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Low-severity metacarpal and phalangeal fractures treated with miniature plates and screws

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Abstract *Introduction* The results reported in the literature of metacarpal and phalangeal fractures treated with miniature plates and screws are scarce and contradictory. The aim of our study was to evaluate the functional results after low-severity metacarpal and phalangeal fractures treated by miniature plates and screws. *Materials and methods* We retrospectively reviewed 44 patients of a consecutive series with 56 low-severity metacarpal and/or phalangeal fractures stabilized with miniature plates and screws with a mean follow-up of 24 months to assess objective and subjective outcomes and complications. The objective assessment included measurement of the range of motion (ROM) of the involved finger, prehension, sensory function and strength. The subjective evaluation assessed the impairment and pain felt by the patient. *Results* At the final check-up, average total active movement of the involved digit was 256° (range 175°–260°), and average score for prehension was 49.3 (range 30–50), with 41 patients with a full score. The Jamar test pointed to a significant reduction in grip strength (−5.2%) of the injured hand compared with the other hand. Average subjective impairment score for all the fractures was 15.5 (range 10–16), with 39 patients having a score between 16 and 14 (no impairment). Fracture reduction was anatomic in 42 fractures (75%), satisfactory in 11 (19.6%) and unsatisfactory in 3 (5.4%). There were no contractures, non-unions, infections or tendon ruptures. Twenty patients (45%) presented with one or more complications in 23 fractures (41.1%). *Conclusion* These very favourable results suggest that miniature plates and screws are a possible choice in the treatment of these fractures.

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Introduction

Fractures of the metacarpals and phalanges are common injuries that can lead to impairment of hand function. Unstable metacarpal and digital fractures are difficult to treat, and the results are not always satisfactory [19]. The severity of the fracture (comminution and articular involvement), soft-tissue damage, poor reduction and poor fixation, surgical trauma, and inadequate postoperative management are the main factors adversely affecting functional outcome [5, 12, 19].

Several authors [10, 14, 20] have stressed the importance of a rigid fixation to maintain an adequate stability to allow both fracture healing and early active digital motion. The method or the implant(s) selected do not necessarily have to be the strongest available, but a threshold of stabilizing force that will reliably allow fracture healing in concert with early rehabilitation must be achieved.

Plate and screw fixation can provide rigid fracture immobilization [11, 15, 16], and dedicated mini-screws and even mini-plates have been designed for hand surgery. The main advantages of these implants are the added stability provided by fracture compression and the resultant or independent neutralization of bending, rotational and shear forces acting upon the fracture site. These features help to ensure timely fracture healing and to allow earlier and more intensive digital rehabilitation. On the other hand, hardware and the instruments necessary to apply them are relatively expensive compared with Kirschner wires and other wiring systems, and their insertion is technically more demanding and is associated with a longer learning curve.

The first report on the use of mini-screw fixation in the hand was published by Heim et al. [13] in 1973, but after 29 years the related literature is still scarce and the results debated [18].

Excellent results were reported by Dabezies and Shutte [6] and Bosscha and Snellen [2], but in two recent studies [17, 18] the complication rate was 57%, and total active movement (TAM) was poor for 30% of the patients in one study [17] and fair/poor for 48% in the other one [18].

Since the initial fracture severity is a strong determinant of the final outcome, it is likely that the fair results reported by Ouellette and Freeland [17] and Page and Stern [18] are mainly due not to the plates and screws themselves but to the circumstances in which they are used [19].

The conclusions drawn from their studies suggest that in particular subsets of patients, e.g. those without severe soft-tissue injuries or open fractures, fixation with miniature plates and screws may be more advantageous.

The aim of our study was to evaluate the functional results after low-severity, closed and extra-articular metacarpal and phalangeal fractures treated by miniature plates and screws.

