Phalangeal fractures treated with osteosynthesis plates

Short-term results

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Abstract

Introduction: We carried out a prospective cohort study to evaluate functional results in workers with phalanx fractures treated with plates, and to outline the factors behind patients' poor prognosis.

Materials and Methods: From May 2012 to May 2014, 55 workers with phalanx fractures were consecutively operated on by reduction and osteosynthesis with plates and screws. We assessed forty-two patients (39 males averaging 30.76 years old) with 68 phalanxes fractures operated on (15 first phalanx, 53 second phalanx). Twenty-eight percent of them were open fractures; 38.24%, comminuted fractures and 11.76%, joint fractures. The average follow-up was 3.38 months.

Results: We got bone healing in all fractures at month 1.8. Thumb mobility (Gingrass) was good in two cases and fair in one case. In the remaining fingers (Belsky), it was excellent (35%), good (55%), and poor (9%). The average DASH score was 18.53. We verified poorer outcomes in first phalanx fractures as compared with those in second phalanx fractures, and in elder patients as compared with the younger ones, with statistic significance in both. There was no correlation between outcomes and the other variables in analysis. Four patients suffered complications (9.5%).

Conclusions: At the time of comparing ours to other published series, there were fewer complications and our results were similar; however, contrarily to other authors, usually we do not remove material nor do we carry our tenolysis and arthrolysis. We got bone healing in all cases, and results were satisfactory in 90% of the cases.

Key words: Hand; phalanx; fracture; osteosynthesis; plate.

Level of evidence: IV

Fracturas de falanges tratadas con placas de osteosíntesis Resultados a corto plazo

Resumen

Introducción: Se realizó un estudio de cohorte prospectivo para evaluar los resultados funcionales de pacientes laborales con fracturas de falange tratadas mediante placas y establecer factores de mal pronóstico.

Materiales y Métodos: Desde mayo de 2012 hasta mayo de 2014, 55 pacientes laborales con fracturas de falange fueron operados consecutivamente, mediante reducción y osteosíntesis con placa y tornillos. Cuarenta y dos (39 hombres, edad promedio 30.76 años) fueron evaluados, con 68 falanges operadas (primera falange 15, segunda falange 53). El 28% de las fracturas fueron expuestas; el 38,24%, conminutas y el 11,76% tenía compromiso articular. El seguimiento promedio fue de 3.38 meses.

Conflict of interests: The authors have reported none.

Resultados: Se logró la consolidación ósea de todas las fracturas a los 1.8 meses. La movilidad para el pulgar (Gingrass) fue buena en dos casos y regular en uno. En los restantes dedos (Belsky), fue excelente (35%), buena (55%) y mala (9%). El puntaje DASH promedio fue de 18,53. Se observaron peores resultados en las fracturas de la primera falange respecto de la segunda falange y en pacientes con más edad que en los más jóvenes, ambos con significancia estadística. No hubo relación entre el resultado y las demás variables estudiadas. Cuatro pacientes tuvieron complicaciones (9,5%).
Conclusiones: Al comparar nuestra serie con otras publicadas, hubo menos complicaciones y los resultados fueron similares, pero a diferencia de otros autores, no acostumbramos a retirar el material ni a realizar tenólisis ni artrólisis. Se logró la consolidación ósea en todos los casos y los resultados fueron satisfactorios en el 90% de los pacientes.

Palabras clave: Mano; falange; fractura; osteosíntesis; placa.
Nivel de Evidencia: IV

Introduction

Hand phalanx fractures are the commonest of all, standing for 10% of all injuries in the skeleton.[1] Most of them are treated conservatively with early immobilization followed by mobility exercises in the finger.[2]

Nevertheless, due to different reasons such as displacement, comminution, irreducible pattern, rotational misalignment and loss of bone stock, among others, some fractures require surgical treatment. There are a number of different methods for reduction and osteosynthesis (percutaneous procedures with pins, external fixation, open procedures with pins, wires, screws, plates, etc.)— each one of them has advantages and disadvantages.

The biomechanical strength that characterizes plates and screws, which is higher than that in other therapeutic options, has been timely acknowledged.[3] Open reduction and internal fixation (ORIF) with plates provides the device with the necessary stability for earlier and deeper mobilization. Nevertheless, due the poor outcomes and high complication rates reported by some authors[4,5] even today ORIF efficiency is still controversial.

