Cast wedging: a systematic review of the present evidence

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Abstract

Purpose The objective of this systematic review was to summarise the outcome after cast wedging due to loss of angulation in conservative fracture treatment of children's fractures.

Methods Electronic searches were performed using MEDLINE, PubMed, OVID, CENTRAL and EMBASE without language restrictions.

Results Three studies comprising 316 patients (210 radius, 52 forearm/both bone forearm fractures and 54 tibia fractures) were included in the present analysis. Cast wedge failures occurred in 14 of 316 (4.4%) patients. Three patients (0.9%) needed surgical fixation and 11 patients (3.4%) ended up with a healed deformity. Furthermore, eight of 316 (1.8%) patients needed remanipulation and cast change.

Conclusion Cast wedging reflects a reliable treatment option for secondary displaced long-bone paediatric fractures.

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Introduction

Tibial, forearm and distal radius fractures are among the most frequent fracture types in children.[1,2] The goal of any treatment is to restore length, rotation and axis of the bone to recover full function. Often, these injuries can be treated with closed reduction, cast immobilisation and clinical and/or radiological follow-ups.[3,4] Loss of acceptable angulation after conservative management of forearm shaft fractures has been described in up to 39%.[5-7] When secondary loss of reduction leads to angulation outside the frame of the natural remodelling potential of the juvenile bone, several conservative treatment options including cast wedging or cast replacement are possible instead of closed/open reduction. Cast wedging reflects a commonly performed, simple and non-invasive treatment procedure for secondary displaced long-bone fractures[8,9] that was first described by Krömer and Heuritsch in 1936.[10-12]

The aim of this meta-analysis was to summarise the present evidence about the effectiveness of cast wedging as conservative treatment of secondary displaced forearm, distal radius and distal tibia fractures.

Materials and methods

Inclusion and exclusion criteria

Inclusion criteria consisted of all types of studies including patients aged < 18 years with cast wedging as conservative treatment of paediatric extremity fractures.

Data extraction

Data from selected studies were extracted by two authors (SG and RNV). Extracted data were managed using a preformed data sheet.

Graphical and statistical analysis

Common descriptive and inferential meta-analysis methods were used to assess failure rates after cast wedging across different studies. The association between study size and study results was analysed in funnel plots, by plotting Logit Transformed proportion on the horizontal

axis against the standard error of the study on the vertical axis.[13]

The effect estimates along with the confidence intervals (CIs) of included studies were plotted in a forest plot. Heterogeneity between studies was examined with standard chi-square tests, and the I-square statistics measuring the proportion of variation in treatment effect estimates due to between-study heterogeneity were calculated.[14] Depending on the non-significant result of the heterogeneity test, a fixed effects model was used to combine the results from the different studies.[15]

Results

Unsystematic literature search

First, in order to estimate the number of included studies, an unsystematic literature search was performed in MEDLINE using the search term: '(Cast AND Wedging)'. This search was performed on 25 January 2016 and yielded 28 titles. Hereby, three studies were identified (Fig. 1).

Systematic literature search

Following the unsystematic literature review, a systematic search was performed. Search terms were generated by the first author of the present meta-analysis (SG).

For the PubMed search, the following search term was used: '(cast OR plaster cast OR plaster bandage) AND (wedge OR wedging)'. The PubMed search resulted in 142 titles with two relevant studies and ended on 25 January 2016.
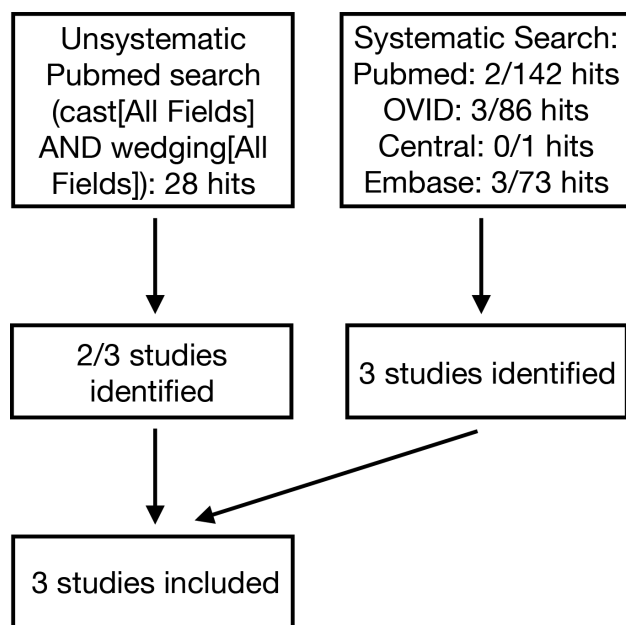
For OVID (MEDLINE) the following search term was used: '(casts, surgical OR splints) and (wedge OR wedging)'. The search ended on 25 January 2016 and resulted in 86 hits with three relevant papers, from which two were already identified using PubMed.

