Comparison of closed and open surgical technique for second to fifth metacarpal shaft fractures, based on 10-year comparison of 142 surgically treated patients

Submitted
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Abstract

Objectives

Assess surgical treatment of multiple metacarpal shaft fractures to determine if multiple second to fifth metacarpal shaft fractures can be safely treated with Closed Reduction and Internal Fixation (CRIF), without higher risk of complications and re-operation in comparison with Open Reduction and Internal Fixation (ORIF).

Material and methods

Consecutively treated patients in the period January 1, 2007 to December 31, 2017, were retrospectively analysed. Fracture type, surgery time, loss of reduction, rotational deformity, infection, pain, functional impairment, and re-operations were recorded from the patients' medical files.

Results

One-hundred-forty-two patients were included. Median age was 35 years. Single and multiple shaft fractures were treated, 105 and 37, respectively. Fracture types were spiral, oblique, transverse, and comminuted. ORIF and CRIF were both used in all fracture types. ORIF was performed in 121 patients and CRIF in 21 patients. Median follow-up was 2 months (1-4). Significant shorter surgery time was found in CRIF patients, 21 vs 50 minutes. Pain during exercise and infection were seen in ORIF and CRIF. Loss of reduction, rotational deformity and functional impairment were only seen in ORIF patients. Re-operations were only performed after ORIF. Reasons for re-operations were loss of reduction, rotational deformity, infection, pain, functional impairment and hardware irritation as experienced by the patient.

Conclusion

Spiral, oblique, and transverse second to fifth metacarpal shaft fractures can be safely treated by CRIF resulting in good outcome, shorter operation time, and less re-operations than ORIF. Secondly, the results of CRIF for multiple metacarpal shaft fractures are as good as ORIF treated patients with less risk of complications.

***Level of Evidence*: Therapeutic study, Level III/IV**

Introduction

A large percentage of fractures of the skeletal system are metacarpal fractures and account for 36% of hand and wrist fractures [3, 8, 92-94]. Incidence of metacarpal shaft fractures is highest between 20 and 40 years and result in significant societal costs [16, 95]. The majority of metacarpal fractures are sub-capital fifth metacarpal (Boxer's) and first metacarpal base fractures. Shaft fractures of the second to fifth metacarpal represent a smaller percentage of hand fractures.

Non-operative treatment is applicable in a majority of these metacarpal shaft patients [17, 96]. Indication for operative treatment are malrotation, angulation, longitudinal shortening, multiple fractures and fractures with associated soft tissue injury or bone loss [15-18]. Open reduction and internal fixation (ORIF) gained popularity by the introduction of new stable fixation techniques allowing early mobilization post-operatively [29, 34, 85]. Combined with a better knowledge of biomechanical principles of internal fixation and the possibly the availability of antibiotics to reduce infection surgeons decided for ORIF more frequently than closed reduction and percutaneous fixation techniques (CRIF) [16-18, 97]. Parallel to this surge in open technique, multiple articles have been published reporting on different percutaneous techniques and their outcome in the last decade [17, 18, 90, 93, 98, 99]. What type of surgical fixation is preferable based on fracture pattern or the number of fractures is still unclear. Recent analysis in a systematic review suggested open reduction and intern fixation to be less favourable than percutaneous fixation in the treatment of single fractures [16]. Although a majority of patients were reported to have good functional outcome for both techniques a large percentage of the ORIF treated patients experienced functional impairment, which required reoperation in 17% of these patients. No reoperations were necessary for percutaneous treated patients. The systematic review debates ORIF might be a less preferable surgical technique in comparison to K-wire fixation in the treatment of a single metacarpal shaft fracture. Further research was suggested to focus on the comparison between ORIF and K-wire fixation for single and multiple metacarpal shaft fractures.

For multiple reasons, not least of which is the difficulty of recruiting patients willing to undergo surgical randomization, previous authors have suggested that a randomized clinical trial might not be performed in the near future [15, 100]. The current study was therefore designed to determine if the review's results could be substantiated in one large comparative single centre study and therefore confirming that closed percutaneous technique can be safely used in the treatment of second to fifth metacarpal shaft fractures.

