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ORIGINAL STUDY

Advantages of a compression screw for the arthrodesis of the first metatarsophalangeal joint of the foot : comparative study

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The purpose was to determine whether or not an additional compression screw to an arthrodesis of the first metatarsophalangeal joint (MTP1) by plate conferred any clinical and radiological benefits for the patient.

One hundred and five cases (95 patients) were prospectively enrolled and analysed in two groups : PLATE-only with 2 small plates fixation (n=51) and PLATE+compSCREW with an additional compression screw fixation (n=54). Both groups were followed up over 4-years and were compared using the AOFAS score and a radiologic assessment to determine the fusion rate.

PLATE-only reported 6 failures : 2 cases of clinical mobilisation of the joint and 4 cases of painless fibrous fusion. In the PLATE+compSCREW group, there were 3 cases of painless fibrous fusion. When considering the fusion rate, there was a significant statistical difference between the two groups.

The use of an additional compression screw reduced the time to joint fusion and decreased the failure rate at last follow-up.

***Study design :* Prospective comparative cohort study.**

Keywords : Arthrodesis ; fibrous fusion ; non-union ; compression screw.

INTRODUCTION

The first metatarsophalangeal joint actively participates in the push-off phase of the gait cycle. However, in a great number of pathological events, generally painful conditions, it can be completely disrupted, leading to a reduced range of motion and limited function *(9,18)*. First metatarsophalangeal arthrodesis (MTP1) is an operative technique, which has been used for a long time to relieve pain and restore its functional efficiency. It is indicated in the treatment of various pathologies mainly the hallux rigidus and the severe hallux valgus *(6,12,25)*. The described operative techniques differ according to the type of resection of the joint surfaces (plane, concave / convex) and according to the mean of fixation (screw, plates, staples) *(15,24)*.

The majority of MTP1 arthrodesis are actually performed by dorsal plates including a compression system *(16)*. On this new type of device, the available studies report promising results but remain non-

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comparative descriptive studies, with a poor level of evidence. It is therefore difficult to know if these good results are due to more anatomic plates with locked screws or the additional compression system. Moreover, the exclusive use of compression screws is also increasingly used with the advent of percutaneous surgery *(2)* the first ray mobility being essentially in the interphalangeal (IP).

We hypothesized that the use of an additional compression screw during the MTP1 arthrodesis procedure would improve the clinical and radiological outcomes.

The main purpose of this study was to determine whether or not an additional compression screw to an arthrodesis of the MTP1 joint by plate conferred any clinical and radiological benefits for the patient.

METHODS

A prospective, comparative and continuous study was conducted to investigate the effect of a compression screw added to an MTP1 arthrodesis by plate. Between April 2012 and April 2013, patients diagnosed with symptomatic MTP1 osteoarthritis (OA), severe hallux valgus (HV) defined by a M1/P1 angle over 40°, inflammatory disease (rheumatoid arthritis), or recurrence of the HV deformation (secondary surgical revision) and deemed suitable for a MTP1 arthrodesis were prospectively invited to participate. Exclusion criteria were patients with an intellectual or mental impairment, and people who declined to participate.

From 110 cases (100 patients), after all exclusions, 105 cases (95 patients) were prospectively enrolled and analysed in two groups : PLATE-only with 2 small plates fixation (n= 51) and PLATE+compSCREW (n=54) with an additional compression screw fixation (Figure 1). The first 47 patients (51 cases) were included in the PLATE-only group and the next 48 patients (54 cases) were included in the PLATE+compSCREW group. There was no patient lost to follow-up (FU). Patients signed a written consent form after reading the information sheet describing the procedure, the difference between modes of treatment, its potential benefits, and possible hazards.

