Article published online: 2021-06-19

Phalangeal and Metacarpal Fractures in Children: A 10-Year Comparison of Factors Affecting Functional Outcomes in 313 Patients

Ailbhe L. Kiely[1] Michelle Griffin[2] Faith Hyun Kyung Jeon[2] Grant S. Nolan[3] Peter E. Butler[2]

[1] Department of Plastic & Reconstructive Surgery, Queen Elizabeth Hospital, Mindelsohn Way, Birmingham, United Kingdom
[2] Department of Plastic Surgery, Royal Free Hospital, Pond Street, London, United Kingdom
[3] Whiston Hospital, Warrington Road, Prescot, Merseyside, United Kingdom

Address for correspondence Ailbhe Kiely, MB BCh BAO MRCS, Department of Plastic & Reconstructive Surgery, Queen Elizabeth Hospital, Mindelsohn Way, Birmingham, B15 2TH, United Kingdom (e-mail: kielya1@tcd.ie).

J Hand Microsurg 2023;15:124–132.

Abstract

Introduction It is widely believed that fractures in children have excellent clinical outcomes due to their capacity to remodel. There are, however, certain fractures that require careful management to avoid long-lasting functional impairment. Functional outcomes following hand fractures in children are poorly studied.

Materials and Methods We performed a retrospective cohort study of consecutive children and adolescents who had operative treatment for metacarpal and phalangeal fractures (2008–2018). Tuft fractures and replantations were excluded. Functional outcomes were measured by total active motion (TAM) scoring, where a "good" outcome = TAM > 75%. Fractures were categorized by location, classification, and by the fixation they required.

Results Three hundred thirteen children were included. For proximal phalangeal fractures, those treated by manipulation under anesthesia, had a higher proportion of "good" functional outcomes than Kirschner-wire or open reduction internal fixation at discharge from hand therapy ($p = 0.043$). Middle phalanx fractures had excellent functional outcomes, with no difference between fixation methods ($p = 0.81$). For metacarpals, there was no statistically significant difference in functional outcomes across all managements ($p = 0.134$). Fractures in the thumb had poorer postoperative function at mean 7.26 weeks than those in the long fingers ($p < 0.0001$), and the data suggested a trend toward worse outcomes in the distal phalanx, pediatric Bennett fractures, Seymour fractures, and oblique fractures.

Conclusions Fractures in the thumb and phalangeal fractures that require percutaneous or open fixation may need closer early postoperative monitoring in children to optimize their potential for good function.

Keywords
- hand surgery
- pediatric
- metacarpal
- phalangeal
- proximal phalanx
- middle phalanx

Introduction

Pediatric hand fractures are common, representing 2.3% of emergency presentations in children and 15% of all pediatric fractures.[1,2]

Due to anatomical considerations such as an open physis or growth plate, and unique healing properties such as well-vascularized periosteum and bony remodeling potential, fractures in children warrant special evaluation and

article published online
June 19, 2021

DOI https://doi.org/10.1055/s-0041-1730885.
ISSN 0974-3227.

Thieme Medical and Scientific Publishers Pvt. Ltd. A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

management. Perfect anatomical reductions and internal fixation are often less necessary in this population and most bony healing occurs within 3 or 4 weeks.[1]

Phalangeal fractures are the most commonly occurring hand fractures in children. The incidence is highest in younger children (207 per 100,000 from 0 to 4 years)—marking the highest incidence for any age group except for over 85 years.[3] The incidence remains high, at 185 per 100,000 in age 5 to 14 years.

Metacarpal fractures account for 10 to 39% of pediatric hand fractures. These tend to occur in patients aged 13 to 16 years, as sporting injuries.[4,5]

The choice of treatment for pediatric metacarpal and phalangeal fractures depends largely on patient age, fracture location, classification, and deformity.[6] In more cases than not, due to the rapid healing of children's bones and their capacity to remodel, treatment is short and usually uncomplicated.[6,7] Many fractures in children will only require a closed manipulation and splint.[8] Nevertheless, as in other locations, there is a limited capacity to remodel angular deformity and no capacity to remodel rotational deformity.[7] Operative fracture fixation, when used, is most commonly achieved through Kirschner (K-wire) insertion, which can be percutaneous or open, or open reduction internal fixation (ORIF) with a plate and screws or lag screws alone. Indications for fixation include deficient reduction, rotation, unstable fractures, and displaced intraarticular fractures.[9] The question remains whether a more conservative approach to some of these indications could apply, for example inadequate reduction, given the well-documented remodeling capacity of the open physis.

The hand is an integral tool to the child's development. From early developmental years to adolescence, hand-skill activities promote the development of children's cognition as well as fine motor skills—even their emotional intelligence.[10] As such, functionality should be a treatment priority following any injury to the hand in a child.

Range of motion (ROM) is an essential component of hand function evaluation and one of the more commonly measured variables by hand surgeons, due to capacity to measure it objectively using a goniometer.[11]

Total active motion (TAM) scores have been standardized by the American Society for Surgery of the Hand. The TAM score of a digit is the sum of the active metacarpophalangeal, proximal interphalangeal, and distal interphalangeal arc of motion in degrees of an individual digit. This value can then be compared with that of the contralateral hand or a standard normative value. A "good" TAM score is described of a score of 75% of the ROM of the standard value for that digit or the value from the contralateral hand. A "fair" outcome equates to 50 to 74% of this value and a "poor" outcome equates to $< 50\%$ of the contralateral or standard value.

