REVIEW ARTICLE

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Re-fractures of the paediatric radius and/or ulna: A systematic review

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Abstract

Background: Fractures of the radius and/or ulna are one of the most common injuries in children. Evidence identifying risk factors for refracture, however, has not been summarised in a systematic review. Guidance for counselling patients and parents to minimise the risk of refracture is limited. The aims of this study are to 1) to determine if casting time 6 weeks or less is a risk factor for refracture after paediatric radius and/or ulna fractures, 2) to identify other risk factors for refracture after paediatric radius and/or ulna fractures and 3) to develop more accurate guidelines for counselling parents after a radius and/or ulna fracture in their child.

Methods: A thorough search was performed in accordance with the Joanna Briggs Institute (JBI) guidelines for systematic review. JBI Critical Appraisal checklists were used for risk of bias assessment.

Results: Diaphyseal both-bone fractures treated non-surgically should be casted for longer than 6 weeks. Surgically treated patients can be casted for less than 6 weeks. Diaphyseal and greenstick fractures have a higher risk of refracture. Residual angulation and incomplete healing in greenstick fractures may lead to a higher risk of refracture. Gender does not affect refracture risk. Falls, use of wheeled vehicles, playground activities and trampolining confer high-risk of refracture. Refracture risk is greatest up to 9 months from initial fracture.

Conclusion: Further case-controlled studies with sub-group analysis are required to further investigate risk factors for refracture after radius and/or ulna fractures in children.

Introduction

Fractures of the radius and/or ulna are one of the most common injuries in children,[1] accounting for 23–40%[2–5] of all paediatric injuries. Most radius and/or ulna fractures heal without complication; 1–7%,[6–11] however, are complicated by refracture. This refers to a repeat fracture of one or both bones at the same site of an earlier known fracture.[12] Although the refracture rate is low, the high incidence of fractures in the radius and/or ulna in children results in a considerable number of refractures every year. Despite the burden imposed by these refractures, there is little consensus about risk factors for refracture. Risk factors proposed in the literature so far have been related to patient demographics, initial fracture details and treatment details. Of these factors, casting is of particular interest as it is a modifiable risk factor. Identifying risk factors could allow high risk cases to be identified and parents to be appropriately counselled regarding post-operative management of their child's fracture. This may help to reduce the refracture rate. Evidence identifying risk factors for refracture of the radius and/or ulna has not been summarised in a systematic review. Therefore prevention of these refractures still remains challenging[13] and guidance for counselling parents remains limited.

The aims of this study are: 1) to determine if casting time 6 weeks or less is a risk factor for refracture after paediatric radius and/or ulna fractures, 2) to identify other risk factors for refracture after paediatric radius and/or ulna fractures and 3) to develop more accurate guidelines for counselling parents after a radius and/or ulna fracture in their child.

Methods

This review was registered with the International Prospective Register of Systematic Reviews (PROSPERO, CRD42020149051) prior to commencement and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (Appendix 1).[14] A thorough literature search was conducted in keeping with the Joanna Briggs Institute (JBI) guidelines for a systematic review.[15] First, a preliminary search was conducted on Ovid MEDLINE to identify keywords and index terms. A secondary search was then conducted on 20 May 2021 on Ovid MEDLINE, Embase, The Cochrane Central Register of Controlled Trials and The Cochrane Database of Systematic Review using these keywords and index terms (Appendix 2). Studies without full texts available were obtained by request. Thirdly studies from the references of articles included for data extraction were considered for inclusion.

The inclusion criteria were set to include patients aged 2–16 years old with refractures of the radius and/or ulna. Patients treated both non-surgically and surgically were included. This population is highly heterogenous and so subgroup analysis was performed, separating studies by fracture location and treatment method where possible. Data from studies including both surgical and non-surgical patients was separated where possible. Data from studies including diaphyseal and non-diaphyseal fractures was also separated where possible. Exclusion criteria were set to exclude patients with medical conditions affecting bone health, iatrogenic fractures and refractures suffered away from the original fracture site.