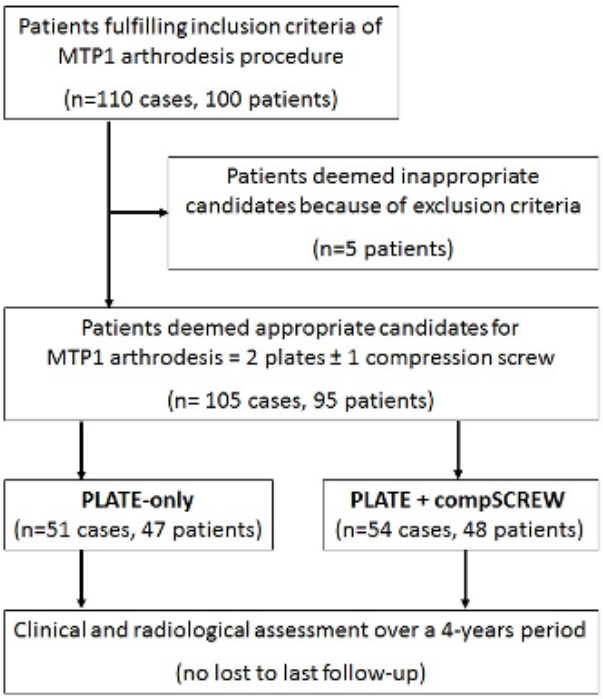

Figure 1. — Study flowchart demonstrating recruitment and evaluation over the 4-years period.

All procedures were performed by a single surgeon (RP). The patient was placed in the supine position with a surgical tourniquet applied on the calf. The skin incision was made with respect to the first metatarsophalangeal joint at the junction of plantar skin and dorsal skin taking care to avoid the dorsal collateral nerve. The capsule was incised longitudinally and sesamoid were released. Exostoses were excised. The head of the first metatarsal was exposed and a plane osteotomy angled 10° with regard to the horizontal line was performed. Then the base of the proximal phalanx was exposed and a plane resection was also made.

For the PLATE-only group, the arthrodesis was fixed by a temporary pin allowing placement of two locking plates, one on the dorsal face and one on the medial face. These fixation plates were made from titanium and secured using titanium screws locked in the PEEK (XS plate®, BIOTECH ORTHO, France). For PLATE+compSCREW group, an additional compression screw was inserted in an oblique inside outside way (BIOTECH ORTHO, France) in addition to the two plates.

For all patients, the postoperative rehabilitation program was uniform, and included a 6-week period of using a forefoot discharge shoe, combined with a self-rehabilitation programme from the 21st postoperative day (passive mobilization of the toes of the lateral rays) until the 6-month time point.

All patients were assessed by an independent examiner (TN, orthopaedic surgeon). Clinical and radiologic assessment were performed preoperatively and postoperatively at 6-week, 3-month, 6-month, 12 month, then every year until a minimum of 4 years at final FU.

For clinical evaluation, the American Orthopaedic Foot and Ankle Society (AOFAS) scores were collected pre-operatively, as well as 4-year after the surgery *(23)* the FFI, and the SF-36 questionnaires. The questionnaires were scored and Pearson correlation coefficients were determined between the three domains of the FFI and the eight SF-36 sub-scales, as well as the two SF-36 summary scales.\nRESULTS : Sixty-nine patients completed an adequate number of items to be included in the study. The mean age of the patient sample was 46 (range 16 to 82).

The radiologic evaluation was performed by the same expert observer. The studied radiological criteria were the first-second intermetatarsal angle (M1-M2 angle), the first-fifth intermetatarsal angle (M1-M5 angle) and the angle between the first metatarsal and the proximal phalanx (M1-P1 angle) by using the diaphysal axis. The analysis of axes was performed based on the diaphysal axis rather than the mechanical axis connecting the centre of the metatarsal head and the centre of the proximal joint as described by Schneider *et al*. *(17,22,26)* five different methods for drawing the axis of the first metatarsal have been published. This study aimed to evaluate differences in the resulting angles that depend on the method of drawing this axis. Using pre- and postoperative radiographs of 20 patients who had surgery on the hallux (chevron procedure. Moreover, as the postoperative head position was modified after MTP1 arthrodesis, the axes cannot be compared any more. We also analyzed the length of the first metatarsal with regard to that of the second metatarsal. The radiographic criteria used for the assessment of joint fusion included disappearance of the MTP1 joint space and the absence of fracture and/or mobilization of the fixation device *(3)*followed by fixation of the arthrodesis with a lag screw and a dorsal plate (Synthes Modular Hand Set. Fibrous fusion was defined as the persistence of a partial thin gap within the articulation but having no clinical impact (no pain, no joint mobility) nor effect on the fixation device (breakage…). All cases of radiological fibrous fusion and clinical pseudarthrosis were considered as failures.

