REVIEW

Removable wrist splint in the treatment of paediatric buckle fractures: a systematic review

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ABSTRACT

Traditional treatment for buckle fractures is immobilization in a plaster cast for 3-4 weeks. However, the cast is usually heavy for children, may get wet or broken, and a follow-up visit is necessary for removal, rendering treatment costly. These drawbacks call for the use of alternative strategies, among which a removable wrist splint is a promising option. This review aimed to summarise the evidence regarding the safety and practicality of removable wrist splints in the treatment of paediatric distal forearm buckle fractures. An electronic search of MEDLINE, CINAHL, EMBASE, Cochrane Library, Google Scholar, and Best Bets was performed for studies published in English from 1997 to 2017. The used search terms included 'Fracture' AND 'wrist' OR 'distal radius' OR 'buckle fracture' OR torus AND 'splint' OR 'cast'. Seven studies were retrieved. Narrative synthesis showed that a removable wrist splint was comparable in efficacy to the standard cast. All fractures healed without deformity or re-fracture in either group. Pain scores tended to be higher in the splint group, though the difference was not statistically significant. The wrist splint was superior to the standard cast in terms of cost-benefit analysis and the rate of complications. Paediatric buckle wrist fractures can safely be managed by a removable wrist splint accompanied by a discharge information leaflet and no further follow-up. However, further randomized clinical trials with adequate sample sizes are warranted to fill the gap in the current literature, particularly regarding the experienced pain and the resumption of activities.

Keywords: Bone Fracture, Splint, Surgical Cast, Wrist Joint

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INTRODUCTION

Paediatric fractures account for around 20% of all Emergency Department paediatric attendances [1]. Fracture of the distal radius is the most common paediatric fracture [2], of which up to 50% of these are buckle fractures [3].

Buckle (Torus) fractures are described as fractures due to the impact of indirect violence or a fall on an outstretched hand. This crumples the dorsal cortex (compression side), without disruption of the volar cortex (tension side) of the bone [4].

Buckle fractures are stable because of the intact cortex on both sides [5]. This is different from greenstick fractures, where there is a collapse of the bony cortex due to severe injury [6].

No gold standard treatment is documented for buckle fractures [3] due to

their stability and low risk of displacement [7], where most cases are managed by different methods of immobilization [3]. A traditional method is immobilization in a plaster cast for 3-4 weeks [8]. Although it is an effective method of immobilization, it has some drawbacks. These include the fact that the cast is usually heavy for children, with the possibility of getting wet [8] as well as the need for a second orthopaedic follow-up visit for cast removal, rendering it quite costly [7]. These drawbacks have led to an alternative strategy, using a removable wrist splint that can be removed at home with no further follow-up required. This reduces the workload on the follow-up clinic resulting in cost-saving [7].

Although the evidence shows that removable splints allow better physical function and less difficulty with daily activities [8], they can be associated with more pain [9]. Therefore, the optimal approach to managing these injuries is still debatable.

METHODS

The conduction of this systematic review followed the principles of the Cochrane Handbook for Systematic Reviews of Interventions, version 6, and it was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [10].

Research aims and objectives

This systematic review aimed to collect and summarize the evidence regarding the safety and practicality of removable wrist splints in the treatment of paediatric distal forearm buckle fractures.

The review had the following objectives: (a) to assess the safety of removable wrist splints in the treatment of paediatric distal forearm buckle fractures and (b) to compare the efficacy of removable wrist splints to that of full-cast immobilization.

Inclusion Criteria for studies

This systematic review included observational studies (cohort or case-control) and clinical trials published in English between 1997 and 2017. The participants were pediatric patients with buckle (Torus) fractures of the distal forearm treated by removable wrist splints.

Exclusion criteria

The following articles were excluded: conference abstracts or posters, duplicate publications, case-report, narrative reviews, editorials, and commentaries. In addition, studies were excluded if: (a) conducted on animals; (b) included adult patients (> 18 years-old); (c) participants had greenstick, angulated, or transverse distal radius fracture; and (d) assessed treatment modalities other than those specified in the inclusion criteria, such as a bandage, Tubigrip, and soft cast.