Materials and methods

This retrospective study was performed in a single Level I Trauma Centre after the institution's ethics committee's approval was given.

An electronic search in the Digital Patients Medical Database was performed using diagnostic codes, treatment codes, and (erroneous) spelling varieties of "Metacarpal fracture". All patients

treated between January 1, 2007 and December 31, 2017 were included. All medical files were screened for eligibility. Inclusion criteria were single or multiple second to fifth metacarpal shaft fractures surgically treated with Closed Reduction Percutaneous Fixation (CRIF) or Open Reduction Internal Fixation (ORIF) and minimum age of 16 years at time of injury. There were no exclusion criteria. Of all included patients baseline characteristics were noted from the patient's medical record together with any additional injuries and the type of surgery applied. Patients records, postoperative complications and reoperations were fully assessed and documented. All radiographs were examined by a panel of two researchers to determine fracture type and secondary dislocation (APAG and MK). Consensus was reached by discussion.

The Statistical Package for Social Studies (SPSS) Version 24.0 was used for all statistical analyses. Normality of data was evaluated using a Shapiro-Wilk test. Since all continuous data deviated from the Normal distribution, they are shown as median with P_{25}-P_{75}. Categorical data are shown as numbers with percentage. Statistical significance of difference between the ORIF and CRIF group was tested using Mann-Whitney U-test (for continuous variables) or using a Chi-squared or Fisher's Exact test (for categorical variables). A 2-sided p-value less than 0.05 was considered statistically significant.

Results

Patient characteristics

The search identified 142 patients, who were all included (**Table I**). The median age was 28 (P_{25}-P_{75} 22-46) years. Ninety-six (68%) were male. Median follow-up time was 2 (P_{25}-P_{75} 1-4) months. The dominant hand was injured in 79 (67%) patients.

Mechanism of injury was mostly frequently related to a fall from standing height (46%). Other trauma mechanisms were a strike (30%), crush injury (14%) and a traffic accident (9%). Thirty-three percent of the patients did smoke. Medical history showed no relevant injuries or illnesses prior to the treatment of the metacarpal shaft fracture.

Fracture characteristics

Hundred five patients were treated for a single metacarpal fracture (**Table II**). Thirty-seven patients were treated for multiple fractures. ORIF was applied in 121 patients and CRIF in 21 patients. Multiple fractures were not more frequently operated with open or closed technique, 26% vs 29%, respectively.

The most frequently treated type of fracture was a transverse type in 50 patients (34%). Spiral fractures were treated in 46 patients (32%). Less frequent were oblique fractures (26%) and comminuted fractures (8%). ORIF was used in all single second metacarpal fractures and 86% of the single third metacarpal fractures. Comminuted and open fractures were not more frequently treated using either one of the techniques.

Table I Patient Characteristics, Trauma Mechanism and Follow-up

	Total	CRIF	ORIF	p-value
	n=142	n=21	n=121	
Age (years)	28 (22-46)	31 (22-54)	27 (22-45)	0.426
Male	96 (67.6%)	14 (67%)	82 (67.8%)	1.000
Smoking*	48 (43.2%)	8 (40%)	40 (44.0%)	0.807
Right side fractured	88 62.0%)	13 (62%)	75 (62.0%)	1.000
Dominant side injured **	79 (66.9 %)	13 (68%)	66 (66.7%)	1.000
Multiple Fractures	37 (26.1%)	6 (29%)	31 (25.6%)	0.791
Trauma mechanism				
Fall	66 (46.5%)	12 (57%)	54 (44.6%)	0.182
Strike	43 (30.3%)	3 (14%)	40 (33.1%)	
Crush	20 (14.1%)	5 (23.8%)	15 (12.4%)	
Traffic accident	13 (9.2%)	1 (5%)	12 (9.9%)	
Follow-up (months)***	2.0 (1.0-4.0)	3.0 (2.0-5.0)	2.0 (1.0-4.0)	0.084