All statistical analyses were performed using SPSS Statistics software (version 21, SPSS Inc., Chicago, IL, USA) and the significance threshold was set at $P<0.05$. A power analysis was performed (G*Power, version 3.1) to determine the appropriate sample size, for a moderate effect size (f=0.4), an alpha risk at 0.05 and a power at 0.80 (b= 0.20). The number of cases to include was 102 (n=51 for each group).

The assumption of normality was tested before preforming the statistical comparisons. Patient demographics (age, BMI), clinical score and postoperative alignment were compared between groups using either Student's t tests, or non-parametric Mann-Whitney tests. Pre and postoperative comparison of means (difference between preoperative and 4-year time points), for clinical and radiological quantitative variables was carried out with Student T-tests, for acceptance or rejection of the null hypothesis. Comparisons of pre and postoperative qualitative variables were conducted using the Chi-squared test. Where conditions were not fulfilled, a Fisher's exact test was performed.

RESULTS

The comparative analysis of demographics, aetiologies and additional procedures distributions between groups are reported in Table 1.

There were no differences in demographic data between the both groups for the mean age at surgery (P=0.76) and for Body Mass Index (BMI) (P=0.76). Both groups were predominantly female (87% for PLATE-only and 85% for PLATE+compSCREW groups).

Table 1. — Comparison between demographics data, aetiology and additional procedure for PLATE-only and PLATE+compSCREW groups

	mean age at surgery (years)	mean BMI	sex (M/F)	aetiology (n=)		additional procedures (n=)	
PLATE-only (n=51)	62.2 ±10.3 [48, 90]	30.4 ±3.5 [28.4, 31.3]	6/41	severe HV	26 (51%)	Weil osteotomy	16 (31%)
				hallux rigidus	12 (24%)	toe arthroplasty	9 (18%)
				HV recurrence	8 (15%)	lateral head resection	4 (8%)
				RA	5 (10%)		
PLATE + compSCREW (n=54)	64.2 ±10.6 [44, 84]	30.1 ±3.8 [27.8, 31.5]	7/41	severe HV	26 (48%)	Weil osteotomy	15 (28%)
				hallux rigidus	15 (28%)	toe arthroplasty	10 (18%)
				HV recurrence	7 (13%)	lateral head resection	5 (9%)
				RA	6 (11%)		

(HV : Hallux, Valgus, BMI : Body Mass Index, RA : Rheumatoid Arthritis).

The distribution of aetiologies was similar between the PLATE-only and the PLATE+compSCREW groups, with a predominance of severe hallux valgus (respectively 51% and 48%) and hallux rigidus (respectively 24% and 28%).

Concerning the additional procedures, the same distribution was reported between the PLATE-only and the PLATE+compSCREW groups. They included Weil osteotomy (respectively 31% and 28%), toe arthroplasty (18% for both groups) and lateral head resection for rheumatoid arthritis (respectively 8% and 9%).

Clinical consolidation, defined by the absence of pain during mobilization of the MTP1 joint and during walking, was reported in 98 % of cases for the PLATE-only group and 100% for the PLATE+compSCREW group.

The mean preoperative AOFAS scores were similar between the PLATE-only and the PLATE+ compSCREW groups (respectively 45.3 and 44.2). These scores were significantly increased at 4-year FU ($P<0.05$), with a comparable evolution between both groups (respectively 75.4 and 74.5).

The immediate postoperative management was simple for all the patients. There was no healing disorder and no postoperative infection. At last FU, one patient (1.96%) was revised for removal of the fixation device and another patient (1.96%) underwent a new arthrodesis procedure in the PLATE-only group. In the PLATE+compSCREW group, only 1 patient (1.85%) was revised for removal of their fixation screw. A late complication (1.96%) was reported in the PLATE-only group due to a fatigue fracture of the second metatarsal (M2) diagnosed during the third postoperative month. Hopefully, this fatigue fracture healed after a 2 month discharge period (Figure 2). In the same group, one patient (1.96%) was revised for clinical non-union associated with pain and joint mobility (Figure 2), another one (1.96%) presented a pathologic MTP1 mobility but without pain.