This study aimed to determine functional outcomes following a range of pediatric hand fractures and their treatments by assessment of ROM scores, to highlight fracture patterns that warrant close follow-up. Introduction is fine.

Methods

A retrospective cohort study was performed, using a comprehensive hand trauma database. All children (age < 18) from 2008 to 2018 who presented to a United Kingdom (UK) tertiary hand trauma service with metacarpal or phalangeal fractures were identified and included. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed for the collection and reporting of data.[12]

Treatment of metacarpal and phalangeal fractures at this institution consists of closed manipulation under anesthesia (MUA) and splinting, percutaneous fixation with K-wires under X-ray image intensifier guidance or ORIF with a plate and screws, screws alone, plate and wires, or screw and wires. Patients who have K-wires typically have these removed at 2 to 4 weeks postoperatively. All patients are referred for postoperative hand therapy rehabilitation. Standard preoperative radiographs include anteroposterior (AP), lateral, and oblique views, with further imaging intraoperatively, and postoperatively, if indicated.

Electronic medical records were reviewed to identify age, sex, side, digit, site, mechanism of injury, fracture classification, procedure type, postoperative complications, postoperative range of movement, length of hand therapy follow-up, preoperative fracture angulation, and postreduction angles.

Medical records were further analyzed to determine joint ROM achieved by the end of hand therapy; these were classified into TAM scores, where the affected digit's ROM was expressed as a percentage of the range of the corresponding digit on the opposite hand. All patients had their first follow-up with hand therapy within 1 week, and treatment duration and frequency of appointments thereafter were determined on a case-by-case basis.

Patients were excluded if their operative records were unavailable or they were lost to follow-up (minimum of 2 weeks). Distal phalangeal fractures that were coded as "tuft" fractures were not included in the initial screen, due to the rare need for operative reduction or metalwork, with the potential of skewing outcomes in favor of "good" function. Other exclusions included skeletally mature patients with radiological evidence of a fused growth plate and replantations (defined as reattachment of digital nerves, arteries, and veins, as well as bone fixation for an amputated digit). Patients for whom both postoperative X-rays and hand therapy notes were unavailable were excluded from the cohort. Patients who had had therapy notes but not a postoperative X-ray were included, as were those with X-rays but not hand therapy notes.

The primary outcome measure was the proportion of patients achieving an objectively "good" functional outcome at maximum follow-up, defined by the ROM achieved (TAM score), based on each method of reduction for each fracture type (proximal phalanx, middle phalanx, metacarpal).

Secondary outcome measures included observed degrees of angulation on X-ray postoperatively in patients who achieved "good" clinical function, complications noted

during follow-up and predictions of outcome by age group, sex, classification, and location.

Potential confounders identified included remodeling properties of younger and older pediatric bone (i.e., age) and demographic details such as sex, side, site, digit, and type of fracture. To identify any bias in treatment allocation, univariable comparisons of these factors were made using a chi-squared test.

Statistical Analysis

Descriptive statistics were presented as percentages for categorical variables and mean and standard deviation (SD) for continuous data. Where continuous variables appeared to be normally distributed, Kolmogorov–Smirnov testing supported this hypothesis ($p \geq 0.05$) and therefore mean and SD were reported.

Nonparametric continuous variables (degrees of fracture angulation vs. TAM scores) were evaluated using the Kruskal–Wallis test; nominal data were analyzed using Pearson's chi-squared test or Fisher's exact test where zero values were included in the comparison. Post-hoc analysis was only performed in the case of a statistically significant result following chi-squared analysis. Where post-hoc pairwise testing was performed, a Bonferroni correction was used to account for multiple comparisons and reduce the probability of a type 1 error.

Two-tailed p-values were reported throughout and a p-value < 0.05 was considered statistically significant. Data were analyzed using SPSS version 25 (IBM, United States).

Results

Patient Demographics and Bias

A total of 313 children meeting the inclusion criteria were identified from 2008 to 2018. A flow diagram of patient inclusion is shown in ►**Fig. 1**. The mean age was 9.83 years (SD: 4.17). Mean follow-up time was 7.26 weeks (SD: 5.01) Analysis of treatment allocation showed that there was a significant difference in the proportion of patients allocated to each treatment by age group (►**Fig. 2**) and fracture classification (►**Fig. 3**) ($p < 0.05$). This was explored by subgroup analysis for age group, which attributed this difference to the 5 to 12 age group. There was no evidence of bias among the other variables ($p > 0.05$).

Fractures Requiring K-Wire or ORIF

One-hundred and twenty-two out of 313 or 39% of fractures that needed manipulation required ORIF or percutaneous fixation. Near equal numbers of intraarticular fractures (50%) and extraarticular fractures (43%) were felt to require fixing. The median preoperative angulation for those requiring pinning or ORIF was 8 degrees (interquartile range [IQR]: 0–24.5) radially or ulnarly in the AP plane and 25 degrees (IQR: 12.5–43) dorsally or volarly in the lateral plane. This compared with a median of 10 degrees (IQR: 0–20) in AP and 14 (IQR: 3.5–23.75) in the lateral plane for those who had MUA and splint alone. The most common fracture classification that required fixation was transverse (42%), followed by Salter–Harris (SH) fractures in general (28%), followed by oblique (17%).