Search strategy

Electronic searches

The following databases were searched in the main health Service Executive (HSE) library: (a) MEDLINE from 1997 to June 2017,

via EBSCOhost; (b) CINAHL from 1997 to June 2017, via EBSCOhost; and (c) EMBASE from 1997 to June 2017. Other searched sources of evidence included the Cochrane Library, Google Scholar, and Best Bets.

Other resources

Relevant studies that were obtained from electronic search underwent scrutinization of their reference lists to identify other potentially relevant studies.

Selection of studies

After the removal of duplicate articles from the search results, the first author filtered all papers by reviewing the titles and the abstracts. The full text of articles that were potentially relevant was then retrieved and assessed for eligibility. The second author checked the search results, the screening of titles and abstracts, and the review of full-text articles.

Data extraction

The first author extracted data from the included studies using a standardised datasheet. The extracted data included: (a) the study characteristics (the geographic location, design, study duration, and sample size); (b) patients' characteristics (age and sex); (c) the intervention (number of patients for each intervention and the duration of follow-up); and (d) complications. The second author checked the collected data.

Measured outcomes

The primary outcomes of this review included pain after application of the intervention, deformity, and complications. The secondary outcomes included cost reduction as well as satisfaction of patients and/or parents.

Assessment of the risk of bias in the included studies

The Critical Appraisal Skills Programme reviewer checklist [11] was used to assess the included clinical trials. The checklist comprises ten questions, which were answered by yes or no. The questions cover the issues of the research question, randomisation, allocation into the treatment groups, blinding, the loss to follow-up, data collection and equal observation of the groups, the sample size adequacy, presentation of the results and their precision, and applicability.

Data synthesis

The data were combined and summarised using the narrative synthesis methods by reporting the summary of effect estimates methods and vote counting by direction of effect. A narrative synthesis table was created as recommended by Grimshaw (2003). For each comparison, the following was reported: a summary of the comparison in individual studies, the number of studies showing a positive direction of effect, and the number of studies with statistically significant effects.