Figure 2. — MTP1 Arthrodesis at 6 months FU with a stress fracture on the second metatarsal bone.

Table 2. — Comparison of both series considering radiological results

	PLATE-only (n = 51)	PLATE + compSCREW (n = 54)	Comparison of the 2 groups
M1 M2 angle at 4-year FU (degrees)	9.4 [3-15] *	11.7 [7-26] *	
M1P1 angle at 4-year FU (degrees)	9.8 [10-40] *	10.1 [2-25] *	
Variation M1M2 distance (mm)	+ 1.6	+1.8 *	
M1M5 angle at 4-year FU (degrees)	24.2 [10-40] *	24.6 [12-45] *	
Arthrodesis fusion at 6-week FU	78% (n=40)	92% (n=50)	P = .03
Arthrodesis fusion at 4-year FU	88% (n= 45)	98% (n=53)	P =.01

(* : significant difference (P < .05) between preoperative and 4-year time points).

Figure 3. — Clinical and radiological failure of an arthrodesis without compression screw at 6 months FU.

The comparisons between groups are summarized in Table 2. There were no differences between groups for the average intermetatarsal angles (M1-M2, M1-M5) and the M1P1 angle (NS), but there were significant differences regarding the fusion rate at 6-week and 4-year time points (respectively, P=0.3 and P=0.01).

More specifically, the average M1-M2 intermetatarsal angle was reduced by 4.8° from 14.2° [3, 25] preoperatively to 9.4° [3, 15] postoperatively for the PLATE-only group (P < .05). This evolution was similar for the PLATE+compSCREW group, with a decrease of 1.6° from 13.3° [7.6, 24] preoperatively to 11.7° [7, 26] postoperatively (P < .05). The average intermetatarsal M1-M5 angle was reduced by 6.6° from 30.8° [18, 48] preoperatively to 24.2° [10, 40] postoperatively in the control group, and it

Figure 4. — MTP1 Arthrodesis with an additional screw compression at 6 months FU.

was reduced by 4.6° from 29.2° [21, 47] to 24.6° [12, 45] (P < .05) in the PLATE+compSCREW group. The average M1P1 angle was reduced by 23.2° from 33° [18, 48] preoperatively to 9.8° [10, 40] postoperatively in the first group. In the second group, it was reduced by 20.4 from 30.5° [6, 78] to 10.1° [2, 25] (P < .05). The mean M1-M2 distance was increased by 1.6 mm from 1.6 mm [-10, 7] in the preoperative period to 3.2 mm [-10, 8] in the postoperative period (NS), for the PLATE-only group. In the PLATE+compSCREW group, this length was increased by 1.8 mm from 1.7 mm [-9, 8] to 3.5 mm [-10, 8] (P < 0.05).

Radiographic healing was achieved in 40 out of 51 cases (78 %) at 6-week FU and in 45 cases (88 %) at 4-year FU in the PLATE-only group. There were 6 cases of radiological non-union among which 3 presented with forefoot rheumatoid. In the PLATE+compSCREW group, radiographic healing was achieved in 50 out of 54 cases (92 %) at 6-week FU and in 53 of the cases (98%) at 4-year postoperative. Figure 4 represents an example of good fusion at 6-month FU with an additional compression screw.

DISCUSSION

Previous studies have demonstrated improvements in fusion rates and clinical outcomes in MTP1 arthrodesis with plate in case series *(10)* ; others have demonstrated the same improvements with compression screw alone *(1)*, and with plate integrating a compression system *(16)*. As far as we are aware, there are no prospective comparative investigations of the outcome of additional compression screw as an adjunct to plate for MTP1 arthrodesis versus plate fixation alone. According to the main finding of our study, the use of an additional compression screw reduced the time to fusion and decreases the rate of fusion failures at last follow up.