Functional Outcomes

Mean follow-up in hand therapy clinic for rehabilitation and clinical assessment was 7.26 weeks (SD: 5.01). Postoperative range of movement values were documented and a TAM score was calculated based on the ROM of the opposite digit: among 264 patients whose functional outcome data could be retrieved, 205 (78%) had a TAM score $> 75\%$, equating to a "good" functional outcome at

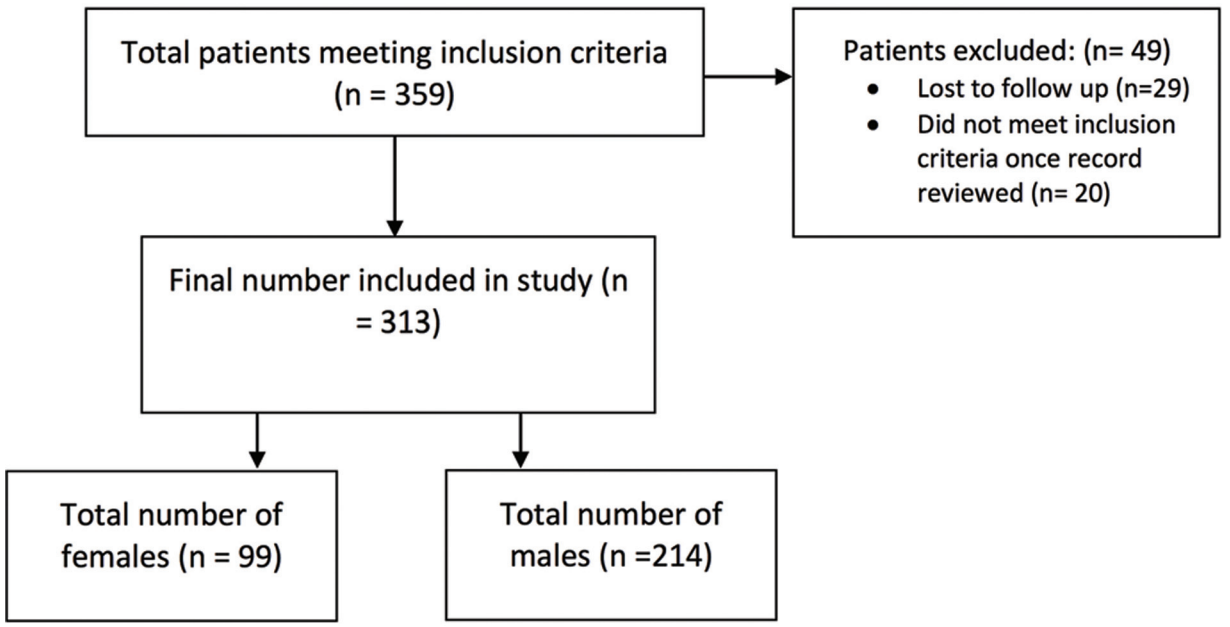

Fig. 1 Flow diagram of patient inclusion.