The aim of this study was to evaluate the outcomes in the treatment of hand phalanx fractures with plates by means of a prospective cohort study, and outline poor prognosis factors.

Materials and Methods

From May 2012 to May 2014 we operated on 55 consecutive patients with hand phalanx fractures carrying out reduction and osteosynthesis with plates and screws. All patients were under workers compensation coverage (ART, by Spanish acronym). Four patients were excluded from the study because they had suffered open fractures with extreme comminution and serious joint and soft tissues injury— one of them needed primary arthrodesis in proximal interphalangeal joint in one of their fingers. One patient refused assessment. Eight patients were ruled out from the study after surgery by ARTs; they underwent follow-up at other institutions, and we could not continue assessment.

Therefore, the study group was eventually made up of 42 patients (39 males and 3 females) who averaged 30.76 years old (ranging from 21 to 63).

The mechanisms of injury were finger crush at work (15 cases), finger blow during robbery attempt (17 cases), fall from motorcycle or bicycle (7 cases), and fall from own height (3 cases).

The dominant hand was the affected one in 21 cases (50%); 19 right hands and 22 left hands. One patient suffered fracture in both hands and was subject to ORIF treatment. Fractured phalanxes amounted to 91 (18 first phalanxes and 73 second phalanges; we did not include fractures in distal phalanxes). Sixty-eight phalanxes were

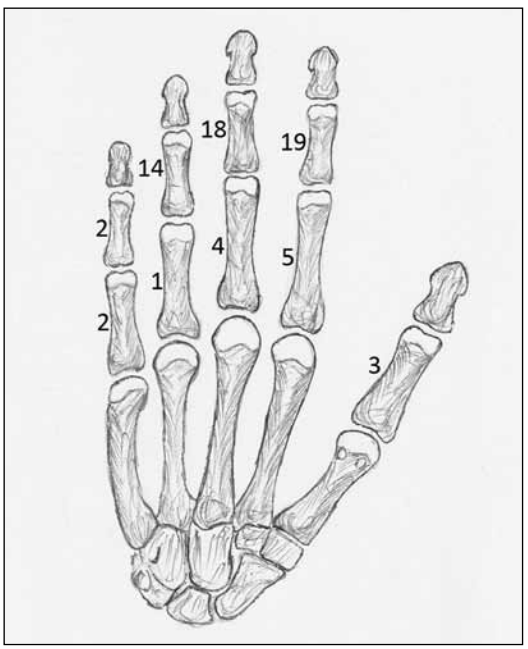


Figure 1. Distribution of the 68 phalanxes that we operated on. Second phalanx fractures clearly outnumber first phalanx fractures in index, middle and ring fingers.

Figure 2. Different models of 1.7 mm osteosynthesis plates.

operated on with plate-ORIF (15 first phalanxes and 53 second phalanxes); the remaining 23 phalanxes were subject to conservative treatment. Thirty-eight patients (16 cases) needed ORIF in more than one phalanx. The distribution of injuries in fingers and phalanxes is illustrated in Figure 1.

Twenty-eight percent of the fractures operated on using ORIF were open fractures (19 fractures); 13 of them were Gustilo grade I fractures and 6, Gustilo grade II fractures.[6] We verified comminution (considering more-than-three-fragment fractures as such) in 26 cases out of all of the fractures that were operated on using ORIF (38.24%). In eight fractures (11.6% of all the fractures operated on using ORIF) there was joint injury.

As it has already been stated, apart from the fractures that needed ORIF we gave 23 fractures conservative treatment (15 patients [35.71%] had suffered this kind of fractures).

The average time that passed between the injury and the ORIF treatment was 13 days (ranging from 4 to 24; 5.18 standard deviation). In patients with open fracture we carried out surgical toilet within 24 hours.