Experimental, quasi-experimental and analytical observation study designs from after 1950 were included. Our systematic review investigated variables including patient age and gender, fracture location, fracture type, residual angulation after treatment, incomplete consolidation before re-fracture, casting time, time until removal of hardware (ROH), time between initial fracture and refracture and mechanism of refracture. The effect of each exposure was recorded as a risk ratio or difference in means where calculable. In studies where one group had no refractures, a difference in risk ratio (RR) was recorded. In studies of refractures only, the percentage of refractures affected by the exposure was recorded (Table 1). The sole outcome in this study was the incidence of refracture.

Four independent investigators (P.P., B.O., A.B. and E.H.) undertook the inclusion and exclusion of articles, and the critical appraisal for methodological quality. Any discrepancies between reviewers were resolved after discussion with the senior investigator (C.G.). Articles were first excluded by title and abstract, and then by full text. Two independent investigators (A.B. and R.A.) then critically appraised the remaining articles for risk of bias using the Joanna Briggs Institute Critical Appraisal Checklist for the corresponding study type (Appendixs 3–5).[15] Cohort studies with complete follow-up were scored out of 10, while those with incomplete follow-up were scored out of 11.

Two independent investigators performed data extraction from studies approved after critical appraisal. The data was collated into a spreadsheet using the software Microsoft Excel (version Excel for 365, Microsoft Corporation, Redmond, Washington, USA). Meta-analysis was not possible due to the heterogeneity of the data. Qualitative data was synthesised with thematic and tabular synthesis as described by JBI.[15] Data was categorised to compare patients casted for 6 weeks or less with those casted for longer than 6 weeks. This data was obtained from studies that casted all patients in one of these categories, as well as studies that separated data from patients in these categories.

Results

Forty-nine articles were included for data extraction. These included five prospective cohort studies, 33 retrospective cohort studies, one retrospective exploratory study, three case series and seven case reports (Fig. 1). According to Merlin's hierarchy of evidence,[52] our study included 36 articles with Level III-2 evidence, four articles with Level III-3 evidence and nine articles with Level IV evidence.

Casting time

Surgically treated diaphyseal both-bone fractures

Two studies reported an insignificant average difference in casting time of 0 and 4 days (no p-value, $p = 0.323$) between non-refractures and refractures (Table 2).[26,28] Both studies casted for longer than 6 weeks on average. Comparing data from eight eligible studies,[16,17,19,23,24,26,27,37,40] 9/290 (3%) fractures that were casted for 6 weeks or less suffered refractures, while 5/48 (10%) that were casted for more than 6 weeks refractured. Although unclear in four studies, 9/16 refractures occurred with hardware in situ. Data from another study was not able to be categorised by casting time.[28]

Non-surgically treated diaphyseal both-bone fractures

One study reported an insignificant difference of 1.5 weeks in casting time between non-refractures and refractures ($p > 0.05$).[18] However, all fractures in the study were casted for longer than 6 weeks. No studies casted for 6 weeks or less. The two studies that casted all patients for longer than 6 weeks resulted in 26/263 (10%) fractures refracturing.[18,19] Another study only studied refractures and reported that half were casted for longer than 6 weeks.[49]

Surgically treated diaphyseal single-bone fractures

Two studies allowed meaningful separation of data for surgically treated single-bone diaphyseal fractures.[9,38] A total of 2/14 (14%) patients from these studies suffered a refracture. Refractures occurred with hardware in situ in 1/2 refractures.

Non-surgically treated diaphyseal single-bone fractures

One study of diaphyseal refractures reported 1 non-surgically treated diaphyseal single-bone refracture that was initially casted for 6 weeks.[49]

Surgically treated undifferentiated diaphyseal fractures

Three studies did not allow for meaningful separation of data on single-bone and both-bone diaphyseal fractures treated surgically.[32,33,36] One study casted all patients for 6 weeks or less[32];

Table 1 Summary of study characteristics, casting time and gross results of casting