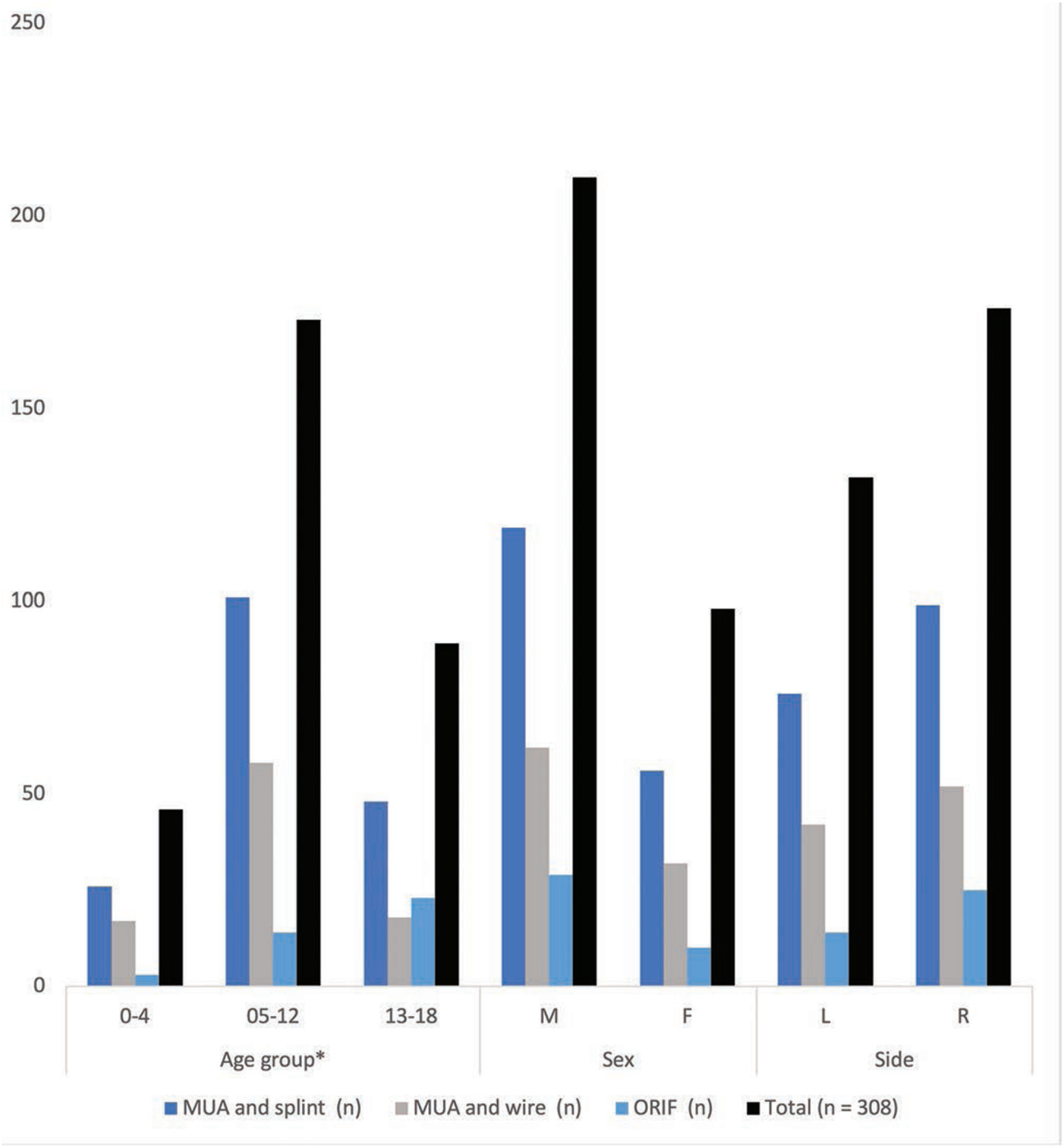

Fig. 2 Comparison of patient demographics between treatment groups. Asterix = significant difference in treatment allocation by chi-squared test. MUA, manipulation under anesthesia; ORIF, open reduction internal fixation.

the time of discharge from hand therapy. There was no difference in the proportion of phalangeal (174/225–77%) and metacarpal (31/39–79%) fractures that achieved a "good" outcome ($p = 0.089$). Overall, across all fractures in combination, there was no statistically significant difference in the functional outcome at maximum follow-up of patients who required fixation than those who had a simple MUA and splint (82% [120/147] MUA and splint vs. 73% [56/77] K-wire and 69% [25/36] ORIF [$p = 0.153$]), although this did reach significance in the 5 to 12 age group ($p = 0.039$).

Phalangeal Fractures

For phalangeal fractures overall, 84% (100/119) versus 75% (46/61) versus 64% (16/25) of those who were splinted versus those requiring K-wire or ORIF had a "good" functional outcome ($p = 0.058$) at discharge from hand therapy.

For proximal phalanx fractures, there was a marked difference in the proportion of "good" TAM scores for those who were managed with a splint alone (►**Table 1**).

Middle phalanx fractures had excellent TAM scores overall, and there was no statistical difference between fixation methods (►**Table 1**).

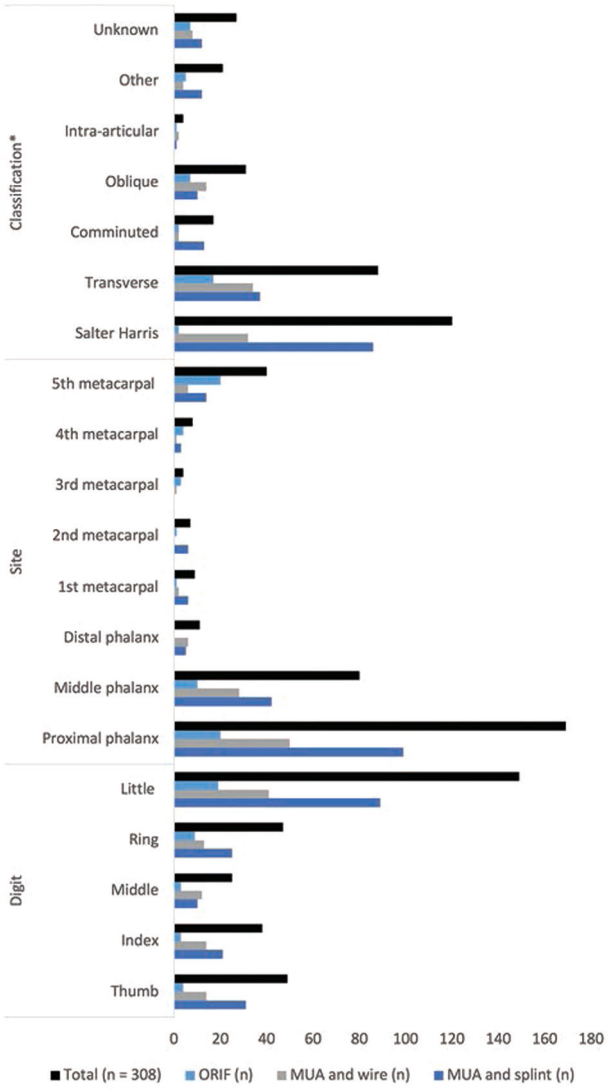

Fig. 3 Comparison of fracture demographics between treatment groups. Asterix = significant difference in treatment allocation by chi-squared test. MUA, manipulation under anesthesia; ORIF, open reduction internal fixation.

