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ORIGINAL PAPER

Open hand fractures: 2 years of experience at a hand centre

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Abstract
Background Despite open hand fractures being relatively common, little has been published regarding their prevalence, mechanism of injury and outcomes.
Methods A retrospective case note review was performed of all patients presenting with open metacarpal, proximal and middle phalangeal fractures over a 25-month period at a regional hand centre.
Results Eighty-five patients were included (median age 43 years). "Sharp" injury was the commonest mechanism (39 %). Forty-three percent were managed with open reduction and internal fixation; this group was significantly more likely to require revision surgery compared to other fixation methods. Four patients developed nonunion. Overall superficial infection rate was 9.4 %, one patient developed deep infection, and there were no cases of osteomyelitis. No infections developed in the group receiving oral antibiotics alone.
Conclusions Further research is necessary, but we postulate that some open hand fractures are suitable for day case surgery with oral antibiotic prophylaxis. The follow-up after these injuries is often protracted, and patients should be counselled accordingly, particularly of the high risk of revision surgery in patients managed with open reduction internal fixation.
Level of evidence: Level IV, therapeutic study.

Keywords Open hand fracture · Antibiotics · ORIF · Tenolysis · Revision surgery

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Introduction

Open hand fractures are relatively common, and like any open fracture elsewhere, they are a multifaceted entity with both the soft tissue and bone needing to be considered in their management [1]. There are well-established guidelines for the management of open fractures in the lower limb, but these are less applicable to open hand fractures [2]. The aims of treatment of open fractures are universal in minimising the risk of osteomyelitis, providing adequate soft tissue coverage and ensuring timely fracture healing. In the hand, achieving sufficient stability of the fracture and early soft tissue closure to allow early mobilisation is of paramount importance to prevent stiffness and subsequent disability [3]. Little has been published regarding the prevalence, demographics, mechanisms of injury and outcomes of open hand fractures. The aim of this study was to examine our outcomes of open hand fracture management and, in particular, infection rates, union rates and the need for revision surgery.

Material and methods

A retrospective case note review was performed upon a consecutive series of open hand fractures presenting to our regional hand centre over a 25-month period (January 2011–January 2013).

We included all patients with open fractures of the metacarpal (MC), proximal (PP) and middle phalanges (MP). Patients with isolated distal phalangeal fractures were excluded as they have a good prognosis, low rates of fixation and revision and so may have skewed the data set [1]. Patients that were initially managed with amputation or that did not attend our unit for initial assessment and primary intervention were also excluded.

Standard treatment in our unit for open hand fractures comprises wound washout in the emergency department, inpatient admission and administration of intravenous antibiotic therapy. Patients would normally have surgery in the form of debridement, washout with or without definitive fixation the following day on a consultant led trauma list.

Bony fixation is performed at the discretion of the operating team using standard methods such as Kirschner wires, open reduction internal fixation (ORIF) with plates or screws or external fixation. The severity of injury then dictates the need for further operative intervention.

Data was collected regarding patient demographics, circumstances of injury, antibiotic therapy, surgical intervention and outpatient follow-up. Primary outcome measures in this study include infection rates, revision surgery and union rates. Infection was classified as superficial or deep, and superficial infection was defined as the administration of oral antibiotics within 28 days of discharge. Univariable analyses were used to investigate the effects of various factors on the rates of infection and revision surgery. For continuous factors, comparisons between the patients in the two outcome groups were made using Mann-Whitney tests, with the groups summarised using medians and quartiles. For categorical factors, Fisher's exact tests were used, with groups summarised by the outcome rates. All analyses were performed with $p<0.05$ deemed to be indicative of statistical significance.

Results

Eighty-five patients were identified over the 25-month period with a total of 122 fractures (Fig. 1). There was a male to female ratio of 4:1, with a median age of 43 years (range 17–85). The majority of the patients were right hand dominant (93 %) with 59 % of the patients sustaining a dominant hand injury. All left hand dominant patients sustained a dominant hand injury.