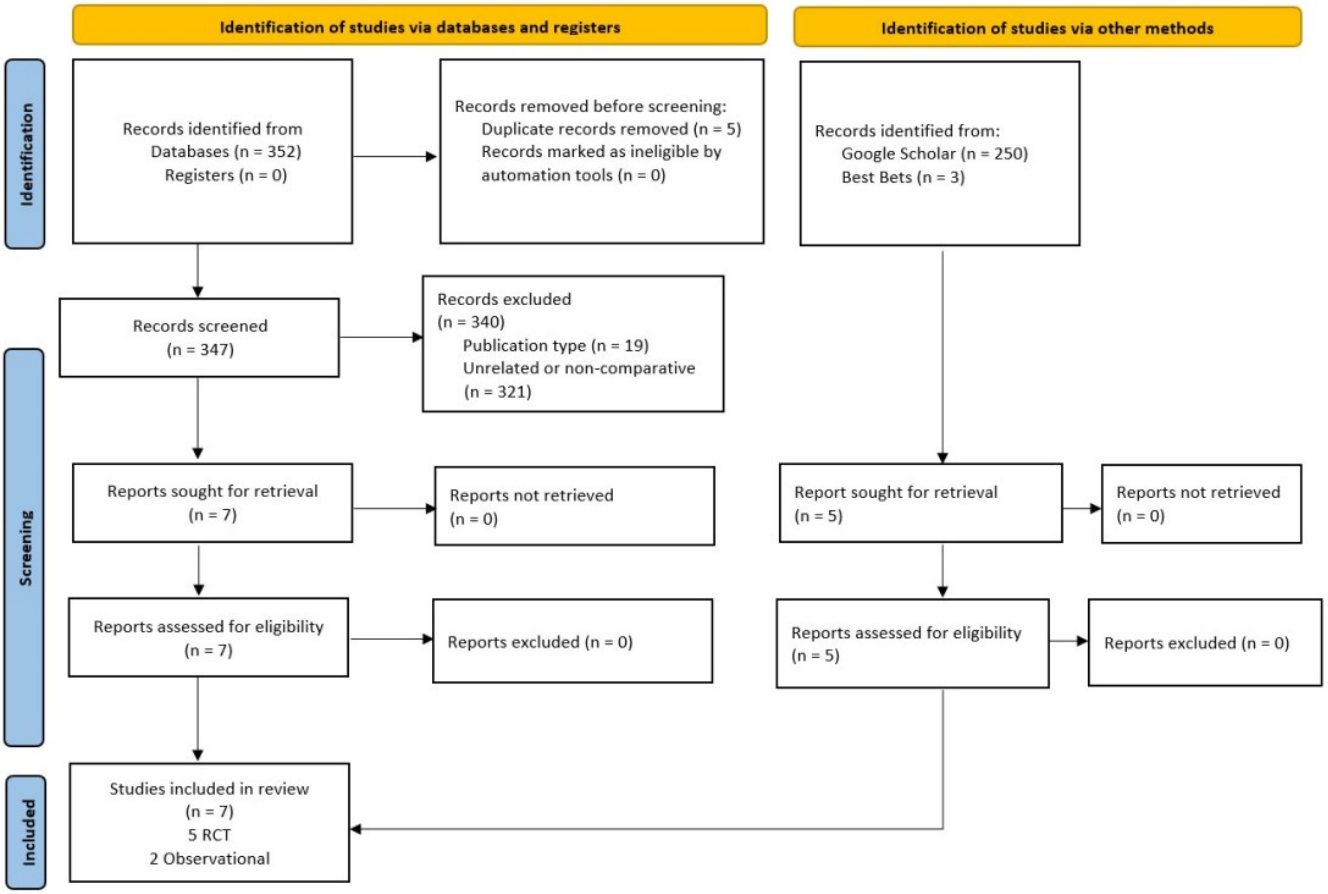

Figure 1. PRISMA flow chart diagram for the results of literature search and study selection.

RESULTS

Results of literature search and study selection

The results of the literature search as well as the process of screening and study selection are summarized in the PRISMA 2020 flowchart (Figure 1). The search yielded 605 results, out of whom 5 results were excluded for being duplicates, 19 for the type of publication, and 321 for non-relevance or the lack of one of the studied interventions. The full text of seven studies was obtained and they were included in the systematic review [7-9, 12-15].

Basic characteristics and summary of the included studies:

- **The basic characteristics of the included studies**

Table 1 outlines the characteristics of the included studies. Five papers were prospective randomized control trials (PRCT) that compared wrist splints to the standard cast [7-9, 12, 15], while two studies were observational studies reporting only on the use of splints. All studies were single-centred.

The studies were conducted in the Unites Kingdom (UK) [7, 13], Canada [8],

Table 1. Characteristics of the included studies (n = 7)