Patients and methods

From October 1995 to October 2000, 79 consecutive patients with metacarpal and/or phalangeal fractures were treated in our institution using miniature screws and plates. We used open reduction and internal fixation in patients with unstable or irreducible fractures. In this retrospective study, 54 of 79 patients (70%) were reviewed: of the patients missing the follow-up, 5 missed the appointment twice, 1 died, 5 refused the check-up owing to work reasons and 1 to unsatisfactory results, 1 fractured the injured hand again at another site before the appointment, and finally, it was impossible to contact 12 patients. However, all these patients attended the last follow-up (6 months after operation), and we observed clinical and radiological healing of the fracture in every case.

Ten of the 54 reviewed patients were excluded because they had intra-articular or open fractures or fractures involving the first ray. Thus, the study group was composed of 33 men and 11 women with 56 fractures (45 metacarpal and 11 phalangeal). Their mean age was 39.4 years (range 17–77 years). Thirty-one fractures were in the dominant hand. The distribution of the injuries showed a prevalence in the fourth and fifth ray. The fracture characteristics are described in Table 1. In 34 cases there was one metacarpal or phalangeal fracture, 8 patients had two fractures in the same hand (6 with two metacarpal fractures, 2 with one metacarpal and one phalangeal fracture), 2 patients presented with a triple metacarpal fracture. None of the patients presented with more than 1 fracture in the same ray. Thirty-four fractures were in the right hand and 22, in the left hand. The mean period between injury and operation was 5.1 days (range a few hours to 28 days).

Table 1 Distribution and characteristics of 56 metacarpal and phalangeal fractures in 44 patients treated with miniature plates and screws (*MC* metacarpal, *P1* proximal phalanx, *P2* middle phalanx)

	No. MC fractures	No. P1 fractures	No. P2 fractures	Total
II ray	7	2	1	10
III ray	8	3	-	11
IV ray	17	2	-	19
V ray	13	3	-	16
Total	45	10	1	56

According to the Tscherne method [22] for the classification of soft-tissue injury, 2 patients were classified as CII, while the other 42 patients were included in the C0 and CI categories.

Operative technique

The operation took place with a tourniquet bandage in position. A dorsal approach was used for both metacarpal and phalangeal fractures with curved incisions. In the metacarpals access to the bone was achieved by transposing the extensor tendons ulnarly or radially and occasionally sectioning the juncture tendinum. A mid-dorsal and dorsolateral extensor splitting incision was used in the proximal and middle phalanges, respectively. The periosteal sleeve was also opened longitudinally and the bone exposed subperiosteally to visualize the fracture. The fracture was then reduced by longitudinal traction on the digit, and the reduction was held in compression by a reduction clamp. Fixation was achieved with either plate or screws according to the standard AO technique (Figs. 1 and 2).

Minicondylar plates and screws were available in 3 sizes, with screw diameters of 2.7, 2.0 and 1.5 mm (Combo Set Leibinger; Freiburg, Germany). Twelve metacarpal fractures were fixed with a plate, 30 with two or more screws, and 3 with a plate and additional screws. Three phalangeal fractures were treated with a plate and 8 with two or more screws.

Postoperative management

Postoperatively, all fractures were protected by means of a plaster for a variable period (mean time 15 days; range 2–90 days, with 19 of 44 patients over 30 days). Exercises were started generally after 2–3 days by the patient him/herself or following a physiotherapist's instructions. The standard follow-up protocol for these surgically treated fractures included clinical evaluation at 1 week, 2 weeks, 1, 3 and 6 months. Radiographs were taken to evaluate bony union at 1 and 3 months, and after 3 months only in those patients in which bony union was not yet achieved.

Fig. 1 Multiple metacarpal fractures with significant displacement, rotation, angulation and instability before and after internal fixation with minifragment plate and screws

Assessment

All the patients were reviewed by two of the authors who were not involved in the surgical treatment. The 'hand computer card' employed by Brefort et al. [3] was used to record anamnestic and clinical data.

The objective assessment included measurement of the range of motion (ROM) of the involved fingers as arc of total active motion (TAM) and evaluation of prehension (10 different tests with grip rated from 1 to 5) [3], sensory function (Weber's test) and strength. The grip strength was tested using the Jamar dynamometer, and the pinch strength was tested with the use of a pinch-meter, with average values given for pulp-to-pulp pinch of each involved finger with the thumb. In both cases, each hand was alternately tested three times, and the mean value was recorded.