The EMBASE database search was performed using the search terms '(wedge OR wedging) AND (cast plaster OR cast application OR cast OR cast OR plaster bandage) AND fracture' and yielded 73 hits with three relevant studies. This search ended on 06 December 2015.

The CENTRAL search was performed using the term 'Cast, surgical AND (wedge or wedging)' and resulted in only one hit without any relevant studies. The CENTRAL search ended 28 November 2015.

Neither the EMBASE nor the CENTRAL searches identified any additional studies to the PubMed and OVID searches to be included.

Results from included studies

Overall, three studies meeting the inclusion criteria mentioned above were identified during the systematic literature search.[16-18] Table 1 gives an overview of the studies' characteristics. In total, 316 patients were included (Keenan and Clegg:[17] six patients, Samora et al:[18] 61 patients, Kattan et al:[16] 249 patients). The study design was prospective in the study by Samora et al,[18] retrospective in the study by Kattan et al[16] and Keenan and Clegg[17] did not provide the study design. The included patients' ages were in the range of 7.1 years to 9.3 years on average. Keenan and Clegg[17] analysed four forearm and two lower leg fractures, whereas Samora et al[18] primarily included 48 both-bone forearm fractures and 22 distal radius fractures. Of these, nine patients had to be excluded due to missing radiographic data. Kattan et al[16] included 197 forearm and 52 lower leg fractures.

Indication for cast wedging was given by Samora et al[18] to be > 20° angulation in distal radius fractures at any plane, > 15° angulation in forearm middle third fractures at any plane or > 10° angulation in forearm proximal third fractures at any plane. Kattan et al[16] used > 5° angulation at tibial side and > 10° angulation at forearm fractures as indication for cast wedging. Timing of cast wedging (mean ten days after initial casting) and duration of immobilisation (mean 7.4 weeks) were only given by Kattan et al.[16]

Patients were followed up for 18 weeks according to Kattan et al[16] and 11.5 weeks according to Samora et al[18] on average.

Cast wedge failures occurred in 14 of 325 patients (Samora et al:[18] 1/61, Kattan et al:[16] 13/249). Of these, three patients needed surgical fixation and 11 patients ended up with a healed deformity: Kattan et al[16] reported two unsatisfactory outcomes following tibial cast wedges,

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┌──────────────────────┐   ┌──────────────────────┐
│     Unsystematic     │   │  Systematic Search:  │
│    Pubmed search     │   │  Pubmed: 2/142 hits  │
│   (cast[All Fields]  │   │    OVID: 3/86 hits   │
│   AND wedging[All    │   │   Central: 0/1 hits  │
│   Fields]): 28 hits  │   │   Embase: 3/73 hits  │
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│     2/3 studies      │   │  3 studies identified │
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Fig. 1 Flow diagram of literature search and selection for meta-analysis.

Table 1. Characteristics of included studies.

