bandage was used on the ankle as a tourniquet. The adductor tendon was released after osteotomy in all patients. Procedures were guided by an image intensifier.

Group 1: Bosch osteotomy

The Bosch osteotomy[7] begins with a 2 mm medial incision in the nail fold. A 2 mm Kirschner pin is introduced superficial to the periosteum from the distal end of the hallux, backwards up to the distal metaphysis of the first metatarsal. A 1-cm-long skin incision follows at the neck level. Dissection by planes is carried out carefully to avoid damaging nerves. A small periosteum elevator is used to unstick it both at the dorsal and plantar levels to create a safe working area. A 1.4 mm Kirschner pin is placed as a cutting guide perpendicular to the diaphysis of the first metatarsal. Osteotomy is made with a 5 mm x 15 mm x 0.4 mm cutting saw; the cutting guide pin is removed and the head is laterally shifted with the aid of a grooved probe. The intramedullary Kirschner pin is advanced for fixation in the base of the first metatarsal (Figure 4). Wounds are closed and bandaged using compressive self-adhesive bandages.

Group 2: Bosch osteotomy plus one screw

Same as the procedure for G1. Once the Kirschner pin has been placed, a 2 cm proximal and medial osteotomy incision is made and a 1.0 mm guide pin is placed obliquely directed towards the first metatarsal head, without interrupting the joint surface. The guide pin is then measured and drilled to ensure proper placement. Following this, a 3.0 mm double-thread, cannulated screw is placed (Figure 5). Wounds are closed and bandaged using compressive self-adhesive bandages.

Group 3: Bosch osteotomy plus two screws with no pin

Same as the procedure for G1. Once the Kirschner pin has been placed, two proximal and medial osteotomy incisions are made at 2 cm and 5 cm; two 1.0 mm parallel guide pins are placed obliquely directed towards the first metatarsal head. The guide pin is then measured and drilled to ensure proper placement. Following this, two 4.0 mm double-thread, cannulated screws are placed, first the proximal one, then the distal one. The 2 mm Kirschner pin is removed (Figure 6). Wounds are closed and bandaged using compressive self-adhesive bandages.

Patients began immediate weight-bearing with the use of stiff-soled postoperative footwear. Bandages were changed on the first week and on the third week. In G1 and G2, Kirschner pins were removed on the third week.

Statistical Analysis

With respect to the descriptive statistics, the absolute and relative frequencies of qualitative variables were calculated,

Figure 4. Bosch osteotomy plus temporary pin (Group 1), 24-month follow-up.

and double-entry tables were drawn up, calculated per column. The mean, median, and standard deviation of quantitative variables were also estimated. For statistical inference, Pearson's chi-squared test was used, when possible, to study the relationship among qualitative variables; when its use was not possible, Fisher's exact statistic was calculated in the 2x2 tables. To analyze the difference between quantitative variables, the usual Student's t-test was used for independent samples, related samples and for the analysis of variance (ANOVA). For statistical analyses, SPSS for Windows v. 22 was used, and the level of significance in all cases was the usual, 0.05.

Results

A total of 60 hallux valgus in a total of 55 patients were included (5 bilateral). Each group was made up of 20 feet. Demographic data of groups can be seen in table 1.

The mean follow-up time was 60 months (SD: 8.1), 34.4 months (SD: 8.7), and 13.7 months (SD: 20.5) for G1, G2, and G3, respectively, with a statistically significant difference ($p < 0.05$).

Angular radiographic values showed significant modifications in each group and when comparing the preoperative and the end of follow-up values (Table 2). For G1, changes were: preop IMA: 13.5° (SD: 5.6), postop IMA: 8.0° (SD: 2.4), $p < 0.0003$; preop MTPA: 25.8° (SD: 8.6), postop MTPA: 9.1°

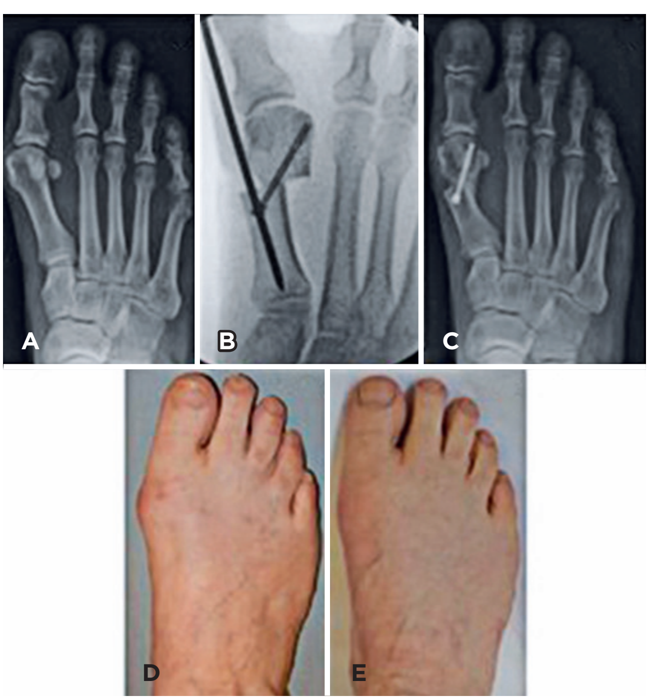

Figure 5. Bosch osteotomy plus temporary pin (Group 2), 18-month follow-up.