The subjective evaluation assessed the impairment (4 criteria: acts of daily life, precision grip, power grip, professional acts; 4 degrees: *1* normal, *2* mild impairment, *3* major impairment, *4* impossible) [3] and pain (5-degree scale) felt by the patient [3].

The final radiographs were used to evaluate fracture reduction (anatomic; satisfactory, if residual dislocation was lower than 2 mm; unsatisfactory, if residual dislocation was greater than 2 mm), fracture consolidation, presence of angular deformities or malrotations, and bone healing.

Results

The mean time from surgery to final clinical assessment in our patients was 24 months (range 5–67 months).

The average return to activities of daily life and to work for the whole group of patients was 29.6 days (range 4–180 days) and 59.5 days (range 6–210 days), respectively.

Fig. 2 A malrotated oblique proximal phalanx fracture with apex volar angulation, before and after internal fixation with minifragment plate and screws

In all fractures, the average TAM of the involved digit was 256° (range 175°-260°). Average TAM in digits after metacarpal fracture was 257° (range 175°–260°) and in digits after phalageal fracture, 251° (range 215°–260°): no significant differences were observed in average TAM between metacarpal and phalangeal fractures (Student's *t*-test, $p = 0.19$).

In all fractures, the average score for prehension was 49.3 (range 50–30): 41 patients (93.2%) had a full score (very good, normal hand), 2 patients scored 40 (average: compensation) and 1 patient scored 30 (poor result). No significant differences were observed between metacarpal vs phalangeal fractures regarding prehension scores. Sensory assessment with the Weber test showed normal results in all patients.

The Jamar test pointed to a significant reduction of the grip strength (−5.2%) in the injured hand compared with the other hand (39.1 ± 12.3 vs 41.2 ± 12.1; Student's *t*-test, $p < 0.01$), whereas the pinch test did not show any significant difference in the pinch strength between the two hands (3.8 ± 1.1 vs 4.0 ± 1.1). No statistical correlation was found between the grip strength reduction in the injured hand and the time since surgery or the immobilization time.

Compared with the contralateral side, the average reduction in grip strength was significantly higher in patients with a phalangeal fracture than in patients with metacarpal fractures ($-10.9\% \pm 20.1$ vs $-3.2\% \pm 10.1$; Student's *t*-test, $p < 0.05$).

The average subjective impairment score for all fractures was 15.5 (range 10–16): 39 patients (88.6%) had a score between 16 and 14 (no impairment), 1 patient scored 12 (little impairment), 1 patient scored 10 (significant impairment). Residual pain was referred to as pain on pressure in 3 patients, motion-related in 4 patients, cold-related in 11 patients and completely absent in 26 patients. Disabling pain was not mentioned by anyone.

The radiological parameters according to the last radiograph performed revealed that reduction was anatomic in 42 fractures (75%), satisfactory in 11 (19.6%) and unsatisfactory in 3 (5.4%). The fracture callus was normal in 48 fractures (85.7%) and abundant in 8 (14.3%). Seven minor malunions without functional consequences were recorded: 5 malrotations lower than 10° and without finger superimposition and 2 unsatisfactory reductions with residual dislocation greater than 2 mm.

There were no contractures, non-unions, infections or tendon ruptures. Twenty patients (45.4%) presented with one or more complications in 23 fractures (41.1%). The complication rate was significantly higher in phalangeal fractures than in metacarpal fractures (81.8% vs 31.1%; Student's *t*-test, $p < 0.01$) (Table 2).