In all fractures subject to surgical treatment (68 phalanxes) we used straight plates—T-shaped plates, L-shaped plates, Y-shaped plates, double-row plates or condylar screw-plates, depending on the type of fracture (Figure 2). The implants we used for both proximal phalanxes and middle phalanxes were 1.3- mm (Compact Hand, Synthes^{R}), 1.7 mm- (Profyle Hand Standard Plates, Stryker^{R}), 1.5 mm- (Small Bones System, Jeil Medical Corporation^{R}). The use of one trademark or other was random, and it was determined by the provision of the implant following ART-bidding. In no case did we use locking plates.

With respect to the surgical technique, we carried out a "V" skin dorsal approach upon the fractured phalanx. This triangular flap, which includes soft tissues, is distinct from the finger extensor apparatus. The periosteal incision is longitudinal and lateral to avoid the fracture line. The

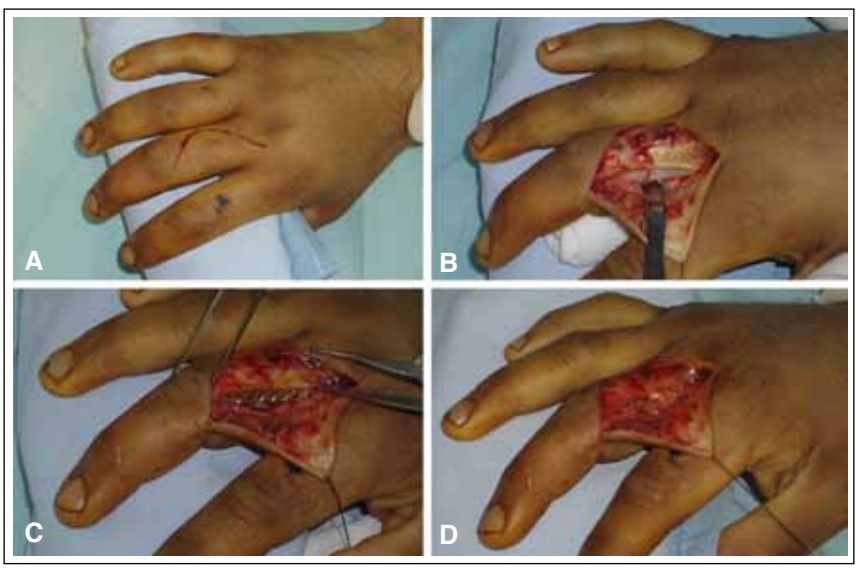


Figure 3. A. Dorsal approach. **B.** Lateral exposure of the fracture line. **C.** Ostesynthesis. **D.** Periosteum stitches.

extensor tendon remains undamaged because it lies dorsal to the periosteal incision, and it should be lifted together with the periosteum with no distinction between layers. So as to avoid adherences, it is key that skin incision and periosteum incision are carried out separately—the skin incision on the back of the finger and the periosteum incision on the lateral aspect of the phalanx. Plates are invariably inserted on the lateral aspect of the phalanx, away from the extensor apparatus. Moreover, for the plate to slide better, the periosteum should be stitched using 4-0 nylon covering the osteosynthesis (Figure 3).

In 33 fractures (48.53%), the ostesynthesis had to be inserted immediately proximal to the joint line due to either joint injury or proximal or distal metaphyseal fracture. In these cases it was necessary to use T- or L-condylar plates, or straight plates, holding the epiphyseal fragment with just one screw because of its small size.

Due to comminution, impaction or loss of bone stock, in 11 fractures (16.18%) it was necessary to add spongy bone graft that, in all cases, was taken from the homolateral olecranon using usual techniques.

All patients followed a rehabilitation protocol with phisio-kinesiotherapy or Occupational Therapy depending on the fracture extent (immediately after the surgery or at most two weeks later).

Patients were assessed at the doctor's office with X-rays to determine bone healing, which was considered as such if there was bone bridging at fracture line level. At the time of discharge patients were evaluated for ROM in every finger operated on by means of a goniometer and using the Gingrass criteria[7] (Table 1) and the Belsky criteria[8] (Table 2) to determine results in respectively the patients' thumb and the remaining fingers. At the time of discharge the patients also answered the DASH (Disabilities of the Arm, Shoulder and Hand) questionnaire.[9]

We studied the relationship between the potential factors behind patients' poor prognosis and patients' ultimate fingers ROM together with their subjective DASH questionnaires.