Study	Study type	Risk of bias score	Fractures included (diaphyseal or all, both-bone or all)	Treatment method	Casting duration (refractures/ total cohort)
Antabak et al.[16]	Retrospective cohort study	8/10	Diaphyseal, Both-bone	Surgical	1 week (1/88)
Fernandez et al.[17]	Retrospective cohort study	7/11	Diaphyseal, Both-bone	Surgical	No cast (3/64)
Gruber et al.[18]	Prospective cohort study	10/11	Diaphyseal, Both-bone	Non-Surgical	av: 7.5 weeks (26/199)
Kailis et al.[19]	Retrospective cohort study	7/10	Diaphyseal, Both-bone	Mixed	Non-surgical: 8 weeks (0/64), Surgical: No cast (1/11)
Mittal et al.[20]	Case report	7/8	Diaphyseal, Both-bone	Surgical	–
Muensterer and Regauer[21]	Case report and biomechanical study	7/8	Diaphyseal, Both-bone	Surgical	No cast
O'Neill et al.[22]	Case report	6/8	Diaphyseal, Both-bone	Surgical	No cast
Rousset et al.[23]	Prospective cohort study	10/11	Diaphyseal, Both-bone	Surgical	6–12 weeks (5/48)
Sahin et al.[24]	Retrospective cohort study	8/11	Diaphyseal, Both-bone	Surgical	av 4 weeks (1/40)
Shahid et al.[25]	Case report	6/8	Diaphyseal, Both-bone	Surgical	1 month
Shoemaker et al.[26]	Retrospective cohort study	8/10	Diaphyseal, Both-bone	Surgical	av 8.4 weeks (2/28)
Sinikumpu et al., 2013	Case Series	5/10	Diaphyseal, Both-bone	Surgical	4–6 weeks (1/3)
Sinikumpu et al.[27]	Retrospective cohort study	9/10	Diaphyseal, Both-bone	Mixed	–
Tsukamoto et al.[28]	Retrospective cohort study	8/10	Diaphyseal, Both-bone	Surgical	Med 42 days (6/60)
Victor et al.[29]	Case report	7/8	Diaphyseal, Both-bone	Non-Surgical	10 weeks
Zhamilov et al.[30]	Case Report	6/8	Diaphyseal, Both-bone	Surgical	8 weeks
van Egmond et al.[31]	Case report	7/8	Diaphyseal, Single-bone	Surgical	4 weeks
Fernandez et al.[17]	Retrospective cohort study	8/11	Diaphyseal, All	Surgical	–
Garg et al.[32]	Retrospective cohort study	7/10	Diaphyseal, All	Surgical	4–6 weeks (1/21)
Gomez et al.[33]	Retrospective cohort study	6/11	Diaphyseal, All	Surgical	av:8.4 weeks (5/75)
Makki et al.[34]	Retrospective cohort study	8/10	Diaphyseal, All	Surgical	–
Makki et al.[35]	Retrospective cohort study	9/10	Diaphyseal, All	Surgical	2 weeks (6/102)
Nielsen and Simonsen[36]	Retrospective cohort study	8/10	Diaphyseal, All	Surgical	av 6 weeks (1/43)
Salonen et al.[37]	Retrospective cohort study	8/11	Diaphyseal, All	Surgical	5 weeks (3/35)
Schmuck et al.[9]	Prospective cohort study	9/10	Diaphyseal, All	Mixed	Non-Surgical: av. 30.6 days (6/87)
Schwarz et al.[38]	Retrospective cohort study	7/10	Diaphyseal, All	Non-Surgical	av 5.12 (refractures only)
Weinberg et al.[39]	Retrospective cohort study	7/10	Diaphyseal, All	Surgical	–
Yung et al.[40]	Prospective cohort study	8/11	Diaphyseal, All	Surgical	4–6 weeks (1/57)
Andaloussi et al.[41]	Retrospective cohort study	7/11	All, Both-bone	Surgical	4 weeks (3/87)
Dincer et al.[42]	Retrospective cohort study	10/10	All, Both-bone	Surgical	1 month (10/192)
Tiosky et al.[10]	Retrospective cohort study	7/10	All, Both-bone	Non-Surgical	av 77 days (37/2590)
Arunachalam et al.[12]	Case series	5/10	All, All	Non-Surgical	–
Baitner et al.[43]	Retrospective cohort study	10/10	All, All	Mixed	–
Bould and Bannister[6]	Retrospective cohort study	8/10	All, All	Mixed	Non-surgical: <6 weeks (33/759), >6 weeks (1/104)
Filipe et al.[44]	Retrospective cohort study	7/10	All, All	Mixed	Non-Surgical: >6 weeks (refractures only)
Griffet et al.[45]	Retrospective cohort study	8/10	All, All	Surgical	No cast, bandage 8–10 days (2/81)
Haasbeek et al.[7]	Retrospective cohort study	6/10	All, All	Mixed	Non-surgical: 6–12 weeks (1/21)
Harbison et al.[8]	Prospective cohort study	6/10	All, All	Mixed	Non-surgical: 2–6 (N/A)
Kelly et al.[46]	Retrospective cohort study	9/11	All, All	Surgical	–
Kruppa et al.[47]	Retrospective exploratory review	6/11	All, All	Surgical	2–4 weeks (10/202)
Kubiak et al.[48]	Retrospective cohort study	6/10	All, All	Mixed	–
Lascombes et al., 1990	Retrospective cohort study	9/10	All, All	Surgical	5–6 weeks for 29 cases, then discontinued
Park et al.[49]	Retrospective cohort study	6/10	All, All	Mixed	Non-surgical: av. 8.5 weeks (refractures only)
Tredwell et al.[11]	Retrospective cohort study	9/10	All, All	Mixed	–
Vopat et al.[5]	Retrospective cohort study	8/11	All, All	Surgical	–
Holdsworth and Sloan[50]	Case series	6/10	Unknown	Mixed	Non-surgical: 4–10 weeks (refractures only)
Kim et al.[51]	Retrospective cohort study	7/10	Unknown	Surgical	No cast (2/44)
Schmittenbecher et al., 2000	Retrospective cohort study	5/10	Unknown	Unknown	–
Simanovski et al., 2006	Retrospective cohort study	5/10	Unknown	Unknown	–