Studies	Design & settings	Intervention	Comparison	Eligibility criteria	Measured outcomes	Follow-up
Davidson et al.[7]	- Prospective RCT & postal questionnaire - single centre in UK - In 2000	Futura-type (Velcro) splint (n = 98)	Standard plaster-of-Paris forearm cast (n = 81)	Inclusion: Children with buckle fracture of distal radius	- Cost-benefit analysis - Fracture union & deformity - Complications	3 weeks
Plint et al.[8]	- Prospective RCT single tertiary centre in Canada - between August 2002 and September 2003	Removable splint (n = 42)	Short arm casts (n = 45)	Inclusion: Children (aged 6-15 years) with buckle fracture of distal radius or ulna Exclusion: another fracture of the same limb requiring immobilization, fractures of both wrists, metabolic bone disease, language barrier, or living outside the hospital catchment area	Primary outcome: ASKp score at 14 days Secondary outcomes: - ASKp score at days 7, 20, & 28 postinjury - Pain (VAS) - Ability to perform daily & sporting activities (4-point Likert scale) - Length of splint use - Parent & child satisfaction on day 28 - Refracture at 6 months.	3 weeks then at 6 months
Oakley et al.[9]	- Prospective RCT single centre in Australia - between March 2002 and March 2003	Fibre glass volar slab (n = 42)	below-elbow plaster-of-paris cast (n = 42)	Inclusion: Patients aged ≤ 18 years old presenting with a torus fracture of distal radius &/or ulna. Exclusion: any other injury to the upper limb, other serious injuries, inadequate English	Primary: - Daily pain score - Duration of pain - Willingness to use the immobilization again Secondary: - Resumption of normal daily activity - Medication usage - Time off school or work	2 weeks
Karimi Mobarakeh et al.[12]	- Prospective RCT single centre in Iran - between July 2010 and December 2010	Velcro splint (n = 64)	Complete plaster cast (n = 73)	Inclusion: Patients (<17 years old) with forearm distal fracture	- Pain (no pain, pain on activity, pain at rest) - Patients' satisfaction (Verhaar scale) - Cost-benefit Analysis - Complications	3 weeks
Williams et al.[15]	- Prospective RCT single centre in USA - between April 2006 and May 2009	Velcro splint alternative splinting (n=43)	Fibreglass short-arm cast (n = 51)	Inclusion: children (2-17 years) presenting with confirmed distal radial buckle fractures. Exclusion: skeletally mature, previous distal radial buckle fractures, concurrent other fractures (except ipsilateral ulnar buckle fracture), metabolic bone diseases.	Primary outcome: Pain (10 points-VAS) Secondary outcomes: - Satisfaction & convenience - Resources use	3 weeks
Solan et al.[13]	- Prospective case series single centre in the UK - Date and duration were not specified	Dynacast Prelude Slab (n = 41)	None	Inclusion: children (age ≤ 12 years) presenting with an isolated torus fracture of distal radius	- Patient satisfaction - Compliance with the cast	3-4 weeks
Van Bosse et al.[14]	- Retrospective review single centre in the USA - From May 2001 to October 2004	removable plaster-of-Paris volar splint (n = 33)	None	Not specified	Fracture healing and angulation	4 weeks

ASKp: Activities Scales for Kids performance; RCT: randomised clinical trial; VAS: visual analogue score

Table 2. Assessment of the risk of bias of the included clinical trials using the Critical Appraisal Skills Programme reviewer checklist (total n = 5 studies)

reviewer checklist	Davidson et al.[7]	Plint et al.[8]	Oakley et al.[9]	Williams et al.[15]	Karimi Mobarakeh et al.[12]
Did the study ask a clearly focused question?	No	Yes	Yes	Yes	Yes
Was this a randomized-controlled trial (RCT) and was it appropriately so?	Yes	Yes	Yes	Yes	Yes
Were participants appropriately allocated to intervention and control groups?	No	Yes	Yes	Yes	No
Were participants, staff and study personnel 'blind' to participants' study group?	No	No	No	No	No
Were all of the participants who entered the trial accounted for at its conclusion?	Yes	Yes	Yes	No	Yes
Were the participants in all groups followed up and data collected in the same way?	No	Yes	Yes	Yes	No
Did the study have enough participants to minimize the play of chance?	No	Yes	Yes	Yes	No
How the results presented and what are is the main result?	Yes	Yes	Yes	Yes	Yes
How precise are these results?	Yes	Yes	Yes	Yes	Yes
Were all important outcomes considered so the results can be applied?	Yes	Yes	Yes	Yes	Yes
Total answers in the affirmative	5/10	9/10	9/10	8/10	6/10

Table 3. Summary of the main results of narrative synthesis of the included clinical trials (n = 5 studies)