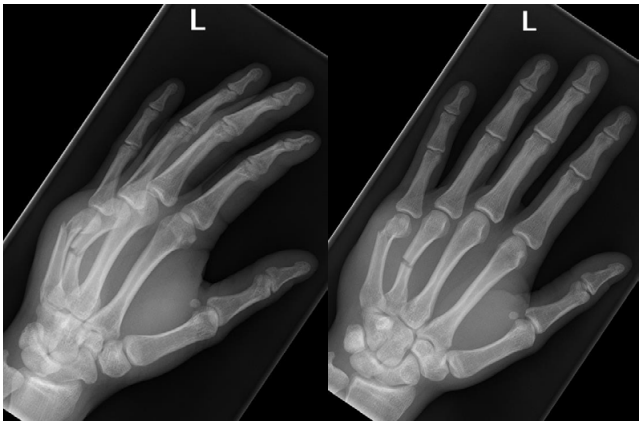
ORIF= Open Reduction Internal Fixation
CRIF= Closed Reduction and Percutaneous Fixation
Data are shown as median (P_{25}-P_{75}) or as N (%).
* Missing data for 1 patient in percutaneous and 20 in ORIF group.
** Missing data for 2 patients in percutaneous and 22 in ORIF group.
*** One patient (ORIF) lost to follow-up direct post-operatively

Table II Fracture Classifications

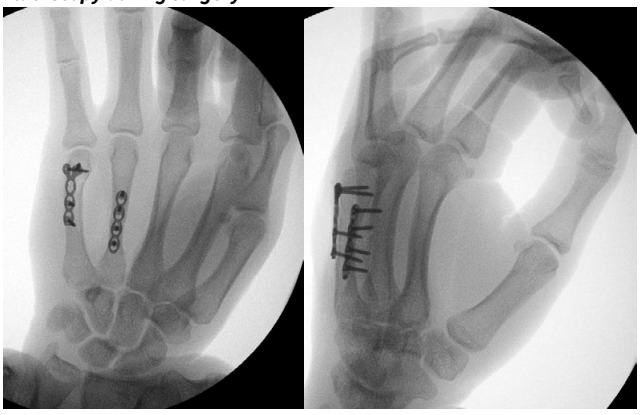
	Total	ORIF	CRIF	p-value
	n=142	n=121	n=21	
Fracture Type				0.633[$]
Spiral	45 (31.7%)	38 (31.4%)	7 (33.3%)	
Oblique	35 (24.6%)	28 (23.1%)	7 (33.3%)	
Transverse	50 (35.2%)	45 (37.2%)	5 (23.8%)	
Comminuted	12 (8.5%)	10 (8.3%)	2 (9.5%)	0.477[^]
Single Fracture				0.054[$]
MC II	7 (6.7%)	7 (7.8%)	0 (0%)	
MC III	7 (6.7%)	6 (6.7%)	1 (6.7%)	
MC IV[*]	38 (36.2%)	28 (31.1%)	10 (66.7%)	
MC V[#]	53 (50.5%)	49 (54.4%)	4 (26.7%)	
Multiple Fractures				0.018[$]
MC II + III + IV	3 (8.1%)	1 (3.2%)	2 (33.3%)	
MC II + III + IV + V	1 (2.7%)	1 (3.2%)	0 (0%)	
MC III + IV	11 (29.7%)	11 (35.5%)	0 (0%)	
MC III + IV + V	4 (10.8%)	3 (9.7%)	1 (16.7%)	
MC III + V	1 (2.7%)	0 (0.0%)	1 (16.7%)	
MC IV + V	17 (45.9%)	15 (48.4%)	2 (33.3%)	
Open Fracture	4 (2.8%)	3 (2.5%)	1 (5%)	