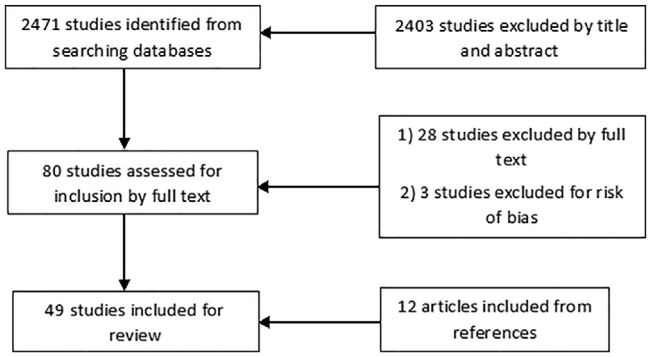

Fig 1. PRISMA diagram detailing the inclusion and exclusion of articles

however, all other studies did not cast all patients for greater than or less than 6 weeks, making interpretation difficult. There was one refracture after ROH.

Non-surgically treated undifferentiated diaphyseal fractures

Two studies did not allow for meaningful separation of data on single-bone and both-bone diaphyseal fractures treated non-surgically.[9,38] One study reported that refractures were casted significantly longer than non-refractures by 1 week ($p = 0.04$).[9] Refractures were casted for greater than 6 weeks. The other study reported an equivocal number of refractures casted for less than and greater than 6 weeks.

Surgically treated undifferentiated fractures

Five studies did not allow for meaningful separation of data on diaphyseal and non-diaphyseal fractures treated surgically.[41,42,45,47,51] Altogether, 27/606 (4%) of undifferentiated surgically treated fractures casted for 6 weeks or less refractured. No studies casted for longer than 6 weeks. Refractures occurred after ROH in 8/27 refractures.