Variables	Davidson et al.[7]	Plint et al.[8]	Oakley et al.[9]	Karimi Mobarakeh et al.[12]	Williams et al.[15]	Direction of effect (number of studies) and significance [a]
Pain intensity	NR	VAS scores in splint > cast on days 7 (P=0.092) & 14 (P = 0.768)	VAS scores in Splint > cast (P=0.48)	Mild to moderate pain with activity in splint > cast (41.3 vs. 31.2%, P = 0.61).	VAS in splint > cast group immediately (P<0.005) and on days 1, 3, 7, and 21 (P>0.05)	+ve: 0/4 -ve: 4/4 (3/4 NS, 1/4 S)
Improved function	NR	Returning to regular sporting/physical play activities in splint > cast on days 20 & 28 postinjury (P = 0.031 & 0.008, respectively).	Resumption of normal activity in splint < cast (P = 0.001).	NR	NR	+ve: 1/2 (S) -ve: 1/2 (S)
Fracture union & deformity	None	NR	None	None	NR	-
Refracture	None	None	None	None	Not directly reported	-
Complications	NR	4 (8.9%) cast vs 0.0% splint (P = 0.117)	24% splint VS. 55% cast (P = 0.004)	5 (3.5%) patients developed edema under the cast.	NR	+ve: 2/3 (NS 1/3, S 1/3) -ve: 0/3
Cost analysis	£65.75 in splint vs. £116.98 in cast	NR	NR	$9.3 in Splint vs. $15.3 in cast	Less resource use in splint vs. cast group	+ve: 3/3 -ve: 0/3
Patients' satisfaction	NR	95.2% of splint vs. 21.7% of cast (P<0.001)	74% of splint vs. 71% cast (P = 0.8)	89% of splint vs. 86% of cast group (P = 0.52)	Significantly higher in splint > cast group at days 1, 3, and 21 P<0.05)	+ve: 4/4 (NS 2/4, S 2/4) -ve: 0/4
Parents' satisfaction	NR	85% in splint vs. 48% in cast (P = 0.010)	NR	NR	Greater percentage of parents in splint vs. Cast at all time points	+ve: 2/2 (S) -ve: 0/4

a: Positive direction (+ve) indicates a favourable outcome in the splint group and negative direction (-ve) indicates an unfavourable outcome in the splint group compared to the cast group; NR: not reported; NS: non-significant (p-value>0.05); S: significant (p-value<0.05).

Australia [9], Iran [12], and the United States (USA) [14, 15].

Of the five PRCT papers, three studies [7, 12, 15] compared the traditional below elbow cast versus new prefabricated splints, while two [8, 9] used a plaster splint as the intervention. In the non-randomized studies, Solan et al. [13] used a Dynacast Prelude fibreglass splint, and Van Bosse et al. [14] used a plaster-of-Paris volar forearm splint.

Three RCTs [8, 9, 15] were designed with a block randomization, while two papers [7, 12] had a quasi-randomization by day of attendance. Four of the five RCTs [7, 8, 12, 15] had a three-week follow-up, whereas that of Oakley et al. [9] had a two-week follow-up. The two observational studies followed up patients for four weeks [13, 14].

- **Summary of the included studies:**

A prospective RCT by Davidson et al. [7] was conducted in Alder Hey Children's Hospital, Liverpool (UK) in 2000. Two hundred and one children (2–15 years) with buckle fractures were randomized by day of attendance (quasi-randomization) to a plaster-of-Paris forearm cast or a Futura – type splint. Three weeks later, patients underwent clinical examination and re-X-Ray. No difference in the outcome was observed between both groups, either clinically or on X-Ray. They recommended that no follow-up is required after the first visit to the Fracture Clinic. Usage of a splint accrued a saving of £51.23 per patient while minimizing the need for patient follow-up, thus decreasing the workload on the hospital.

Plint et al. [8] performed an RCT in an academic, tertiary care children's hospital in Ottawa, Canada between August 2002 and September 2003. One hundred and thirteen children (6-15 years) with buckle fractures were randomised (block randomisation) to either a plaster cast or a removable plaster splint, with a follow-up at three weeks in the clinic and six months by phone. The primary outcome measure was the child's Activities Scales for Kids performance (ASKp) at 14 days and the secondary outcomes included ASKp at 7, 20 and 28 days, patient's and parental satisfaction at 28 days and re-fracture at 6 months. The removable wrist splint was associated with a significantly improved ASKp on day 14 ($p=0.041$), with less difficulty in bathing and showering on days 7, 14, and 20 ($p<0.001$). Furthermore, splints had a higher rate of patients' and parents' satisfaction, with no re-fracture at six months. In the cast group, four patients developed cast-related complications. The two groups showed no significant difference regarding the visual analogue score (VAS).

The RCT by Oakley et al. [9] compared the use of fibreglass volar slab to encircling plaster-of-Paris cast for immobilizing a buckle fracture in a large urban children's Hospital in Australia between March 2002 and March 2003. Ninety-five patients were recruited (age <18 years), but only 84 were analysed (42 in each arm). The splint group had a longer duration of pain ($p=0.009$). However, there was no significant difference in the severity of pain using VAS ($p=0.06$), nor in the pain duration after the data was stratified by a pain score of <50 ($P=0.63$) or a pain score of >50 ($p= 0.27$). The cast group was 1.5 times more likely to return to normal activity at two weeks compared to the splint group ($p=0.001$).