ORIF= Open Reduction Internal Fixation; MC= Metacarpal
CRIF= Closed Reduction and Percutaneous Fixation
Data are shown as median (P_{25}-P_{75}) or as N (%).
[$] Pearson Chi Square test
[^] Fisher's exact test
[#] most frequently injured in dominant hand (p<0.05)
[*] most injured in non-dominant hand (p<0.05)

Fourth and Fifth Metacarpal Fractures



Fluorscopy during surgery



Radiological follow-up 9 weeks post-operatively

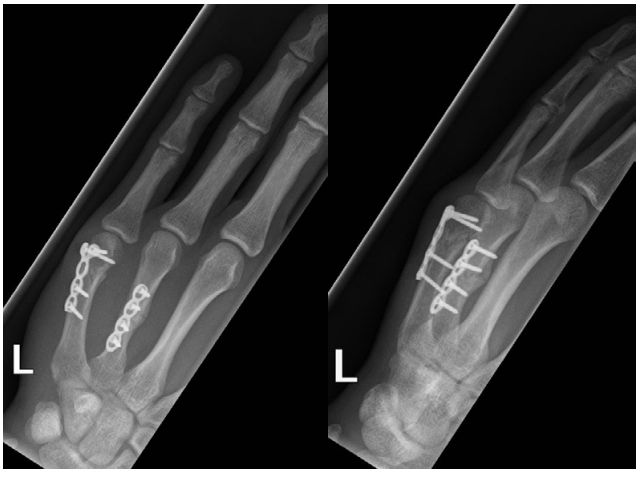


Figure 1. Example of ORIF in the treatment of Multiple Metacarpal Shaft Fractures

Treatment characteristics

All operations were performed by a Consultant Orthopaedic Surgery. Choice for type of treatment was based on personal preference. Surgery time was significantly shorter for percutaneous than for the open technique, *i.e.*, 21 (P_{25}-P_{75} 14-29) vs. 50 (P_{25}-P_{75} 34-69) minutes (**Table III**). Fixation type was most frequently plate fixation in the ORIF group and transverse K-wire fixation in the CRIF group (**Figure 1 and 2**).

Post-operative cast immobilization was found in 13% of the ORIF patients and in 95% CRIF patients (**Table III**). Of the ORIF patients 15 were immobilized post-operatively. Of these 15 patients, nine had a single fracture and six had multiple fractures. Cast immobilization after ORIF resulted in seven of these 15 patients to develop functional impairment post-operatively. All but one of the CRIF patients were given post-operative cast immobilization. All CRIF patients including made a full functional recovery.

Table III Treatment Characteristics

	All	ORIF	CRIF	p-value
	n=142	n=121	n=21	
Time to surgery (days)	7 (5-11)	7 (5-11)	6 (4-11)	0.462
Surgery time (minutes) *	44'' (33-66)	50'' (34-69)	21'' (14-29)	<0.001
Single fracture		49''	23''	
Multiple fractures		84''	62''	
Fixation type				
Single fracture		33 x screws	3 x IM	
		57 x plates	12 x trans	
Multiple fractures		12 x screws	3 x IM	
		19 x plates	3 x trans	
Cast immobilization				
number of patients	36 (25.4%)	16 (13.2%)	20 (95.2%)	<0.001
duration of immobilization (weeks)	4.0 (2.8-8.0)	3.0 (2.0-4.0)	6.0 (4.5-11.0)	<0.001

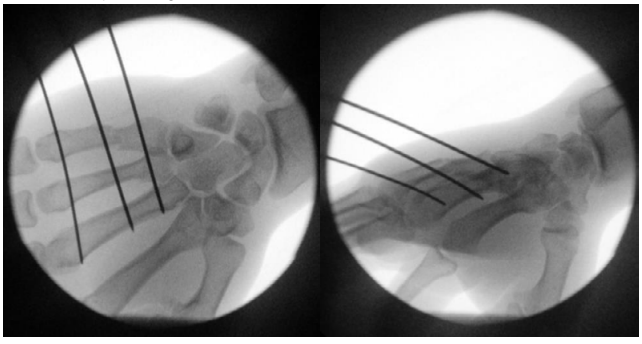
ORIF = Open Reduction and Internal Fixation
CRIF= Closed Reduction and Percutaneous Fixation
IM= Intra-Medullary K-wire fixation
trans = trans-metacarpal K-wire fixation
'' = minutes
Data are shown as median (P_{25}-P_{75}) or as N (%)
* missing data in 2 percutaneous and 38 ORIF treated patients