There were multiple mechanisms of injury, which are detailed in Table 1. Injuries by sharp objects including machinery accounted for 39 % of patients in this series, machinery-related injuries 32 % and crush injuries 25 %. The circular saw was responsible for 15 % of injuries and was the most prevalent offending object.

Antibiotic therapy

Seventy patients were admitted for intravenous antibiotics; for 14 patients, the medical team decided to manage the patient with only oral antibiotics (16.5 %) with day case surgery as an outpatient, and one patient although prescribed antibiotics admitted to not taking their prescription. Although this is a recognized way of managing hand injuries, it is not a typical practice for open fractures. There were no cases of osteomyelitis, but the later patient presented for day case surgery with cellulitis that required admission for intravenous antibiotics. Eight patients developed superficial infections (9.4 %) that required oral antibiotics. Three of these patients had wound swabs taken with one positive result for *Enterobacter cloacae*; the others grew no organisms. There were no infections in the patients who only received oral antibiotic prophylaxis.

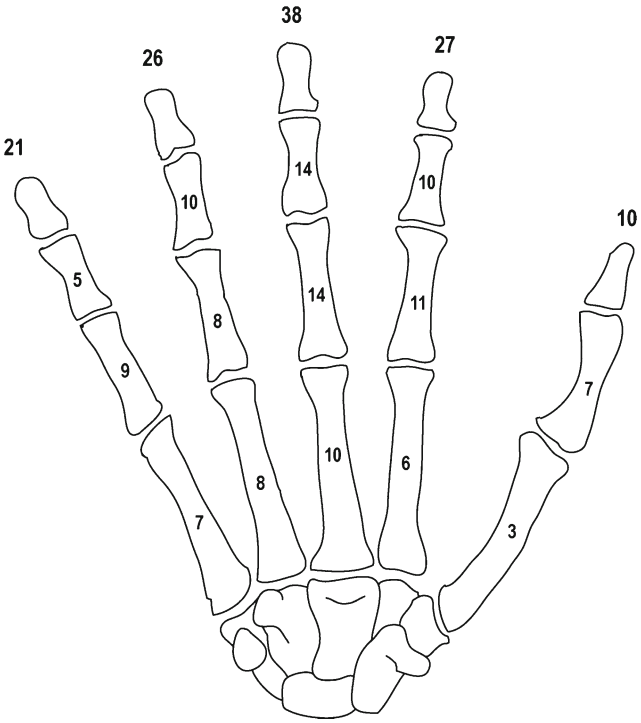

Fig. 1 Diagrammatic distribution of fractures, total number of fractures per digit demonstrated above distal phalanges ($n=122$)

Neither mechanism of injury ($p=0.293$), the use of intravenous antibiotics ($p=0.196$), patient age ($p=0.302$), time to theatre ($p=0.191$) nor time to antibiotics ($p=0.400$) were

Table 1 Mechanisms of injury

Category	Number of patients	Percentage of patients
Machinery–sharp	20	24
Crush	14	16
Sharp–assault/self-inflicted (total)	8/5 (13)	9.4/5.9 (15)
Fall	9	11
Machinery–crush	7	8.2
Bite	7	8.2
Punch	6	7.1
Projectile weapon	4	4.7
RTC	3	4.7
Torsion	2	3.5
Total	85	100

significant predictors of infection in this series. However, an increased duration of intravenous antibiotic therapy was associated with a significantly increased risk of infection within 28 days of discharge from hospital (no infection median 1.8 days (0.7–2.5) vs. infection 3.8 days (3.1–5.0) p=<0.001).

Fixation method

Several methods of fixation were utilised and are shown in Table 2. In proximal phalangeal (P1) fractures, surgeons were significantly more likely to use internal fixation (59.5 vs. 31.3 %, p=0.015), but less likely in middle phalangeal (P2) fractures (20.0 vs. 56.4 %, p=0.001).