Although the splint group was associated with more days off work for parents (21 vs.11 days) and increased time off school (45 vs.16 days), results were statistically insignificant (p= 1.0 and 0.8, respectively). the cast group had more plaster problems(p=0.004) and a higher need to seek medical attention (p=0.09). There was no significant difference between the two groups regarding patient preference for future use of the same immobilization (P=0.81).

Karimi Mobarakeh et al. [12] conducted an RCT in Shahid Bahonar Educational Hospital, Iran, between July 2010 and December 2010. The study compared a removable wrist splint with a short arm cast. One hundred and forty-two children less than 17 years old were enrolled, with follow-up after three weeks either by phone or by clinic review. There were no significant differences regarding the degree of pain (p=0.61), compliance (p=0.53) or major complications between the two groups. Wrist splint application accrued a $6 saving per case while maintaining more patient and parent satisfaction.

The stings of the RCT by Williams et al. [15] were in an academic tertiary care pediatric hospital in St. Louis, USA, between April 2006 and May 2009. Ninety-four children aged 2-17 years were enrolled. The splint group was associated with a significant (p<0.05) difference in median satisfaction score, median convenience score and parental preference at 1,3,21 days, with the biggest difference in the satisfaction on day one (p=0.04). The cast group was associated with more resource utilization (p<0.0001). There was no significant difference in the VAS at any time point after the patient left the ED.

Solan et al. [13] launched a prospective observational study in Kingston Hospital, UK. Forty-one consecutive children ≤ 12 years old with buckle fractures of the distal radius were enrolled in the study and were treated by a Dynacast Prelude back slab to be removed at home. All parents expressed satisfaction with the splint. No serious problems were reported, and no further appointment was required to remove the splint, adding more to the cost benefits. Only four patients reported minor splint-related problems like rash and loose splint.

Van Bosse et al. [14] enrolled 33 patients (1-13 years old) treated with a removable volar forearm splint with symptom-based instructions. All patients resumed their regular activities and had a full range of wrist motion at 4 weeks with no reported complications. The initial and follow-up X-Rays revealed a significant difference in angulation on lateral views (p<0.03). All 33 follow-up X-Rays showed healed fractures, as well as no clinical bony tenderness.

The assessment of the risk of bias in the included studies

The results of the CASP checklist for the five RCTs are presented in Table II. Plint et al. [8] and Oakley et al. [9] both had the highest score with nine correct answers in the checklist, albeit they had a large number of patients lost to follow-up, mostly in Oakley's study [9]. Davidson et al. [7] had the lowest score with only five correct answers from the ten checklist questions.

Results of narrative synthesis:

The findings of the included studies were summarized in this systematic review using the methods of narrative synthesis (Table III). Meta-analysis with pooling of data of the studies was not performed because of the wide variations among the studies regarding the eligibility criteria, the tools used to measure the outcomes of interest, and the difference in time of measurements (i.e., at 7, 14, or 21 weeks).

Pain

Four RCTs [8, 9, 12, 15] reported that the pain scores were higher in the splint group compared to the cast group. The difference was not statistically significant except in the study by Williams et al. [15] which reported significantly higher scores in the splint group immediately after immobilisation ($p<0.005$). However, the study findings showed that pain scores decreased and became non-significantly different from those of the cast group on days 1, 3, 7, and 21. Furthermore, there was no difference in the number or types of pain medications given to patients in the ED ($P = 0.7$).

Oakley et al. [9] reported a longer duration of pain in the splint group compared to cast patients ($p=0.009$). However, stratification of the data according to the intensity of baseline pain scores revealed the lack of significant differences between the two groups. There was a similar duration of pain (two days) in both groups when the initial pain score was <50 and no significant difference with an initial pain score of >50 ($p=0.27$).