Non-surgically treated undifferentiated fractures

Five studies did not allow for meaningful separation of diaphyseal and non-diaphyseal fractures treated non-surgically.[6,7,10,44,50] One

Table 2 Summary of casting time and subsequent outcomes categorised by population (wks = weeks, d = days, pts. = patients)

Population	Studies	Casting time	Effect of casting time on refracture rate	Refractures/total cohort
Surgically treated diaphyseal both-bone fractures	Shoemaker et al.[26]	>6wks: 20 pts. ≤6wks: 6 pts	No significant correlation (mean diff: 0d, N/A)	>6wks: 2/20 <6wks: 0/6
	Tsukamoto et al.[28]	Median: 7 wks	No significant correlation (mean diff: 4d, p = 0.323)	>6wks: 5/6 refractures <6wks: 1/6 refractures
	Antabak et al.[16]	All ≤6 wks	–	1/88
	Fernandez et al.[17]	All ≤6 wks	–	3/64
	Kailis et al.[19]	All ≤6 wks	–	1/11
	Sahin et al.[24]	All ≤6 wks	–	1/40
	Salonen et al.[37]	All ≤6 wks	–	2/33
	Sinikumpu et al.[27]	All ≤6 wks	–	1/3
	Yung et al.[40]	All ≤6 wks	–	0/45
	Rousset et al.[23]	All >6wks	–	5/48
Non-surgically treated diaphyseal both-bone fractures	Gruber et al.[18]	All >6 wks	No significant correlation (mean diff: 1.5wks, $p > 0.05$)	26/199
	Park et al.[49]	Mean: 8 wks	–	>6 wks: 2 refractures <6 wks: 2 refractures
	Kailis et al.[19]	All ≤6 wks	–	0/64
Surgically treated diaphyseal single-bone fractures	Salonen et al.[37]	All ≤6 wks	–	1/2
	Yung et al.[40]	All ≤6 wks	–	1/12
Non-surgically treated diaphyseal single-bone fractures	Park et al.[49]	6 wks	–	1 refracture
Surgically treated undifferentiated diaphyseal fractures	Garg et al.[32]	≤6 wks	–	1/21
	Nielsen et al.[36]	Mean: 6 wks	–	1/43
	Gomez et al.[33]	Mean: 8.4 wks	–	5/75
Non-surgically treated undifferentiated diaphyseal fractures	Schmuck et al.[9]	Mean: 4.4 wks	Refracture correlated with longer casting (mean diff: 1wk, p = 0.04)	6/87
	Schwarz et al.[38]	Mean: 5.1 wks	–	≤6wks: 13 refractures >6wks: 12 refractures
Surgically treated undifferentiated fractures	Andaloussi et al.[41]	≤6 wks	–	3/87
	Dincer et al.[42]	≤6 wks	–	10/192
	Griffet et al.[45]	≤6 wks	–	2/81
	Kim et al.[51]	≤6 wks	–	2/44
	Kruppa et al.[47]	≤6 wks	–	10/102
Non-surgically treated undifferentiated fractures	Bould and Bannister[6]	≤6 wks: 659 pts. >6 wks: 104 pts	Casting ≤6 wks correlated with refracture	≤6 wks: 33/659 >6 wks: 1/104
	Haasbeek et al.[7]	>6 wks	–	1/21
	Filipe et al.[44]	>6 wks	–	47 refractures
	Tiosky et al.[10]	Mean: 7 wks	–	37/2590
	Holdsworth and Sloan[50]	4–10 wks	–	7 refractures

Table 3 Summary of studies supporting or not supporting risk factors other than casting time. Effect sizes given as risk ratio (RR), difference in means (mean diff), difference in RR (RR diff) or percentage of refractures affected by the risk factor (%)