Complications

Loss of reduction and rotational deformity was found in five ORIF patients (**Table IV**). This resulted in five re-operations in which new ORIF were applied. Loss of reduction and rotational deformity was not seen in the CRIF patients.

Fourth and Fifth Metacarpal Fractures

Fluoroscopy during CRIF



Radiological follow-up 10 weeks post-operatively

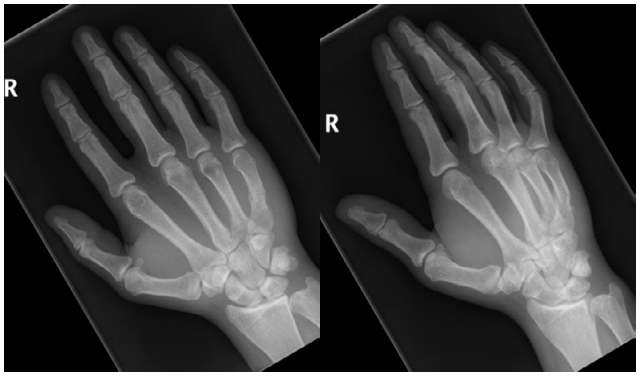


Figure 2. Closed Reduction and Percutaneous Fixation of Multiple Metacarpal Shaft Fracture

Table IV Complications Overall and Selected by Surgery Type

Complications	All (n=142)	ORIF (n=121)	CRIF (n=21)	p-value
Loss of reduction	3 (2.1%)	3 (2.5%)	0	NS
Rotational deformity	2 (1.4%)	2 (1.7%)	0	NS
Infection	2 (1.4%)	1 (0.1%)	1 (4.7%)	NS
Pain during exercise *	13 (9.2%)	10 (8.2%)	3 (17.6%)	0.395[^]
Functional impairment**	16 (11.2%)	16 (16.5%)	0	0.178[$]
Total	36 (28.1%)	32 (29.1%)	4 (22.8%)	0.778[^]

ORIF = Open Reduction and Internal Fixation
CRIF = Closed Reduction and Percutaneous Fixation
NS = not statistically significant
Data are shown as median (P_{25}-P_{75}) or as N (%).
* missing data for 3 patients in percutaneous and 12 in ORIF group
** missing data for 3 patients in percutaneous and 11 in ORIF group
[^] Fisher exact test
[$] Mann Whitney test

Post-operative infections were seen in two patients. One ORIF patient was treated with intravenous antibiotics and required a second operation for wound debridement. One CRIF patients developed a pin-tract infection as was treated with oral antibiotics and K-wire removal after fracture healing and made a full functional recovery.

Pain during exercise was seen in 13 patients. In total ten ORIF patients reported this pain. Two of these patients were re-operated for this reason. These operations consisted of adhesiolysis and removal of osteosynthesis material. All ten patients continued to experience pain during exercise at final follow-up. Three CRIF patients experienced pain during exercise at final follow-up. None required a re-operation.

Functional impairment was found in 16 (16.5%) ORIF patients. Of these, four patients required a second operation (**Table V**).

In total complications were found in 32 (29%) ORIF patients and 4 (22.8%) CRIF patients.

Re-operations

Of all 142 patients, 19 (15.7%) were re-operated. These were all ORIF patients (**Table V**). Pain, infection and loss of reduction was reason for a re-operation in six patients.

Seven patients experienced irritation from osteosynthesis material and required removal of the material. Four patients experienced functional impairment and were re-operated and required hardware removal and adhesiolysis. Two patients had a rotational deformity and were re-operated in which correction and re-osteosynthesis was performed.