In the thumb, all phalangeal surgical fixations had a "fair" or "poor" score at the time of discharge from hand therapy (TAM < 75%) and 72% of those who were splinted also had "fair" or "poor" scores at maximum follow-up ($p = 0.100$). When compared with fractures in the long fingers, 88% of phalangeal fractures in the long fingers versus 16% of phalangeal fractures in the thumb achieved a "good" TAM score ($p < 0.0001$).

Distal phalanx fractures (with the exclusion of tuft injuries) in the thumb and long fingers had inferior TAM scores to proximal or middle phalanges ($p = 0.007$), regardless of the fixation method (►**Table 1**). Eight of sixteen distal phalanx fractures had a "fair" TAM, of which four were Seymour fractures. The remaining four were closed SH injuries.

Metacarpal Fractures

For metacarpal fractures, there was no statistically significant difference in management (splint: 79% [15/19], wire: 64% [7/11], ORIF: 100% [9/9] [$p = 0.134$]).

In the thumb, no metacarpal fractures underwent ORIF, and overall outcomes were inferior—2/5 (40%) of those splinted and 0/5 (0%) of the K-wire group had a "good" outcome ($p = 0.464$) upon discharge from hand therapy. Overall, compared with the long fingers, first metacarpal fractures had worse TAM scores (25% "good" score vs. 94% long fingers, $p < 0.0001$).

Conversely, fifth metacarpal fractures were the most common metacarpal fractures, and 100% of patients who had TAM score data recorded for this fracture had a "good" functional outcome ($n = 17$) upon discharge.

Fracture Classification

Oblique fractures appeared to have inferior outcomes compared with transverse or SH injuries, although this did not reach statistical significance (oblique: 64% [18/28], transverse: 85% [64/75], SH: 79%,[13] [$p = 0.063$]). Most oblique fractures were K-wired. Twenty-five percent of intraarticular and 40% of spiral fractures had a "fair" or "poor" outcome.

"Poor" or "Fair" Functional Outcomes

Of all fractures with sufficient functional follow-up data, 22% (59/264) had a "poor" or "fair" TAM score. Of these, 56% were thumb fractures. By univariable regression analysis, fractures in the thumb were significantly more likely to result in a "poor" or "fair" TAM score (chi-squared test $p < 0.00001$) at mean follow-up of 7.26 weeks. Thirty patients (50%) with a "poor" or "fair" TAM score were SH fractures, of which 21 were SH type 2; however, overall SH classification was not predictive of a bad functional outcome ($p = 0.925$). Sex, fractures in the metacarpal versus the phalanx, in the right or left hand or with documented complications were not predictive of a "poor" or "fair" TAM score ($p > 0.05$). The median postreduction angulation for these fractures was 5 degrees (IQR: 0–11.25) in AP and in 5 degrees (IQR: 0–18) in the lateral plane.

Radiographic Reduction

In general, there was no relationship between anatomical reduction of fractures (i.e., minimal or no displacement postmanipulation) and a "good" or "fair" functional outcome at maximum follow-up. *p*-Values for an association between minimal angulation (0–5 degrees) postreduction in AP and lateral planes and a "good" TAM score by Kruskal–Wallis testing are listed in ►**Table 2**.

A scatter plot (►**Fig. 4**) of all patients with "good" or "fair" functional outcomes did not demonstrate a higher proportion of favorable functional outcomes with lesser degrees of postreduction angulation.

Eponymous Fractures in Children

Extra-octave, phalangeal neck fractures, pediatric Bennett and Seymour fractures were examined in more detail. The results are summarized in ►**Table 3**. Overall, Bennett and Seymour fractures had the lowest proportion of "good" TAM scores, with only 38 and 29% achieving TAM > 75% upon discharge form hand therapy, respectively. These findings were contrasted to outcomes from the existing literature in ►**Table 4**.

Table 1 Proportion of patients achieving a "good" TAM score > 75% by location and fixation method

	Splint % "good" TAM (*n*)	K-wire % "good" TAM (*n*)	ORIF % "good" TAM (*n*)	*p*-Value for comparison of fixation
Proximal phalanx	81 (73/90)	57 (23/41)	55 (10/18)	0.043[a]
Middle phalanx	93 (27/29)	90 (18/20)	85 (6/7)	0.810
Distal phalanx	55 (5/9)	60 (3/5)	0 (0/2)	0.315
Thumb	28 (5/18)	0 (0/4)	0 (0/10)	0.100

Abbreviations: *n*, number; ORIF, open reduction internal fixation; TAM, total active motion score.
[a]Statistically significant *p*-value.

Table 2 Association between a "good" TAM score and fracture reduction with minimal angulation (0–5 degrees) on AP and lateral radiographs by Kruskal–Wallis testing

Location	Reduction in AP plane and "good" TAM score ($p =$)	Reduction in lateral plane and "good" TAM score ($p =$)
Overall	0.816	0.861
Metacarpals	0.800	0.144
Phalanges	0.943	0.413
MUA and splint	0.198	0.971
MUA and K-wire	0.603	0.677
ORIF	0.903	0.921

Abbreviations: AP, anteroposterior; MUA, manipulation under anesthesia; TAM, total active motion score.