Numerous arthrodesis techniques have been suggested. They differ by their method of fixation, either double screwing in cross directions, staple fixation, single inter-fragmentary screw ordorsal compression plate. They also differ in the preparation of the joint surfaces, either plane cuttings or conical reaming.

The cadaveric studies of Curtis and Politi reported a better stability using a conical preparation compared with plane resection *(8,19)*. We supported the use of a plane resection because it provided a maximum opposition of the cutting surfaces without major shortening of the first ray and a good positioning of the arthrodesis. However, this study should have included a greater number of participants in order to assess the long-term clinical outcome of clinically consolidated patients but reporting radiological fibrous fusion.

Analysis of our clinical outcomes using the AOFAS score showed a mean increase of 29.9 points in the first series and 30.1 points in the second. These results were comparable to those reported by Goucher *et al*. who found a 31 point increase after MTP1 arthrodesis based on conical preparation and dorsal plate fixation *(14)*. The rate of clinical healing was very good (96% in the first group and 100% in the second group) despite 4 cases of tight pseudarthrosis in the first group and 3 cases of fibrous fusion in the second group. This rate was comparable to that reported by Sage *et al*. using a convex preparation and plate fixation *(21)* 1.3 to 15 months. Our clinical results were thus comparable to those described in the literature *(11,24)*.

Our results, in terms of radiological correction, were also similar to those described in the literature. In both series, the M1P1 angle was reduced by 23.2° and 20.4°, which was comparable to the findings of Pydah *et al*. (22.6°) and Besse *et al*. (25°) *(4,20)*. In our study the intermetatarsal M1-M5 angle was reduced by 6.6° and 4.6° respectively in the two groups and without any additional metatarsal osteotomy, a result that was similar to the findings of Pydah *et al*. (4.5°) and Sage *et al*. (7.9°) *(20,21)* intermetatarsal angle as well as the position of the tibial sesamoid in accordance to the American Orthopaedic Foot and Ankle Society guidelines.\nRESULTS : Postoperatively, there was an improvement in the hallux valgus angle from 33.0 degrees to 10.4 degrees ($p < 0.001$. There was no major shortening of the first ray reported in our study.

The radiographic healing rate was 78% at 6-week postoperative in the first series and 92% in the second one. At 6 month-follow-up, the healing rate was 88% in the first series. Our results were lower than those achieved in series using a concave and convex reaming preparation and plate fixation : 92 % in the study of Goucher *et al*., 98 % at 19 postoperative months for Coughlin *et al*. and 100% for Flavin *et al*. *(7,13,14)*. However, Besse *et al*. in a series of 54 MTP1 arthrodeses using staple fixation, reported a rate of 74% at 6-week postoperative that was similar to our findings *(4)*.

In the group with the additional screw, the healing rate was 98 % at 4 postoperative years that was close to the data from the literature. There was a significant statistical difference between the two groups ; a better and earlier healing rate was reported when using a compression screw secured by means of 2 neutralization plates. On this point there is a significant lack of data. Most of the available studies are only descriptive and report plate results associated with a compression system *(16)*. At our knowledge, only one recent comparative study analyse the effect if the addition a lag screw *(5)*. The authors conclude that the addition of a lag screw to a dorsal locking plate improve stability of

the joint in the sagittal plane over time compared with a dorsal plate alone. However, this is a retrospective study with no comparison of clinical outcomes.

Several limitations of this study should be noted. In order to better compare the two groups, it would have been preferable to use a randomized study design. This study should have also included a greater number of participants in order to assess the long-term clinical outcome of clinically consolidated patients who report radiological fibrous fusion. Another limitation was that only one independent observer analysed clinical and radiological examinations. Lastly, no stratification regarding the diagnosis of MTP joint pathology was performed on patients. The arthrodesis for patients with severe HV or HV recurrence is potentially more difficult compared to those of hallux rigidus, especially in the angle of postoperative dorsiflexion management.

CONCLUSION

To our knowledge, this study is the first to provide a direct comparison of isolated plate fixation to plate with an additional compression screw in MTP1 arthrodesis. By reducing the joint fusion time and decreasing failure rate at last follow-up, the use of an additional compression screw to a plate in MTP1 arthrodesis is justified.

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