Improved function

Plint et al. [8] reported less difficulty in bathing, showering and painting on days 7, 14, and 20 post-injury ($p<0.001$). In addition, more patients in the splint group resumed normal activities by days 20 (18/25 vs. 13/32, $P = 0.031$) and 28 postinjury (25/26 vs 23/34, $P = 0.008$). Controversially, Oakley et al. [9] reported that resumption of normal activities was 1.5 more likely in the cast group at two weeks ($p=0.001$). This might have been influenced by a high initial pain score of >50, as well as the presence of confounders.

Fracture union and deformity

Three RCTs [7, 9, 12] reported that all fractures were successfully united, and no deformity was reported in either group. Van Bosse et al. compared the initial and follow-up radiograms, concluding that all fractures healed without significant clinical change in angulation.

Re-fracture

No re-fractures were reported in either treatment group by the included studies. However, the duration of follow-up varied from 2 weeks [9] up to 6 months post-injury [8].

Complications

Four papers reported minor splint complications like rash [12], loosening [9, 14], or having the splint removed by very young children [7]. Two papers reported cast-related problems like getting wet [8] or broken [9], as

well as experiencing rash or oedema under the cast [12]. Taken altogether, the results of the RCTs by Plint et al. and Oakley et al. [8, 9] showed a lower rate of complications in the splint group compared to the cast group (P = 0.117 and P = 0.004, respectively). The exact incidence of rash in the two groups was not clearly stated by Karimi Mobarakeh et al. [12], thus interpreting the direction of effect and the significance of the results was not feasible.

Cost–analysis

Three papers [7, 12, 15] showed that using removable splints had a significant impact on healthcare costs, owing to either cheap splint material cost, no follow-up and no Re-X-Ray being required.

Patients' preference/satisfaction

Four RCTs compared the satisfaction of patients between the two treatment groups and found the percentage of satisfied patients higher in the splint group [8, 9, 12, 15]. The difference was statistically significant in two studies [8, 15].

Parents' preference/satisfaction

Two RCTs investigated the willingness of the parents to use the same method of immobilization if another fracture occurred [8, 15]. Their results indicated that significantly higher percentages of parents were satisfied with the treatment in the splint group compared to the cast group.

DISCUSSION

Summary of the main findings

Seven studies were selected for this systematic review. Five studies were prospective (RCT) [7-9, 12, 15], while the other two studies were observational.

The results of the studies indicated that a removable wrist splint is comparable in efficacy to the standard cast in the treatment of the buckle fracture of the distal forearm in paediatric patients. All fractures healed without deformity in either group. No re-fracture was reported by any of the included studies in either group.

Pain scores tended to be higher in the splint group compared to the cast group in most studies, with significant differences in one study only immediately after the application of the splint, then the differences became non-significant [15]. This tendency towards higher pain scores in the splint group was found by Oakley et al. [9] to be due to unequal baseline pain scores before treatment. However, this tendency warrants the conduction of further clinical trials that are powered to detect the differences in pain scores between the two interventions and the changes from baseline pain scores.

Only two studies compared the rapidity of resuming normal physical activities between the two immobilisation methods, with contradictory results. While Plint et al. [8] concluded that splint was associated with a more rapid resumption of physical and playing activities compared to the cast group, Oakley et al. [9] returning to normal activities was 1.5 more likely in the cast group. The results of Oakley et al. may be related to the observed higher initial pain score in this study in the

splint group. Other potential confounders should be explored in future studies that may impact returning to normal daily activities. These may include the age of the patients, the type of activities they were practising before the fracture, and parents' worries about performing physical activities before ensuring the complete healing of the fracture.

The reported complications in the splint group were minor, including rash [12], loosening of the splint requiring rebandaging [9, 14], or removal by very young children [7]. The reported cast-related complications included getting wet [8], breaking the cast [9], and developing rash or oedema under the cast [12]. Direct comparison between the two groups was provided in two studies [8, 9], revealing a lower incidence of complications in the splint group.

The superiority of removable splints in terms of cost-benefit analysis was declared by three studies [7, 12, 15]. The savings in the splint group were attributed to the low cost of splint material, besides obviating the need for follow-up visits to the clinic and a second X-ray (follow-up can be achieved through phone calls). The easy removal of the splint at home and the lower incidence of complications reduces the need for a second clinic visit in the splint group.