Revision surgery

The rate of revision surgery (tenolysis and/or metalwork removal) when internal fixation with plates or screws was used was 51 %, significantly greater than for other methods of fixation (51 % vs. 27 %, p=0.026). The overall tenolysis rate in this series was 26 % (78 % of these received plate or screw fixation). Hence, after accounting for the effects of the bone involved, the use of internal fixation still significantly increases the likelihood of revision surgery being required, with an odds ratio of 3.0 (95 % confidence interval=1.1–8.0, p=0.033). The bone involved was found not to be a significant predictor of revision surgery on multivariable analysis MC (p=0.739), P1 (p=0.986) and P2 (p=0.988)).

Hand consultants operated upon 73 % of these patients and this was found to be a significant predictor of revision surgery, with hand consultants having a higher revision surgery rate compared to other surgeons (consultants and trainees) (42.5 vs. 18.2 %, p=0.040). Other factors such as age, time to theatre and mechanism of injury were not predictors of the need for revision surgery.

Union rates

There were four cases, which progressed to nonunion in this series, a rate of 4.7 %, with a bimodal age distribution (17, 19, 58 and 60 years old). Three of the nonunions were middle phalanges and one was a proximal phalanx. Two of the patients had good function despite nonunion (most likely fibrous nonunion). The remaining two nonunions required surgical intervention; one underwent bone grafting and the other is currently awaiting further fixation. Three of the patients were smokers.

Table 2 Methods of fixation

Method of fixation	Number of patients
None	16
ORIF	30
ORIF+bone graft	2
K-wire	29
Combination (ORIF+K-wires)	5
External fixation	3
Total	85

Outpatient follow-up

Only 35 % of the patients in this series have been discharged following clinical review. Twenty-two percent remained under follow-up at the end of the study period, and the remaining 42 % did not attend their last outpatient appointment. Eight patients never attended outpatients. The majority of patients required substantial follow-up: the 49 patients whom attended all of their follow-up had a median of five outpatient appointments (range 1–14) and were followed up for a median of 186 days; these outpatient appointments do not include nurse dressing or hand therapy clinics. The patients, who did not attend their last outpatient appointment, excluding those who never attended outpatients, had a median of three outpatient appointments (range 1–12) and were followed up for a median of 61 days. We further subdivided these groups into patients that underwent revision surgery and those that did not. The patients that have completed or are still under follow-up and had revision surgery attended a median of six outpatient appointments (range 2–14) over a median of 215 days (range 12–592). In comparison, those that did not have revision surgery had a median follow-up of 119 days (range 25–560) with four outpatient appointments (range 1–11). The cohort that did not attend their last outpatient appointment but underwent revision surgery had a median follow-up of 85 days (range 51–323) with five outpatient appointments (range 3–12). Patients in this cohort that did not undergo revision surgery had a median follow-up of 55 days (range 12–319) attending two outpatient appointments (range 1– 6).

Discussion

There are well-established guidelines for the management of open fractures in the lower limb, but these are less applicable to open fractures in the hand [2]. The Gustilo-Anderson classification was not developed using data from hand fractures but has been shown to correlate with incidence of infection and functional outcome in open hand fractures [4, 5]. Open tibial fractures with soft tissue injuries can have infection rates as high as 45.7 % in the developed world whilst even in grossly contaminated open hand fractures infection has been reported to occur in 20.5 % of cases [4, 6]. Equally, nonunion following open hand fracture is rare, whilst in open tibial fractures, it remains a significant risk [7, 8]. These findings are most likely related to the rich vascular network of the hand

with a significant collateral circulation, which construes greater potential for fracture healing and resistance of infection.