Discussion

This study tested the hypothesis that the child's capacity to remodel leads to desirable functional outcomes, as measured by active ROM.

Across the breadth of children's hand fractures, from metacarpal to distal phalanx, the most frequent fractures requiring manipulation ± fixation were proximal phalanx fractures (►**Fig. 3**). SH was the most common classification, and hand fractures in general occurred most often in boys aged 5 to 12 years following a fall or sporting injury (►**Figs. 2** and **3**). This was similar to many large series examining pediatric hand fractures across North America and Europe (►**Table 4**).

Overall Functional Outcomes

Rather than focusing on radiographic reduction or complication outcomes, function was elected as the most critical endpoint, in a population who are continuously developing and evolving. Function as an outcome in children has rarely been examined. This study suggests that overall, children have favorable early clinical outcomes post-hand surgery: across 10 years of data, 78% of children in a tertiary center who had an operation for a phalangeal or metacarpal fracture achieved TAM > 75% at the time of discharge from hand therapy (mean: 7.26 weeks). In a population who are known to rehabilitate favorably posttrauma, it is likely that this would improve further with time—some proportion of patients was discharged for continued therapy at home ($n = 11$) and a significant proportion of patients self-discharged before completing their rehabilitation program ($n = 20$). To this end, a longer follow-up period would be useful in future studies.

Function by Management

Across phalangeal and metacarpal fractures, functional outcomes were compared by management. Phalangeal fractures that only required manipulation generally had better TAM scores at mean 7.26 weeks than those who required further care (►**Table 1**). The same was not true of metacarpal fractures, whose ROM outcomes were generally similar regardless of the intervention.

Table 3 Outcome data for eponymous children's fractures

Fracture	Number (*n*) of fractures (with TAM data)	Overall % (*n*) of which TAM > 75%	MUA % (*n*) of TAM > 75%	K-wire % (*n*) of TAM > 75%	ORIF % (*n*) of TAM > 75%	% (*n*) with complications	Excluded due to no TAM data
Extra-octave	47	85 (40/47)	86 (32/37)	89 (8/9)	0 (0/1)	13 (7/54)	7
Phalangeal neck	52	84 (44/52)	95 (18/19)	83 (20/24)	63 (5/8)	29 (16/56)	4
Seymour	8	38 (3/8)	50 (2/4)	25 (1/4)	n/a	14 (1/7)	1
Bennett	7	29 (2/7)	0 (0/2)	40 (2/5)	n/a	14 (1/7)	0

Abbreviations: MUA, manipulation under anesthesia; ORIF, open reduction internal fixation; TAM, total active motion score.

Table 4 Studies reporting demographics and outcomes for children's hand fractures

Study	Country	Most common demographics	Most common fracture	Most common classification	Fractures requiring operative treatment	Fractures with poor functional outcomes
This study ($n = 313$)	UK	Age: 5–12 Gender: male Mechanism: fall or sporting injury	Finger proximal phalanx	Salter–Harris 2 Transverse	Not examined	Thumb, pediatric Bennett's, proximal phalanx with metalwork
Hartley et al 2020[14] ($n = 2,783$)	Canada	Age: 12–18 Gender: male Mechanism: sporting injury	Finger proximal phalanx	Salter–Harris 2 Transverse	Base of any phalanx	Not discussed
Liu et al 2014[15] ($n = 70$)	Canada	Age: 10–12 Gender: male Mechanism: sporting injury	Little finger and thumb proximal phalanx	Nonepiphyseal	Distal phalanx fractures	Not discussed
Ebinger et al 2001 ($n = 24$)[16]	Germany	Age: not discussed Gender: male Mechanism: not discussed	Phalangeal	Diaphyseal	Axial angulation > 10 degrees	Physeal proximal phalanx fractures
Kreutz-Rodriguez et al 2001 ($n = 4,356$)[8]	USA	Age: 12–15 Gender: male Mechanism	Middle and proximal phalanx`	Not discussed	Intraarticular fractures	Not discussed

Note the similarities between studies in terms of demographics but the differences in those most commonly requiring operation or more at risk of a poor functional outcome.

Function by Anatomical Region

Of particular note to clinicians attending to pediatric hand fractures, all metacarpal and phalangeal fractures in the thumb had poorer outcomes at 7.26 weeks than those in the long fingers ($p \leq 0.001$). This finding was true irrespective of the intervention or fracture pattern. This may be explained by the complex nature of the thumb fractures—for example, the pediatric Bennett fracture, or indeed the more complex biomechanical profile of the thumb compared with the long fingers—while fingers can often compensate for one another, orientation, position, and strength of the thumb are integral to important functions such as pinch and grip.[17] It is also possible that these outcomes would have improved beyond discharge from hand therapy, so the study is limited to reflections for the early follow-up period.