Table 2 Complications associated with 56 metacarpals and phalangeal fractures in 44 patients treated with miniature plates and screws (*TAM* total active motion)

	Metacarpal fractures ($n = 45$)	Phalangeal fractures ($n = 11$)	Total
Major extension lag or stiffness (lag≥35° or TAM <180°)	2	1	3
Minor extension lag or stiffness	3	6	9
Minor malunion (no functional problems)	5	2	7
Delayed union	3	-	3
Asymptomatic hardware breakage	1	-	1

Discussion

Our study reports on the outcome of a series of extra-articular, closed metacarpal and phalangeal fractures treated by open reduction and internal fixation. Our fractures could be described as low-severity fractures, with moderate soft-tissue injury recorded in only 2 patients. The final outcome was recorded using a complete hand evaluation system [3], which allows the assessment of mobility, sensitivity, prehension, and strength and of the impairment and pain felt by the patient.

In our patients, the use of miniature plates and screws led to convincing results. All but one of the patients fully regained their previous activity, over 93% of the patients recovered their prehension abilities completely, and subjective impairment was totally absent in over 88% of the patients. Complications were recorded in 41% of the patients, but most of them were minor events without functional consequences: only 3 patients suffered a major extension lag or stiffness, and 3 delayed unions were observed. The delayed unions were due to poor fracture fragment compression, and satisfactory healing was achieved at 5–6 months without further surgery.

The radiographic assessment confirmed the good results, with an anatomic reduction in 75% of the fractures and satisfactory in 19.6%. In 5.4% of fractures, there was an unsatisfactory reduction, with residual dislocation greater than 2 mm, which did not impair the functional recovery of the injured hand.

We had poor results in only 1 patient, who reported significant impairment for every parameter evaluated. This unsatisfactory outcome was in an elderly person (75 years old) with a long period (28 days) lapsing between injury and operation, and concomitant fractures in the same upper limb that interfered with recovery and rehabilitation.

In our series, we observed only minor differences in outcome between phalangeal and metacarpal fractures. We did not record a higher rate of soft-tissue adhesion or limitation in tendon gliding with phalangeal fractures, so that the average ROM and subjective impairment score at the final follow-up were not significantly different between metacarpal and phalangeal fractures. However, the phalangeal fractures showed a significantly higher complication rate and grip strength reduction.

The most common concerns with the use of miniature plates and screws is that the operating trauma of a wider exposure can impair the gliding function of the flexor and extensor tendons, that the soft-tissue volume available for accommodating implants is relatively small, especially in the digits, and that the screws and plates might be too bulky and might interfere with the balance and function of joints and tendons [12]. We had only 3 cases (5.3% of patients) with a deficit in extension or flexion greater than 10°, so the final ROM of the associated joints in our series indicates that the gliding tissues were not adversely affected by the surgical dissection or hardware interference. This has been confirmed by the fact that none of the patients required hardware removal.

An interesting finding in our assessment was the significant reduction of grip strength with the Jamar test in the injured hand compared with the other hand. The reduction was still present at an average time of almost 2 years after the fracture occurrence. We were not able to give it a prognostic value, but it should be useful in assessing the potential subtle residual impairment.

The use of screws or screws and plates in metacarpal and phalangeal fractures provides a rigid, secure and reliable fixation. Biomechanical studies by Massengil et al. [16], Vanik et al. [23] and Mann et al. [15] showed that Kirschner-wire fixation methods produced weaker fixation than did miniature plates and screws.

The solid stabilization provided by miniature plates and screws may result in a clinical advantage. In a retrospective study, Diwaker and Stothard [7] compared K-wire synthesis with miniscrews and miniplate fixation, evaluating deformity, ROM and grip. The percentage of good results (no deformity, total active movement >210°, strong grip) was 50% in the K-wire fixation group and 79% in the miniplates and screws group. The better results with the latter may be explained by the fact that this fixation allows earlier mobilisation.

Favourable results with miniature plates and screws similar to ours were also reported in other studies. In 1986, Dabezies and Schutte [6] reported on 48 patients with 52 unstable metacarpal and phalangeal fractures; they excluded fractures associated with significant soft-tissue injury. Final total active ROM ranged from 90% in the condylar group to 97% in the metacarpal group. In 1987, Ford et al. [8] reviewed 22 patients with 26 metacarpal fractures unstable, displaced or rotated: the rate and degree of recovery of function were satisfactory, and excellent results (TAM of the affected finger >220°) were achieved in 75% of the patients.