The population of open hand fractures that we present here is consistent with published cohorts by McLain et al. and Swanson et al. over 20 years ago [3, 4]. There is a significant male preponderance with a wide age range and without a predilection for injury based upon hand dominance. Despite the focus on health and safety in the modern era, as in previous reports, machinery and industrial accidents remain prevalent mechanisms of these injuries [1, 3, 4]. The circular saw is the most common instrument of open hand fractures in our series.

Infection rates

The superficial infection rate in our series may be an overestimate of true infection, but nevertheless, our infection rate is comparable to other studies [3, 4, 9]. We were unable to identify any predictors of infection, except the duration of intravenous antibiotics. The latter is likely to correlate with the degree of wound contamination and extent of soft tissue injury, which is a known predictor of infection [1, 3, 4]. The paucity of cases of infection in this series means that the tests have very low statistical power. Therefore, it is not possible to draw any reliable conclusions about the relationship between the factors we analysed and the rate of infection. It is of note that none of the 14 patients that received only oral antibiotic prophylaxis for their open fractures developed infection. These injuries may have had less severe soft tissue injury or have been less contaminated than those admitted for intravenous antibiotics. However, these injuries by definition are all contaminated and some were caused by "dirty" mechanisms including a circular saw injury [10]. Our department does not currently advocate oral antibiotics as routine prophylaxis for these injuries, but there is evidence in the literature suggesting that in the presence of normal gastrointestinal function, oral prophylaxis is equivocal to the intravenous route, which is supported by our findings [9, 11, 12]. Our series and the literature demonstrate that antibiotic prophylaxis has a role in the management of these injuries [12]. However, intravenous antibiotics are expensive, and given the favourable results with oral antibiotics, we postulate that some injuries are being over treated with admission and intravenous antibiotics. It has been shown that acute hand trauma can be managed on an outpatient basis with day case surgery, which improves inpatient delay and reduces total stay [13]. In the current climate of austerity measures, with the drive for more (complex) cases to be performed in the ambulatory care setting rather than requiring inpatient admission, the potential for adequate cover with oral antibiotics is desirable. The authors believe that further research is indicated but that lesser injuries can be treated with oral antibiotics and day case surgery. We must emphasise however that each patient must be assessed on an individual basis, their management tailored appropriately and in those cases that are deemed unsuitable for oral antibiotic prophylaxis and day case surgery, clinicians must insist on appropriate admission and intravenous antibiotic administration.

Revision surgery

An important outcome measure in hand fractures is the requirement for revision surgery such as tenolysis with or without metalwork removal. Tendon adherence is a recognised complication of hand fractures, and in closed uncomplicated fractures using a range of fixation methods, tenolysis rates are said to be 5 % [14]. In open fractures, the degree of soft tissue injury is generally more than in closed fractures, so it is not surprising that the tenolysis rate was considerably higher in our series 26 % [4, 7, 15]. We identified that there was a significant relationship between internal fixation with plates and/or screws and revision surgery, particularly tenolysis, when compared to other methods of fixation. There is no published data on tenolysis rates in open fractures in the literature, but Syed et al. published rates in closed fractures of the metacarpal and proximal phalanx of 20 and 11 %, respectively [15]. Our tenolysis rate in open reduction internal fixation was considerably higher at 46 %. Certain fracture configurations, the condition of the soft tissue envelope, the operative time needed for fixation (especially in the multiply injured patient) and general condition of the patient will probably dictate the method of fixation used. Rigid internal fixation with "permanent" plates and/or screws may well be more appropriate than K-wire fixation for many cases, in particular to permit early mobilisation, but it is important to consider its associated high tenolysis rate when consenting patients and considering the type of fixation to be used. Interestingly, in our series cases performed by a consultant, hand surgeon had a significantly higher rate of revision surgery compared to those carried out by other surgeons. In our department, unless performed by another consultant, all surgery is performed under the supervision of a consultant, so the grade of surgeon was as documented on the operation note which may show more of the cases as being performed by the consultant hand surgeon in this series. Also, anecdotally, more complex cases are referred on to consultant hand surgeons and are less likely to be undertaken by trainees or other consultants. More complex fractures and soft tissue injuries are more likely to have worse outcomes and may need revision surgery [7, 16].