Table V Indications for Re-operations Overall and Selected by Surgery Type

Indications	All (n=142)	ORIF (n=121)	CRIF (n=21)	p-value
Loss of reduction (Re-fixation)	3 (2.1%)	3 (2.5%)	0	NS
Rotational deformity (Re-fixation)	2 (1.4%)	2 (1.7%)	0	NS
Infection (removal + debridement)	1 (0.7%)	1 (0.8%)	0	NS
Pain (removal)	2 (1.4%)	2 (1.7%)	0	NS
Functional impairment (removal + adhesiolysis)	4 (2.8%)	4 (3.3%)	0	NS
Hardware irritation (removal)	7 (4.9%)	7 (5.8%)	0	NS
Total	19 (6.3%)	19 (15.7%)	0	0.052^

ORIF = Open Reduction and Internal Fixation
CRIF = Closed Reduction and Percutaneous Fixation
NS = not statistically significant
( ) = type of re-operation
Removal = Removal of osteosynthesis material
Data are shown as median (P_{25}-P_{75}) or as N (%).
^ Mann-Whitney test

Discussion

The most important new finding of this study is that multiple as well as single metacarpal shaft fractures can be safely treated by CRIF without loss of reduction, rotational deformity and re-operations.

No significant difference in complications is reported by patients after ORIF and CRIF surgery, 29.1% vs 22.8% respectively. However, the consequences of these complications were very different. For the ORIF patients 19 of the 32 patients with complications needed to be re-operated. None of the CRIF patients required a second operation.

The high percentage of re-operations found in the ORIF patients (16%) confirms the results from an earlier review which reported on pooled data from five smaller studies in which all re-operations also occurred in the ORIF treated patients (17%) [16]. Re-operations after ORIF might be explained as a result from the trade-off between the anatomical restoration of the injured metacarpal bone and the consequences of exposure of the fracture site, specifically soft tissue irritation and scar formation [95].

The current study substantiates these earlier review results in a larger patient group in a single Level I Trauma Centre. This retrospective comparative study therefore strengthens these earlier findings. Especially the percentage of complications and re-operations is of clinical significance and could be used during the shared decision-making process whilst informing the patient of benefits and risks related to the operation [101]

Cast immobilization after ORIF resulted in seven of these 15 patients to develop functional impairment post-operatively. An advantage of open surgery is direct functional mobilization in comparison with a percutaneous technique, thereby preventing scar formation to occur between moving anatomical layers otherwise resulting in a limitation of movement of the hand.

The clinical significance of this finding could be found in the importance of direct mobilization after ORIF. The aim of ORIF in hand surgery therefore should be stabilization enabling direct mobilization. When no such stability can be reached and post-operative cast immobilization seems necessary, an additional fixation technique should be considered.

An important limitation is the misbalance between the number of patients treated with ORIF and CRIF. This limits the statistical power of these findings. However, this study is the largest study reporting solely on second to fifth metacarpal shaft fractures without any patients lost to follow-up making these findings clinically important.

Another limitation is the choice for ORIF or CRIF was made by the surgeon based on personal preference. Selection bias therefore might be present. The patient however did not choose to be operated by a specific surgeon. The fact that a patient did not specifically choose a surgeon could also be interpreted as fate [102]. Therefore, randomizing each patient for a specific surgeon and subsequently a treatment type.

Fracture type could be a reason to choose for open or closed technique. Within the CRIF group mostly spiral, oblique and transverse fractures were seen. Comminuted fractures were treated with ORIF mostly. Therefore, spiral, oblique and transverse fractures can be treated with CRIF without the risks associated with ORIF.

The current study shows that spiral, oblique and transverse metacarpal shaft fractures can be safely treated by CRIF resulting in good outcome, shorter operation time, and less re-operations than ORIF [16, 18, 90].

Secondly, the results of CRIF for multiple metacarpal shaft fractures are as good as the ORIF treated patients with less risk of complications.