Figure 6. Bosch osteotomy plus two screws (Group 3), 12-month follow-up.

Table 1. Demographic data

	G1	G2	G3	p
Age, mean	54,6 ± 13,2	52,6 ± 14,9	53,9 ± 12,7	0.90
Sex, female/male	18/2	19/1	17/3	0.52
Side, right/left	10/10	10/10	11/9	0.06

G1: Bosch osteotomy plus one pin; G2: Bosch osteotomy plus one screw; G3: Bosch osteotomy plus two screws.

Table 2. Clinical and radiographic results

	G1	G2	G3	p
Preop AOFAS				
Scale	54.8	53.3	52.3	0.72
Postop	98.2	98.4	98.2	0.92
p	0.001	0.001	0.001	
Preop				
IMA	13.5	13.2	13.6	0.95
Postop	8.0	7.7	6.7	0.18
p	0.003	0.002	0.001	
Preop				
MTPA	25.8	26.1	25.2	0.95
Postop	9.1	9.2	7.1	0.24
p	0.001	0.001	0.001	
LSP-1M				
sixth week	54.7	55.6	57.7	0.85
Postop	47.7	47.8	56.0	0.04
p	0.009	0.002	0.13	
Mgr-DP				
sixth week	0.7	0.5	0.2	0.43
Postop	0.5	0.7	0.3	0.22
p	0.129	0.16	0.21	

G1: Bosch osteotomy plus one pin; G2: Bosch osteotomy plus one screw; G3: Bosch osteotomy plus two screws; IMA: intermetatarsal angle; MTPA: metatarsophalangeal angle; LSP-1M: percentage of lateral shifting; Mgr-DP: dorsal or plantar migration.

(SD: 5.0), p < 0.0001. For G2, differences were: preop IMA: 13.2° (SD: 4.1), postop IMA: 7.7° (SD: 2.5), p < 0.0001; preop MTPA: 26.1° (SD: 9.9), postop MTPA: 9.2° (SD: 3.8), p < 0.0001. For G3, changes were: preop IMA 13.6° (SD: 4.5), postop IMA: 6.7° (SD: 1.9), p < 0.0001; preop MTPA: 25.2° (SD: 9.7), postop MTPA: 7.1° (SD: 4.4), p < 0.0001.

Analyzing the LSP-1M, we detect a loss of correction maintenance, with a significant difference between the sixth week and end of follow-up for G1 and G2, but not for G3. In G1, changes were: sixth week: 54.7% (SD: 10.7), postop: 47.0% (SD: 15.2), p < 0.0009; for G2, sixth week: 55.6% (SD: 16.7), postop: 47.8% (SD: 16.4), p < 0.0028; and for G3, sixth week: 57.7% (SD: 22.3), postop: 56.0% (SD: 23.4), p > 0.13.

With respect to dorsal and plantar migration, there were no significant differences between the sixth week and the end of follow-up in each group. For G1, changes were: sixth week: 0.7 mm (SD: 0.9), postop: 0.5 mm (SD: 0.9), p > 0.12; for G2, sixth week: 0.5 mm (SD: 1.1), postop: 0.7 mm (SD: 1.1), p > 0.16; and for G3, sixth week: 0.2 mm (SD: 1.0), postop: 0.3 mm (SD: 0.9), p > 0.21.

Clinical results (AOFAS scale) showed significant differences in each group between the preoperative and postoperative periods. In G1, changes were: preop: 54.75 (SD: 10.8), postop: 98.8 (SD: 2.4), p < 0.00001; in G2, preop: 53.1 (SD: 9.0), postop: 98.4 (SD: 1.2), p < 0.00001; and in G3, preop: 52.3 (SD: 7.6), postop: 98.2 (SD: 1.7), p < 0.00001. Comparing the radiographic results among the three groups, we did not detect any significant changes in preoperative (IMA: p > 0.95, MTPA: p > 0.95, Mgr-DP: p > 0.43, LSP-1M: p < 0.85) or end of follow-up (IMA: p > 0.18, MTPA: p > 0.24, Mgr-DP: p > 0.22) findings, which did not apply to LSP-1M (p < 0.04). Furthermore, we did not find any significant differences among groups in clinical evaluation (AOFAS scale) in the preoperative (p > 0.72) and end of follow-up periods (p > 0.92).