Risk factor	Studies supporting risk factor	Studies not supporting risk factor
Removal of hardware (IMN = intramedullary nail, KW = Kirschner Wires)	Makki, 2014: IMN < 6 months (RR diff: 25%, $p < 0.05$), Plate <12 months (RR diff: 18%, $p = 0.01$)	Makki, 2017: IMN 6–12 months (N/A, $p > 0.05$) Tsukamoto, 2020: KW (mean diff: 17 days, $p = 0.611$) Kelly, 2014: IMN < 6 months (mean diff: 0.7 months, $p = 0.78$)
Diaphyseal location	Bould, 1999: (RR 8.65, $p < 0.0001$) Baitner, 2007: (RR 1.7, $p < 0.001$)[a] Park, 2007: (83.3%) Tiosky, 2015: (78%)	
Single vs. both bone fracture	Tredwell, 1984: Both-bone (N/A) Salonen, 2012: Radius (RR 8.33, N/A) Kelly, 2014: Ulna (RR 4.26, $p = 0.04$)	Arunchalam, 1975: (58.8%) Makki, 2014: (RR 1.07, $p = 0.2$) Baitner, 2007: (RR 1.16, $p > 0.05$)
Greenstick fracture	Gruber, 1979: (RR 7.73, $p < 0.05$) Weinberg, 2009: (90%) Schwarz, 1996: (84%) Park, 2007: (80%) Filipe, 1979: (75%)	Bould, 1999: (RR 5.38, $p > 0.05$)
Incomplete healing	Baitner, 2007: At Latest Follow-up (RR: 1.54, $p = 0.05$)	Tsukamoto, 2020: At ROH (RR 6.73, $p = 0.059$) Gruber, 1979: At Cast Removal (RR 0.60, $p > 0.05$)
Incomplete healing in greenstick fractures	Weinberg, 2009: (90%) Schwarz, 1996: (84%) Park, 2007: (80%) Filipe, 1979: (71%)	
Residual angulation		Baitner, 2007: (mean diff: 1–2^0, $p = 0.2$–1)
Residual angulation in greenstick fractures	Park, 2007: (80%) Filipe, 1979: (65%)	
Age (y = years)	Bould, 1999: Younger Age (av diff: 1y, $p < 0.05$) Rousset, 2015: Younger Age (mean diff: 3y, $p = 0.009$) Schmuck, 2010: Older Age (mean diff: 3 years, $p = 0.0017$) Makki, 2014: Older Age ($p = 0.04$)	Makki, 2017: (N/A) Kelly, 2014: (mean diff: 1.5y, $p = 0.10$) Baitner, 2007: (mean diff: 0, $p = 0.9$)
Gender	Filipe, 1979: Male (90%)	Schmuck, 2010: (RR 1.59, $p = 0.9$) Rousset, 2015: (RR 1.33, $p > 0.05$) Gruber, 1979: (RR 1.43, $p > 0.05$) Kelly, 2014: (RR 2.03, $p = 0.22$)
Mechanism	Vopat, 2014; Tsukamoto, 2020; Rousset, 2015; Kruppa, 2017; Makki, 2014; Makki, 2017; Kelly, 2014; Baitner, 2007: Falls (35%), Wheeled vehicles (25%), Playground (13.9%), Sport (11%), Trampoline (8%) and Unspecified (7%)	

Note: a: Data for middle third of bone.

study reported casting less than 6 weeks to be a risk factor for refracture (RR 4.47, $p < 0.01$).[6] Combined data from eligible studies demonstrated 33/659 (5%) fractures casted for 6 weeks or less refractured, while 2/125 (2%) fractures casted for more than 6 weeks refractured. Two studies could not be included in this synthesis. Data from one was not able to be categorised by casting time[10] and one was a study of refractures only.[44]

Fracture details

Four studies supported diaphyseal location as a risk factor for refracture (Table 3).[6,10,43,49] No studies negated this. Three studies reported that the number of bones fractured does not influence refracture risk,[12,34,43] Three negated this but were limited by lack of supporting data and bias from small sample size.[11,37,46] Five studies reported greenstick fracture to be a risk factor for refracture.[18,38,39,44,49] One study negated this but produced a RR of 5.4.[6]

Patient details

Three studies have reported no significant correlation between age and refracture risk,[35,43,46] while two reported younger[6,23] and older age[9,34] as risk factors for refracture (Table 3). Four studies have reported no association between gender and refracture,[9,18,23,46] while one has reported male gender with increased risk.[44] The most common mechanisms of refracture were falls, wheeled vehicle use and playground activities. The median average time to refracture was 5 months (range 1 month - 8 years).[5,11,12,18–23,25–31,35,36,38–40,43–45,47,48,51,53,54] Only one study documented an average time to refracture greater than 9 months, recording an average of 20 months.[51] This may be because this was a study of unstable fractures.