The average follow-up was 3.38 months (ranging from 2 to 7). This was the time that took the patients to come back to work following discharge.

Statistical Analysis

We present the average together with standard deviation (SD) for continuous variables and, in some cases, we also present range as minimal-maximal. For discrete variables we present frequencies together with percentages. To model the odds of total active ROM results being Excellent/ Good vs. Fair/ Poor, we used logistic regression models.

The results of the adjustment in such models are shown as odds ratios assessed along with their matching 95% confidence intervals (95% CI). We used the Fisher test or the Friedman-Halton test to compare ratios between

Table 1. Gingrass criteria for assessment of thumb injury

Palmar abduction	Excellent	Good	Fair	Poor
>45°	TF >100°	TF 60°-100°	TF 0°-60°	
40º-45°		TF >75°		
30º-40°			TF >80°	
<30°				TF <80°

TF= Total flexion. It is thumb metacarpophalangeal plus thumb interphalangeal active flexion-extension.
Results go one notch down if interphalangeal flexion is <10°

Table 2. Belsky criteria for assessment of fingers injury

Excellent	Good	Poor
Bone healing without pain, and	Bone healing without pain, and	Non-union or pain, or
no deformity, and	minimal deformity, and	deformity which affects function/cosmetics, or
TAM >215°, and	TAM ≥180°, and	TAM <180°, or
>100° PIP mobility	≥80° PIP mobility	<80° PIP mobility

TAM= total active mobility. It is metacarpophalangeal joint plus proximal interphalangeal joint (PIP) plus distal interphalangeal joint (DIP) active flexion-extension.

groups as necessary. Results with a <0.05 associated ratio are considered to be statistically significant. We carried out statistical analyses using the SAS/STAT[R] program.

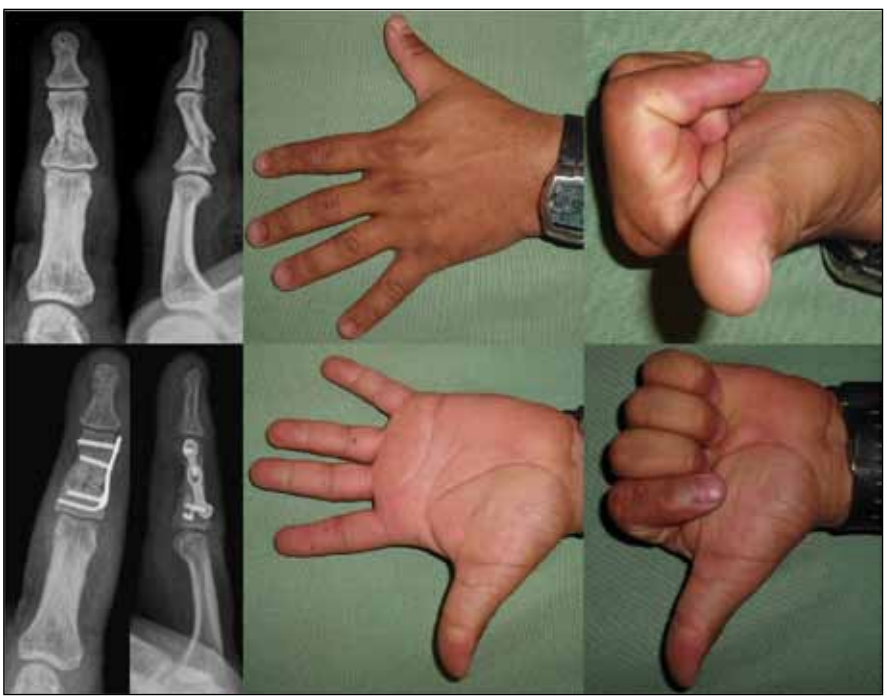
Results

We got bone healing in all fractures in average 1.8 months (ranging from 1 to 5) (Figure 4). The results in the thumb (3 patients with thumb ORIF) were good in two cases and fair in one case. In the remaining fingers (65 ORIFs), 23 were excellent (35%); 36, good (55%) and six, poor (9%). The average DASH score was 18.53 (ranging from 1.7 to 57.8; 10.58 SD).