Nevertheless, less encouraging results have also been reported. In a second study, Ford et al. [9] reviewed their series of phalangeal fractures treated using 1.5 mm and 2 mm miniscrews. Sixteen of 38 fractures were complicated by comminution, skin injuries or damage to the extensor mechanism. According to Belsky's criteria [3], results were excellent in 37% of patients, good in 37% and poor in 26%. The less satisfactory results might be due to the site of the fracture and the high number of intra-articular and open fractures.

In 1987, Stern et al. [21] reviewed 33 patients treated with plates: stiffness, malunion, non-union and tendon rupture were the complications in 16 of 38 fractures (42%). In their series, complications occurred more frequently for phalangeal than metacarpal fractures and more frequently with associated bone or soft-tissue injuries. They suggested that most complications were the result of the initial fracture severity, soft-tissue mobilization during surgery, and plate interference with tendon excursion.

Pun et al. [19] published a prospective study on 52 unstable fractures in 47 patients treated with miniature screws and plates: 61.5% were open fractures and 36.5% comminuted, 40.4% had significant soft-tissue injury, and there were 16 extensor tendon and 6 flexor tendon injuries. Their overall results were not satisfactory: only 27.8% of their patients had good results, 36.1% fair and 36.1% poor. They reported several drawbacks with the design of the miniature plates and screws they used. They also suggested that open or comminuted fractures and soft-tissue injuries were poor prognostic factors, which adversely affected their results.

In the 1994 study of Chen et al. [4] on acute complex hand surgery treated by miniature plates and screws, the overall results were fair and poor in over 53% of their patients, and the authors stated that the end results were significantly affected by bone exposure and comminution and soft-tissue injuries.

Even the two recent studies of Ouellette and Freeland [17] and Page and Stern [18] suggest 'poor prognostic factors' such as open fractures and soft-tissue injuries may be more important than the type of fixation in determining the outcome. In 1996, Ouellette and Freeland [17] published a revision study of 68 consecutive metacarpal and phalangeal fractures in which 37 were open, 19 had severe soft-tissue injury, and 30 required a bone graft. Final TAM was excellent for 17 fractures, good/fair for 15 and poor for 13, and they found a statistically significant relationship between the complication rate and location of the fracture, open vs closed fracture, severity of soft-tissue injury and presence of bone graft.

The retrospective study of Page and Stern [18] reported on 105 metacarpal and/or phalangeal fractures stabilized with plates: they had 37 open fractures, and 7 fractures required bone grafting. They registered major complications in 36% and fair/poor results in 48% of their fractures. They believed that the prime determinant of their outcome was probably not the fixation method itself, but the circumstances in which it was used.

The results of our study and other reports [4, 17] suggest that the outcome after metacarpal and phalangeal fractures is greatly affected by soft-tissue and associated injuries, comminution and exposure of the fracture. In fact, the very favourable results we obtained are to be ascribed to the absence of poor prognostic factors, to the relative prevalence of metacarpal fractures, and to the frequent use of screws alone for fracture fixation.

One possible limitation of our study was that 30% of the patients in this consecutive series was lost at the final check-up. However, the subjects who not reviewed were randomly distributed in the consecutive series of operations, so we can exclude the effect of the first part of the learning method curve, and only 1 of 6 patients who missed the final check-up subjectively mentioned an unsatisfactory outcome. Accordingly, we consider that the functional results of the lost patients probably did not differ from the outcome of the analysed group.

In conclusion, our series of phalangeal and metacarpal fractures suggests that in low-severity fractures treated with miniature plates and screws, very favourable outcomes should be expected, and that this subgroup of fractures could be a good indication for this type of fixation.

The stable bony construct achievable by miniplates and screws is the key to good functional results. Active mobilisation can be started immediately after surgery; oedema, fibrosis and scar formation can be reduced; and tendon gliding can be preserved.

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