This otherwise may be due to less consistent knowledge and reporting of thumb ROM—the values reported in the literature are notably less consistent than those of the long fingers.[18] To the authors' knowledge, there are no studies reporting functional outcomes postfracture in children that look specifically at the thumb. Those who achieved a "good" TAM score in the thumb in our study matched the reported ROM for the joints of the pediatric thumb as reported by Da Paz et al.[19]

Function by Classification

In consideration of classification, anecdotally many hand surgeons will suggest that the mid-shaft transverse fracture is one that requires fixation due to instability or shortening. In keeping with this, the most common fracture classification that required fixation was transverse (42%), followed by SH (28%). This appears to vary across different studies and centers (►**Table 4**), suggesting the decision to proceed to operative fixation is multifactorial and practices differ between units. Oblique fractures appeared to have inferior postoperative function to SH or transverse fractures at mean 7.26 weeks. This may be due to shortening, or perhaps due to the high proportion of these fractures that require ORIF rather than closed manipulation. Comparatively, Ebinger et al[16] found physeal phalangeal fractures to have the most difficulty achieving ROM postoperatively.

Subgroup analysis of certain SH injuries found pediatric-specific fractures such as the pediatric Bennett and Seymour fracture had inferior functional outcomes at mean 7.26 weeks.

Function by Fracture Reduction

We found no relationship between anatomical reduction and a "good" TAM score, and children were shown to achieve "good" TAM scores even with postreduction angulation of up to 50 degrees (►**Fig. 4**).

Limitations

This study has certain limitations due to its retrospective nature. A strength of the study is that it draws upon 10 years of management of pediatric fractures in a busy UK tertiary referral center. As such, it should be a true reflection of both the epidemiology and the outcome data for this cohort. It provides important outcome data for the function of the hand, which is integral to a child's development.

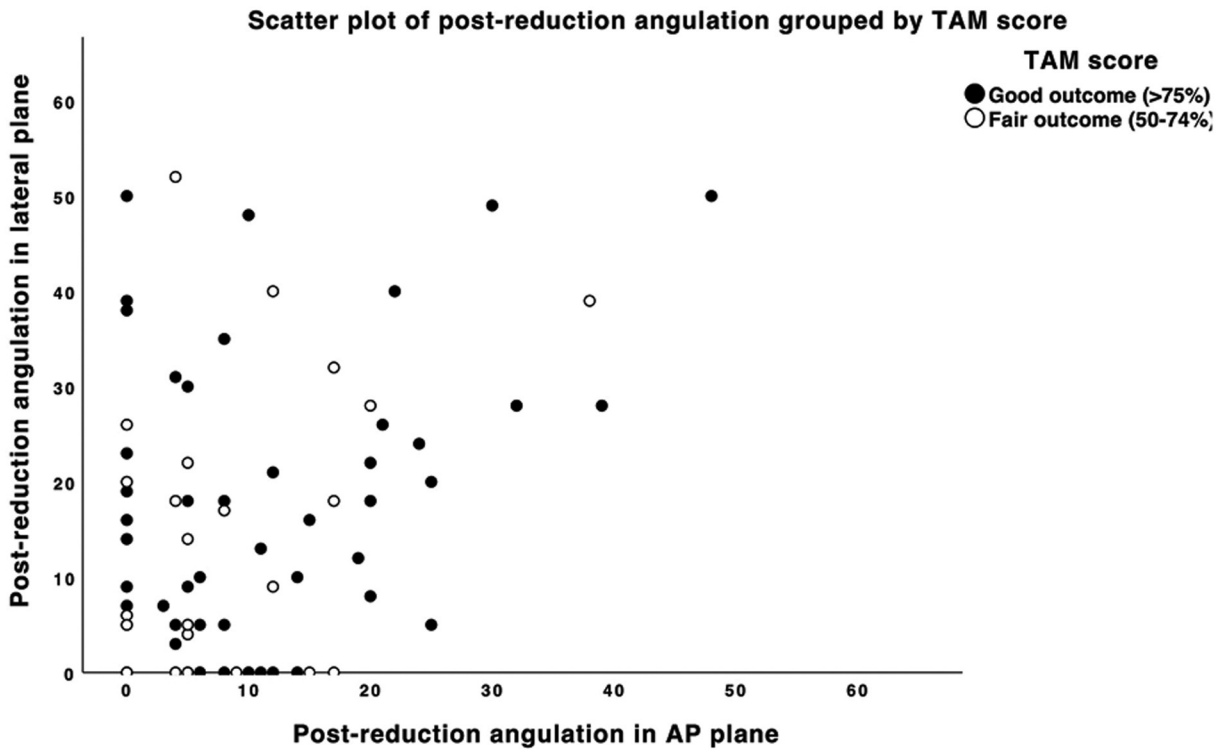

Fig. 4 Distribution of postreduction angulation in anteroposterior (AP) and lateral planes. No correlation seen between a "good" or "fair" outcome and minimal postreduction angulation in AP or lateral planes. TAM, total active motion.

There are, however, limitations to the use of the TAM score as a means of measuring functional outcome. While it is a validated assessment, it does not encompass all aspects of hand function such as grasp and pinch strength, although it is often impractical to measure these in children and the literature is sparse informing benchmark values.[20]

Other limitations of the study include a notable number of patients who did not complete their full follow-up period ($n = 43$), thus limiting the capacity to gauge whether poorer functional outcomes resolved over time. Similarly, with a mean follow-up of 7 weeks, a lack of longer-term patient follow-up did not permit conclusions to be made about patients' function beyond the early follow-up period while under the care of hand therapy, nor definitive tabulation of later complications such as physeal disturbance.