Treatment details

Two studies supported the notion that nails should be removed (RON) after 6 months in order to reduce refracture risk,[34,35] while

two did not (Table 3).[28,46] One study reported removal of plates before 12 months increased risk of refracture.[34] One study supported incomplete healing as a risk factor for refracture,[43] while two did not.[18,28] One study reported that residual angulation at consolidation increases refracture risk.[43] Four studies reported that incomplete healing of greenstick fractures increases refracture risk,[38,39,44,49] while two reported this for residual angulation in greenstick fractures.[44,49]

Risk of bias

The included studies were of moderate methodological quality upon assessment with the JBI Critical Appraisal Checklists corresponding to each study type (Appendixs 3–5).[15] Individual scores for each study can be found in Table 1. The average risk of bias from all studies was 7.37 out of 9.96 (73%). Prospective cohort studies scored 8.60 out of 10.75 (80%) on average; retrospective cohort studies scored 7.53 out of 10.26 (73%) on average; case series scored 5.33 out of 10.00 (53%) on average; case reports scored 6.57 out of 8.00 (82%) on average.

Discussion

Identifying risk factors for refracture can help guide management and inform instructions given to parents. The primary focus of this review was to ascertain if casting for 6 weeks or less increased risk of refracture. Three studies comparing casting time in non-refractures and refractures reported no significant difference between the two groups; most of these patients, however, were casted for more than 6 weeks. All but three studies casted surgical patients for 6 weeks or less with superior results. Casting diaphyseal both-bone fractures for longer than 6 weeks is routinely performed while evidence for other fracture types is inconclusive.

Evidence consistently suggests that diaphyseal and greenstick fractures are at increased risk of refracture. The role of residual angulation and incomplete healing of greenstick fractures needs to be clarified with studies of stronger design. Time intervals at which incomplete healing was assessed as a risk factor for refracture was highly heterogenous disallowing meaningful conclusions to be made. Evidence is limited regarding appropriate timing for ROH and future studies should compare removal of nails before and after 6 months, and removal of plates before and after 12 months.

Gender does not affect refracture risk. Evidence correlating age to refracture risk is too inconsistent to draw conclusions. The most common mechanism of refracture was a fall. Trampoline injuries were more commonly associated with diaphyseal refractures. Refractures mostly occurred before 9 months from initial fracture.

The main limitation of this study was the heterogeneity of data and the population. Furthermore, data could not be categorised from many studies. Twenty-six studies did not differentiate the number of single and both-bone refractures, 20 studies did not classify location using the diaphysis and most reported casting time for the entire cohort, making sub-group analysis difficult. Future studies should perform sub-group analysis for fracture location and treatment method.

Conclusion

Diaphyseal both-bone fractures managed non-surgically should be casted for more than 6 weeks. Casting for 6 weeks or less is acceptable in surgically managed paediatric radius and/or ulna fractures. Parents should be counselled about increased risk of refracture after diaphyseal and greenstick fractures. Incomplete healing and residual angulation in greenstick fractures may increase refracture risk. Gender does not affect refracture risk. Parents should discourage wheeled vehicles and trampolining after diaphyseal and greenstick radius and/or ulna fractures; the risk of refracture is greatest up to 9 months.

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Data Availability Statement

The data from which the results of this study were determined may be made availableby request.

Author contribution

Ameya Bhanushali: Data curation; formal analysis; investigation; writing – original draft; writing – review and editing. **Evelyn Axelby:** Data curation; investigation. **Prajay Patel:** Data curation; investigation; methodology. **Rabieh Abu-Assi:** Data curation; investigation. **Belinda Ong:** Data curation; investigation. **Christy Graff:** Conceptualization; data curation; formal analysis; methodology; supervision; writing – review and editing. **Manuel Kraus:** Conceptualization; data curation; supervision.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix S1: Supplementary digital contentList of supplementary digital content
Appendix 1: PRISMA 2020 checklist
Appendix 2: Search strategy
Appendix 3: JBI critical appraisal checklist for cohort studies
Appendix 4: JBI critical appraisal checklist for case series
Appendix 5: JBI critical appraisal checklist for case reports