The mean consolidation time was 12.9 weeks, 12.3 weeks, and 12.5 weeks for G1, G2, and G3, respectively, without any significant changes among groups (p > 0.637).

Total percentage of complications was 16.7%. In G1, the complication rate was 20%, including two superficial infections at the Kirschner pin entry point, which required early removal and oral antibiotic therapy. One patient experienced a 4-month delay in consolidation that did not require surgery. Another patient had a loss of correction and recurrence of hallux valgus and did not agree to reoperation. In G2, the complication rate was 15%, including one superficial infection of the surgical wound, managed with local healing and oral antibiotics. One patient had a consolidation delay that resolved over 5 months. Another patient had a loose screw that required removal. Additionally, two patients were intolerant to the osteosynthesis material, presenting with skin irritation, and were reoperated to remove the material. In G3, the complication rate was 15%, with one intraoperative fracture of the metatarsal diaphysis while placing the distal screw. It was decided to retain the osteosynthesis and delay weight-bearing for three weeks; consolidation of the osteotomy was observed nine weeks post-surgery. One patient experienced a loosening of one of the screws, removal required, and another patient required screw removal due to prominence and discomfort with footwear. While complication rates for G1, G2, and G3 were 20%, 15%, and 15%, respectively, it is important to note that, due to the small sample size, statistical comparisons among groups are not feasible. Further studies with larger sample sizes are needed to draw definitive conclusions.

Discussion

In current literature, comparative studies on different fixation systems for Bosch osteotomy are lacking. Our study provides a clinical and radiographic analysis with a minimum follow-up of one year, evaluating three fixation systems for this osteotomy. All three systems demonstrated favorable clinical and functional outcomes. No significant differences were found among groups in clinical results or in most radiographic parameters. However, a notable difference was observed in the maintenance of lateral shifting correction, with G3 showing a lower loss of correction.

Since the advent of minimally invasive surgery for the treatment of hallux valgus, techniques have evolved from osteotomy with no fixation (first generation), through transverse osteotomy plus fixation with Kirschner pins (second generation), to chevron-type osteotomy plus fixation with one or two screws (third generation). Although Bosch osteotomy has shown good clinical and radiographic results, some authors criticize the lack of mechanical stability provided by the pin, skin complications related to the procedure, a lack of early mobility, and loss of correction[10,12]. Based on the rationale of lateral shifting, Vernois and Redfern modified transverse osteotomy to a chevron-type osteotomy with two screws, abandoning the use of pins[26]. Although this modification offers inherent advantages for structural stability with the plantar limb, it does not allow for improved control of rotation (pronation), a benefit provided by Bosch osteotomy. The incorporation of two screws in Bosch osteotomy, inspired by the chevron-type osteotomy, has not been extensively studied, highlighting a gap in the literature. Our study observed that the use of two screws in Bosch osteotomy (G3) provided robust fixation, enhancing stability and maintaining the correction. Additionally, our clinical and radiographic results showed no mechanical failures with Bosch osteotomy, confirming its reliability. Aiyer et al. published a study on cadavers comparing failures and stability between Bosch osteotomy and chevron-type osteotomy fixed with two screws in nine pairs of hallux, finding no significant differences in biomechanical stability between these methods, supporting our observations[27].

Few publications exist on Bosch osteotomies with a single screw as the fixation system. In 2020, Carlucci et al. published a retrospective comparative study on Bosch osteotomy with one screw vs. minimally invasive chevron-type osteotomy with two screws. Their results showed similar clinical and radiographic outcomes for both groups with one year follow-up, aligning with the findings for G2 in our study[19]. Yañez Arauz et al. further investigated these techniques in a radiographic prospective study, noting that Bosch osteotomy provided a greater medium-term correction of the IMA, while the chevron-type osteotomy showed better correction and maintenance of the distal joint angle of the metatarsal. However, they did not clarify whether these differences had clinical significance for patients[28].

With respect to complications in general, we report a rate of 16.7%. Though this is similar to reports from other studies, no conclusive comparisons can be made among the three groups due to the small sample size.

While the results of our work are similar among the three fixation systems, cautious is needed in their interpretation due to the limitations of a retrospective study, including a small sample size and the short follow-up period.

Conclusion

All three systems showed favorable clinical and functional outcomes, with no significant differences in clinical results or in most radiographic parameters. However, a statistically significant difference was observed in the maintenance of lateral shifting correction, with the G3 system demonstrating a lower loss of correction compared to the others. While the G3 system requires a longer learning curve, its superior performance in maintaining correction justifies its continued use in clinical practice. Further research is needed to explore long-term outcomes and validate these findings over extended periods.

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