ROM in the thumb and the four remaining fingers is shown in Tables 3 and 4.

As shown by Tables 5 and 6, ROM outcomes in the fingers were significantly better in second phalanx fractures than they were in first phalanx fractures. Using a logistic regression model but ruling out the cases with fracture in both phalanxes, we verify that the odds of Excellent/Good results in patients with fracture in their second phalanx is 14-fold greater than the odds of Fair/Poor results, as compared with those with fracture in their fist phalanx.

Moreover, we verified that the patient's age was inversely proportional to ROM outcomes. Out of the model adjusted only by the effects caused by the patients' age, we estimate that the odds of Excellent/Good results in one finger (vs. Fair/Poor) decrease approximately 8% per year as the patient ages (p=0.015). All in all, the elder the patient is, the lower their chances are to get satisfactory outcomes.



▲ **Figure 4.** Thirty-three years old male. Pre-operative and post-operative X-rays showing bone healing. ROM three months later.

Table 3. ROM in index, middle, ring and little fingers (in degrees)

Joint ROM	Average	Standard deviation	Minimal	Maximal
DIP flexion	32.23	14.77	0	80
DIP extension	1.77	6.59	0	50
PIP flexion	88.98	16.22	20	110
PIP extension	1.66	5.87	-10	35
MTC-PHAL flexion	93.72	15.82	40	120
MTC-PHAL extension	-15.47	7.35	-30	0

DIP= Distal interphalangeal joint; PIP= proximal interphalangeal joint; MTC-PHAL= metacarpophalangeal joint.

Table 4. Thumb ROM (in degrees)

Joint ROM	Average	Standard deviation	Minimal	Maximal
IP flexion	46.67	5.77	40	50
IP extension	10.00	17.32	0	30
MTC-PHAL flexion	43.33	2.89	40	45
MTC-PHAL extension	-6.67	5.77	-10	0

IP= interphalangeal joint; MTC-PHAL= metacarpophalangeal joint

Table 5. Statistical correlation between analyzed variables and results

	Total active mobility Good/Excellent	Total active mobility Poor/Fair	Associated probability
Nº of phalanxes operated on with ORIF (%)	61 (90%)	7 (10%)	-
Comminution (n)	43% (26)	0% (0)	0.038 [a §]
Joint fracture (n)	13% (26)	0% (0)	0.588 [a]
Bone graft (n)	18% (11)	0% (0)	0.587 [a]
Peri-joint fracture (n)	51% (31)	29% (2)	0.429 [a]
Open fracture (n)	28% (17)	29% (2)	1.000 [a]
Fractured phalanx (n)			0.003 [b §]
First phalanx	12% (7)	71% (5)	
Second phalanx	74% (45)	29% (2)	
Both phalanxes	14% (9)	0% (0)	

ORIF = open reduction and internal fixation
[a]Fisher Test
[b]Freeman-Halton Test
§5% Significance

Table 6. Results in adjusted univariate models which were statistically significant

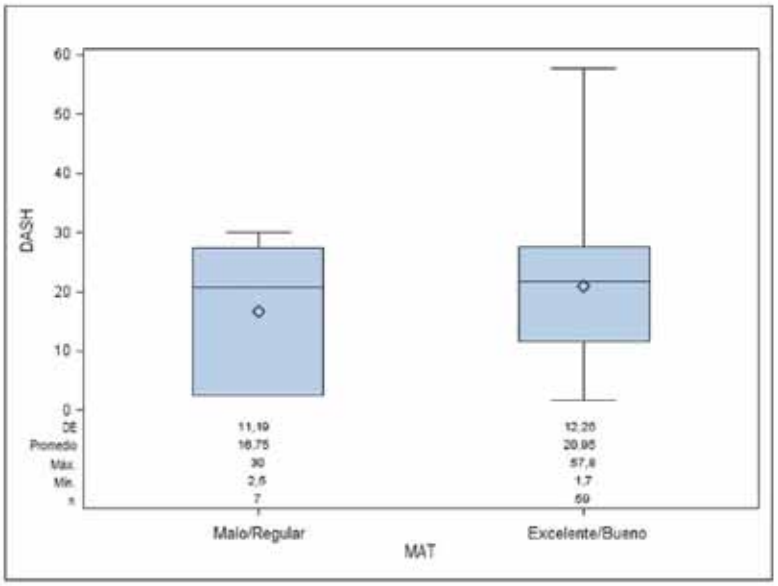
Effect	Estimated OR	95% CI
Age	0.92	(0.86; 0.98)
Fractured phalanx 2 vs. 1	16.07	(2.60; 99,48)
Fractured phalanx 1	0.08	(0.01; 0.46)
Fractured phalanx 2	12.75	(2.16; 75.18)
Nº of fractured phalanxes	2.88	(1.14; 7.29)