Union rates

Nonunion in hand fractures distal to the carpus and proximal to the distal phalanges is rare [17]. Pun et al. published a nonunion rate of 7.7 % in proximal and middle phalangeal fractures, and the majority of these were open injuries [18]. Open hand fractures distal to the carpus have nonunion rates quoted between 2.4 and 9.5 % [3, 7]. Our series is well within

this with a nonunion rate of 4.7 %. In long bone fractures, nonunion is often attributed to high-energy injury leading to periosteal stripping and impaired blood supply [19]. However, in the hand, delayed union has been shown to be unrelated to energy of injury and soft tissue damage [3]. Our four cases of nonunion were due to simple crush injuries (2), a circular saw (1) and a wood saw (1). Due to the mechanism of action of saws, loss of bone and the tearing action on the soft tissues may have been contributing factors, but we were not able to define any relationships between causative mechanism and nonunion in our cohort of patients due to the paucity of cases.

Outpatient follow-up

The majority of our patients attended multiple outpatient appointments over a protracted time period. Our data did not include nurse-led dressing clinics or isolated hand therapy appointments, which are necessary in the management of these injuries. As would be expected, those who required revision surgery had longer follow-up, but even those who did not still attended a median of four outpatient appointments, which probably reflects the severity of these injuries. These patients have a great impact upon the health service overall and must be counselled about the importance of long-term follow-up and their commitment to hand therapy in order to obtain their optimum functional outcome.

Limitations

The authors acknowledge that there are some limitations to this study. Our work is retrospective; so despite attempts to include all patients, some may have been omitted. We minimised this by extensively researching patient notes during the allotted time period that were coded as having a hand fracture and a wound to ensure that appropriate open hand fractures were included. We did not stratify the injuries into severity, as this is multifactorial with both local injury characteristics as well as patient factors that may affect outcome. We thoroughly reviewed each patient notes, but it is difficult to accurately report these factors retrospectively. In our series, superficial infection was defined as being present if the patient was thought to require antibiotics within 28 days of discharge. We acknowledge that some patients may have received oral antibiotics in the community, which we would fail to identify. It is important to note that our definition of superficial infection may cause an overestimation of infection rates, as simple postoperative erythema may be construed by medical or nursing staff as having an infectious aetiology, and antibiotics may be commenced. This opinion was taken only by the clinician assessing the wound, and clinical criteria were not standardised. The fact that only one swab result was positive for bacterial growth may support this. There was a high nonattendance rate (as is common in cohorts of hand surgery patients), which may affect outcome data, in particular patients who develop non- or malunions and also those who may have benefitted from further surgery. Despite the rate of nonattendance though, we have a large cohort of patients with these fractures. We did not assess final functional outcome as this was a retrospective study and outcomes were not standardised sufficiently to allow comparison.

Conclusion

Open hand fractures continue to be a considerable clinical and financial burden to society, as they commonly occur in young (working age) patients, and despite more recent introduction of health and safety measures, machinery remains an important causative factor. Internal rigid fixation of these injuries yields a high rate of revision surgery in comparison to other fixation methods, and follow-up is often protracted in complicated cases, which has further implications to the workforce. We have shown that the infection rate in these injuries can be low with appropriate initial management, and we raise the possibility of managing these patients with oral antibiotic prophylaxis and day case surgery. This must however be a decision that is made by a suitably trained clinician considering both patient and injurious factors, and surgery for these cases should be carried out expediently in office hours by senior hand surgeons.

Conflict of interest Alexander Bolt, Ran Wei, Richard Pinder, James Hodson, Michael Waldram and Darren Chester declare that they have no conflict of interest.

Statement of ethical standards This study is retrospective and involved case note analysis; therefore, no clinical study was undertaken and no ethical approval was required.

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