Finally, the outcomes of this study are subject to selection bias, in that minimally displaced fractures are more likely to be amenable to closed reduction and splinting, while comminuted, intraarticular or unstable fractures are more likely to require percutaneous or open fixation. Therefore, these findings must not be interpreted as promoting one fixation method over the other in terms of function. Instead, this study serves to highlight particular fracture groups that have especially poor early outcomes when compared with fractures of a similar classification and identify these as groups with which to exercise caution.

Recommendations

This cohort study on children's hand fractures correlates clinically relevant outcomes to injury patterns and treatment modalities. While it can be deduced that the functional outcomes in children are generally favorable, this study highlights specific fracture patterns that may prompt clinicians to consider a prolonged follow-up period or indeed the potential for poor function. These include fractures of the distal phalanx, oblique fractures, pediatric Bennett fractures, Seymour fractures, and all fractures occurring in the thumb.

While it is outside of the scope of this study to recommend one treatment modality over another, the above-mentioned fractures should be noted as ones who may require more stringent follow-up to optimize the potential ROM for the child.

Conclusion

Management of children's fractures requires a thorough knowledge of the developing hand.

This study has shown that children achieve "good" ROM during follow-up across most hand fractures, with a few distinct exceptions. Fractures in the thumb and phalangeal fractures that require percutaneous or open fixation may be higher risk for poor ROM, based on early hand therapy outcomes. Specific patterns such as fractures in the distal phalanx, pediatric Bennett fractures, Seymour fractures, and oblique fractures may also contribute to poorer function. Further high-powered prospective controlled studies are required to determine whether these factors are indeed associated with decreased postoperative ROM beyond the early follow-up period.

Conflict of Interest
None declared.

Acknowledgments
With many thanks to Josh Solomon for his help organizing a list of data and to Al Manning for his continued advice and discussion about statistics.

References

1 Nellans KW, Chung KC. Pediatric hand fractures. Hand Clin 2013; 29(04):569–578
2 Worlock P, Stower M. Fracture patterns in Nottingham children. J Pediatr Orthop 1986;6(06):656–660
3 Naranje SM, Erali RA, Warner WC Jr, Sawyer JR, Kelly DM. Epidemiology of pediatric fractures presenting to emergency departments in the United States. J Pediatr Orthop 2016;36 (04):e45–e48
4 Godfrey J, Cornwall R. Pediatric metacarpal fractures. Instr Course Lect 2017;66:437–445
5 Cornwall R. Finger metacarpal fractures and dislocations in children. Hand Clin 2006;22(01):1–10
6 Fischer MD, McElfresh EC. Physeal and periphyseal injuries of the hand. Patterns of injury and results of treatment. Hand Clin 1994; 10(02):287–301
7 Case AL, Hosseinzadeh P, Baldwin KD, Abzug JM. Hand fractures in children: when do I need to start thinking about surgery? Instr Course Lect 2019;68:415–426
8 Kreutz-Rodrigues L, Gibreel W, Moran SL, Carlsen BT, Bakri K. Frequency, pattern, and treatment of hand fractures in children and adolescents: a 27-year review of 4356 pediatric hand fractures. Hand (N Y) 2020;1558944719900565;. Doi: 10.1558.94471 990056510.1177/1558944719900565
9 Hastings H II, Simmons BP. Hand fractures in children. A statistical analysis. Clin Orthop Relat Res 1984;188:120–130
10 Owen SE, McKinlay IA. Motor difficulties in children with developmental disorders of speech and language. Child Care Health Dev 1997;23(04):315–325
11 Culp RJS. Musculoskeletal Examination of the Elbow, Wrist and Hand: Making the Complex Simple. Thorofare, NJ: SLACK Incorporated; 2012
12 von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JPSTROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. Int J Surg 2014; 12(12):1495–1499
13 Leman P, Mukherjee D. Flucloxacillin alone or combined with benzylpenicillin to treat lower limb cellulitis: a randomised controlled trial. Emerg Med J 2005;22(05):342–346
14 Hartley RL, Lam J, Kinlin Cet al.Surgical and nonsurgical pediatric hand fractures: a cohort study. Plast Reconstr Surg Glob Open 2020;8(03):e2703 Doi: 10.1097/GOX.0000000000002703
15 Liu EH, Alqahtani S, Alsaaran RN, Ho ES, Zuker RM, Borschel GH. A prospective study of pediatric hand fractures and review of the literature. Pediatr Emerg Care 2014;30(05):299–304
16 Ebinger T, Roesch M, Wachter N, Kinzl L, Mentzel M. Functional treatment of physeal and periphyseal injuries of the metacarpal and proximal phalangeal bones. J Pediatr Surg 2001;36(04):611–615
17 Imaeda T, An KN, Cooney WP II. Functional anatomy and biomechanics of the thumb. Hand Clin 1992;8(01):9–15
18 Barakat MJ, Field J, Taylor J. The range of movement of the thumb. Hand (N Y) 2013;8(02):179–182
19 Da Paz SN, Stalder A, Berger S, Ziebarth K. Range of motion of the upper extremity in a healthy pediatric population: introduction to normative data. Eur J Pediatr Surg 2016;26(05):454–461
20 Surrey LR, Hodson J, Robinson Eet al.Pinch strength norms for 5-to 12-year-olds. Phys Occup Ther Pediatr 2001;21(01):37–49 Doi: 10.1055/s-0041-1729467ISSN 0974-3227