More patients and parents seemed to be satisfied with the use of removal splint and willing to undergo the same treatment if another fracture occurs [8, 9, 12, 15].

Overall completeness, applicability, and quality of the evidence

This systematic review summarised the current evidence on the efficacy and safety of removable wrist splints as a treatment of buckle fracture in children. These findings suggest that removable splints can be used effectively and safely in the treatment of buckle fractures in children. Apart from a slight increase in pain, no considerable inconveniences were recorded. However, some studies showed that confirmation of the diagnosis is necessary before the use of removable splints, to avoid confusion with greenstick fractures as occurred in some studies [7-9].

The studies adopted different eligibility criteria for including patients. All patients were children, but the age was extended to up to 18 years in some studies while others included those up to 12 years only. Some studies included only solitary radial fractures while others included both radial and ulnar buckle fractures. The material of the splint also varied across the studies, comprising plaster of Paris [14], Velcro [7, 12, 15], and fibreglass [9]. Follow-up was for three weeks in most studies, but one study made a follow-up call six months post-injury [8]. Differences among the studies extended also to the tools used to assess some outcomes such as pain, satisfaction, and cost-benefit analysis. The above-mentioned heterogeneity among the included studies obviated the pooling of data and the conduction of meta-analysis.

All RCTs were level 2b on the evidence-based medicine ranking level [16] as they are non-blinded, single-centre studies with relatively small sample sizes. An assessment of the risk of bias of the included RCTs was

performed. Although randomisation was done in all trials, quasi-randomisation by the day of attendance was done in two studies [7, 12], which may introduce bias in the selection of patients and their allocation into the treatment groups. The other three studies used block randomization [8, 9, 15]. One study showed a considerable difference in baseline pain scores [8, 9, 15]; though the difference was non-significant, this may indicate bias in the selection of the patients or their allocation into the treatment arms. Blinding of patients and doctors providing treatment was not feasible; however, blinding of assessors at follow-up was not mentioned by any of the studies, which may lead to bias in the detection and reporting of the studied outcomes. The sample size was calculated in three RCTs only [8, 9, 15] based on the primary outcome of each study, raising concerns about the power of the included RCTs for detecting other measured outcomes.

An important consideration that was stressed by the results of the included studies is greenstick fractures being misdiagnosed as buckle fractures. This is particularly important if the use of removable splints is decided as the reported inherent stability of buckle fractures obviates the need for follow-up and repeated radiography. In the case of a misdiagnosed greenstick fracture, this will delay the discovery of the true nature of the fracture and, potentially, displacement and complications may arise. Doctors should take care to confirm a diagnosis of buckle fracture before recommending the use of a removable wrist splint to the patients and parents.

Agreements and disagreements with other studies or reviews

A systematic review by Hill et al. [17] summarized the evidence regarding the use of alternative treatment methods instead of the standard cast in children with buckle fractures, including splinting and bandage therapy. Their results regarding the use of removable splints were similar to the present review. However, the narrative synthesis in the review by Hill et al. [17] did not address removable splints separately from bandage therapy and the direction of effect was not clearly indicated for the outcomes. Moreover, some outcomes that have clinical significance, such as patients' or parents' satisfaction, were not addressed.

Limitations

In the present review, pooling of the data could not be performed, and the included studies were not sufficiently homogeneous to combine in a meta-analysis.

CONCLUSIONS, IMPLICATIONS FOR PRACTICE, POLICY, AND FUTURE RESEARCH

The results of the present systematic review indicate that paediatric buckle wrist fractures can be safely managed by a removable wrist splint accompanied by a discharge information leaflet and no further follow-up. Although some papers are susceptible to bias, the overall evidence suggests that the use of removable wrist splints results in good functional outcomes, besides achieving more patient and parent satisfaction. Moreover, the lower incidence of complications and their mild nature as well as

the great cost-saving render removable wrist splints a plausible treatment option from the perspectives of patients and hospitals. However, further randomized clinical trials with adequate sample sizes are warranted to fill the gap in the current literature, particularly regarding the experienced pain and the resumption of activities.

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