OR = *odds ratio*
95% CI= 95% confidence interval

In the remaining variables (comminution, joint fracture, open fracture, fracture requiring peri-joint osteosynthesis or spongy bone graft taken from olecranon, as well as the time that passed between the injury and the surgery), we did not verify any statistically significant correlation with final fingers ROM.

The subjective evaluation of the patients was carried out using the DASH questionnaire, which was not significantly related to the variables in analysis (age, first phalanx surgery vs. second phalanx surgery, comminuted fracture, joint fracture, open fracture, and fracture requiring peri-articular osteosynthesis or spongy bone graft taken from the olecranon). Nor there was a significant correlation with final fingers ROM, as shown by Figure 5.

Four patients suffered complications (9.5%). There was one case of RSD (reflex sympathetic dystrophy) which, at the time of the patient's discharge, continued with ROM deficit and a poor Belsky score for the proximal oblique open metaphyseal fracture in the first phalanx of the index finger, with severe injury to the extensor apparatus. One patient showed intolerance to the condylar osteosynthesis plate in their comminuted distal metaphyseal-diaphyseal fracture in the second phalanx of the ring finger. We removed the implant and the patient's final Belsky score was good for the ring finger and it also was good for the other two fingers that had been operated on (thumb and middle fingers). One patient with one fracture per pha-



SD: standard deviation
Max.: maximal
Min.: minimal
n: number of phalanxes
TAM: total active mobility

Figure 5. Box plot showing the correlation between DASH/total active mobility.

lanx in the second phalanx of the index, middle and ring fingers, which were T-patterned joint distal fractures with metaphyseal comminution, suffered delayed union in the second phalanx of the middle finger with stable implant. The patient underwent a second surgery with the addition of autologous bone graft taken from their contralateral iliac bone and got good results in the Belsky score for that finger. The same patient developed misalignment on the coronal plane in their two other fingers that had been operated on (index and ring fingers), although ROM was excellent in both. Another patient also suffered misalignment on the coronal plane (comminuted joint fracture in the second phalanx of the index and ring fingers); however, Belsky score results were good in both fingers, as they were in their other finger that had been operated on (comminuted diaphyseal fracture in the second phalanx of the middle finger).

Discussion

Osteosynthesis plates for hand mini-fragement fractures were introduced in the market a number of years ago,[10-12] replacing traditional AO steel plates.[13-15] Their multiple designs, many of them being pre-contoured, their delicate craft and their low profile allow the surgeon to get rigid internal fixation with less interference in the normal tendon sliding, and give the patient the possibility to develop early joint mobility and better functional results.

Specialized literature highlights two prospective studies due to their large number of cases. Omokawa et al.[12] evaluated 51 patients with 51 fractures (12 in metacarpal bones and 39 in phalanxes) with peri-joint comminution who were treated with osteosynthesis plates. Results were excellent in 26 patients, good in 17, fair in five and poor in three. They removed osteosynthesis plates in 30 patients and, simultaneously, they carried out tenolysis in 20 patients adding arthrolysis in five cases. Patients with metacarpal fractures got better results than those that had suffered phalanx fractures, with statistically significant differences. The five complications reported occurred in phalanx fractures. Shimizu et al.[16] analyzed 72 patients with 49 phalanx fractures and 23 metacarpals with comminuted joint fractures that were operated on using plates. Results were good (59.7%), fair (18.1%) and poor (22.2%). They removed 33 plates (28 in phalanxes and 5 in metacarpals) with tenolysis in 20 cases and additional arthrolysis in five of these patients. They showed that phalanx fractures, patients' age and soft tissues injury are significantly associated with poorer final outcomes.

Our series has a larger number of phalanx surgeries than the abovementioned series have and, moreover, we do not include metacarpal fractures, which are clearly associated with better results than phalanx fractures are, and distort accurate analyses (Table 7).

Table 7. Comparison between ours and other series

	Number of patients	Metacarpal fractures	Phalanx fractures
Omokawa (2008)	51	12	39
Shimizu (2012)	72	23	49
Our series	42	0	68

Results were similar in the three works (Table 8), but in our series we only removed one plate out of the 68 that we inserted, with no need for tenolysis (Table 9). We believe that the skin dorsal "V" flap approach and the periosteal longitudinal lateral approach, plus the lateral insertion of the osteosynthesis plate with stitches to the periosteum might be associated with the satisfactory active ROM that we got, and the low rates of additional implant removal, tenolysis and arthrolysis. That patients do not have to undergo successive surgeries is of outmost importance in our practice with ART's patients, because this way treatment duration and costs are decreased, with earlier patients' discharge to come back to work.

In our population, we verify a clear prevalence of second phalanx fractures (a total of 73, 53 that were operated on) as compared with first phalanx fractures (a total of 18, 15 that were operated on), contrarily to what has been reported by other authors,[17-19] in whose series fractured first phalanxes outnumbered fractured second phalanxes.

Although open reduction and osteosynthesis with plates is a challenging technique, in our series complication rates were lower than those in other series. In a retrospective study of 54 patients operated on consecutively with ORIF with plates in 64 phalanx fractures, Kurzen et al.[4] reported 57% of the patients with complications. The main complication was rigidity (41%, 22 patients), considering <180° ROM as such. Moreover, they report two cases of non-union and two cases of delayed union, three cases of plate loosening and one of material failure, plus nine patients with dystrophy and two cases of deep infection. Fifteen patients (27%) suffered persistent pain in the finger that had been operated on, or in their whole hand. In our series, four patients suffered complications (dystrophy, intolerance to the osteosynthesis material, delayed union and misalignment in four fingers). Moreover, to those four cases we can add five cases in which ROM in any of the fingers that had been operated on was <180°, what would increase our number of complications to nine (21.42%).

With respect to the factors behind patients' poor prognosis, we were able to identify two statistically significant ones. Results were poorer in first phalanx fractures than they were in second phalanx fractures. Although it has been acknowledged that metacarpal fractures do postoperatively better than phalanx fractures, [12,16] prognostic post-operative differences between first phalanx and second phalanx fractures had not been statistically proved in specialized bibliography yet.

Table 8. Comparison between ours and other series. Results

	Excellent	Good	Fair	Poor
Omokawa (2008)	26 (51%)	17 (33%)	5 (10%)	3 (6%)
Shimizu (2012)	0	43 (60%)	13 (18%)	16 (22%)
Our series	23 (34%)	38 (56%)	1 (1.4%)	6 (8.6%)

Table 9. Comparison between ours and other series. Complications and consecutive surgeries

	Complications	Material removal	Tenolysis	Arthrolysis
Omokawa (2008)	5 (10%)	30 (59%)	20 (39%)	5 (10%)
Shimizu (2012)	6 (8%)	33 (46%)	20 (28%)	5 (7%)
Our series	4 (9%)	1 (1.4%)	0	0

The second factor behind patients' poor prognosis was the patients' age, with poorer functional results at elder ages. This finding coincides with those in Omokawa et al.[12] and Shimizu et al.[16]'s series. In our study, we acknowledge as the greatest weakness our short follow-up, what does not allow us to identify long-term complications such as degenerative joint changes. Nevertheless, we have a large number of cases and we have operated on a large number of fingers in a population of workers, all of them undergoing the same technique which was carried out by two hand surgeons, and all of them assessed with accuracy both subjective and objectively.

Conclusions

We believe this is a valuable experience, especially for professionals who treat workers. In our series, the treatment of phalanx fractures with plates and screws-ORIF got bone healing in all cases and satisfactory results in 90% of the cases, with complication rates similar to or lower than the figures reported in specialized literature. Nowadays this is our treatment of choice for displaced hand phalanx fractures.

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