	Keenan and Clegg[17]	Samora et al[18]	Kattan et al[16]
Year of publication	1995	2014	2014
Time of inclusion	n.a.	2011 to 2012	2005 to 2012
Study design	n.a.	Prospective	Retrospective
Primary or secondary outcome	Primary	Primary	Primary
Included patients (n)	6	61 (13 distal radius fractures, 48 both-bone forearm fractures)	249 (197 radial fractures, 52 tibial fractures)
Exclusion criteria	n.a.	Pathologic fractures, forearm fracture dislocations, incomplete data sets, open fractures, refractures, neurovascular injuries, closed distal radial physis	Wedging in fractures other than radius or tibia, osteogenesis imperfecta
Excluded patients (n)	n.a.	Primary: 9/79 Secondary: 9/70 due to loss of follow-up	11/260
Reason for exclusion	n.a.	Primary: incomplete radiographic data (n = 9) Secondary: incomplete radiographic follow up data (n = 9)	Wedge at different anatomic position (n = 9), osteogenesis imperfecta (n = 2)
Age (yrs)	n.a. (2 to 14)	8.4 (3 to 14)	9.3 (1 to 18)
Male / female	n.a. / n.a.	45 / 25	184 / 65
Technique of cast wedging	Opening	Opening	Opening
Location of cast wedging	n.a.	n.a.	At the fracture site (proximal and middle third), 5 cm proximal to the fracture (distal third)
Cast material	Plaster of Paris	Probably synthetic	n.a.
Wedge material	n.a.	n.a.	Plastic, radiolucent
Wedge size (mm)	n.a.	n.a.	Lower leg: 21 (9 to 41) Forearm: 22.9 (11 to 41)
Reason for cast wedging	Incomplete correction of fracture	Secondary loss of reduction	Improvement of alignment
Location of fractures (with cast wedging)	Forearm, lower leg	Distal radius, forearm	Lower leg, forearm
Indication for cast wedging	n.a.	> 20° angulation (distal radius; any plane; younger children) > 15° angulation (forearm middle third; any plane, younger children) > 10° angulation (forearm proximal third; any plane younger children / all locations older children)	> 5° angulation (tibia; any plane) > 10° angulation (forearm; any plane)
Timing of cast wedging (days after initial casting)	n.a.	n.a. (n.a. to 21)	10 (0 to 46)
Duration of cast immobilisation after wedging (wks)	n.a.	n.a.	7.4 (1 to 19)
Improvement in coronal (anteroposterior) alignment	n.a.	Forearm: 8.3° (y), 4.4° (o) Distal radius: 4.7° (y), 3.0° (o)	Lower leg: 4.1° Forearm: 5°
Improvement in sagittal (lateral) alignment	n.a.	Forearm: 12.1° (y), 8.2° (o) Distal radius 15.7° (y), 13.9° (o)	Lower leg: 1.8° Forearm: 6.3°
Complications due to cast wedging	n.a.	3/61	0/249
Length of follow-up (wks)	n.a.	11.5 (4.7 to 58.9)	18 (5 to 69)
Definition of cast wedge failure	≥ 10° of malunion in any plane	n.a.	- Excessive amount of valgus and procurvatum angulation in tibial fracture - 6.6° of residual varus malalignment in tibial fracture - Angulation > 20° apex-ulnar and 17° apex-volar - Range of pronation-supination < 120° and residual malalignment of 17° - Residual malalignment up to 21° but normal range of pronation-supination
Cast wedge failure (surgery necessary / healed deformity)	0/6 (0%) Distal radius: 0/0 Forearm: 0/4 (0%) Lower leg: 0/2 (0%)	1/61 (1.4%) Distal radius: n.a./13 Forearm: n.a./48 Lower leg: 0/0	13/249 (5.2%) Forearm: 11/183 (6.01%) Lower leg: 2/52 (3.8%)
Dealing with cast wedge failure	n.a.	1 surgical fixation	2 surgical fixations 11 healed deformity
Need for re-wedging, remanipulation	0	n.a.	8/249

Data are given as absolute values or as mean with range in brackets

Younger children (y): female < 8 years, male < 10 years; older children (o): female ≥ 8 years, male ≥ 10 years
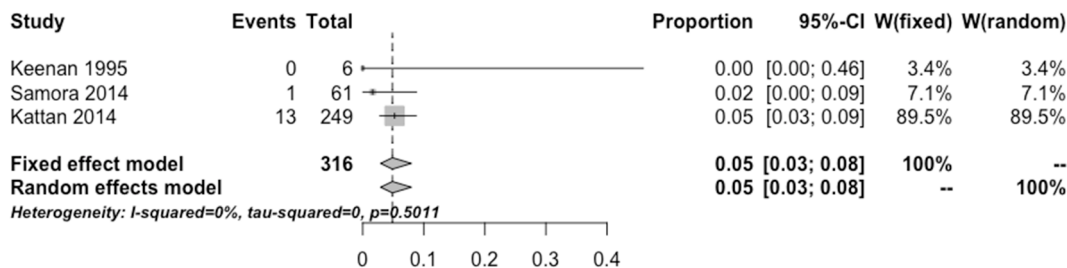
n.a., not assessed

Fig. 2 Forest plot of overall incidence of cast wedge failure.

with one patient needing surgical fixation and one patient showing residual varus alignment (of 6.6°). Eleven of 183 (6.01%) forearm fractures had unsatisfactory outcomes. Of these, one patient needed surgical fixation and healed deformities were seen in ten patients. Samora et al[18] reported one surgical fixation due to residual unacceptable angulation after cast wedging (without giving the fracture localisation).

Eight patients, reported by Kattan et al,[16] needed remanipulation and cast change (two tibial and six radial fractures).

The range of correction following cast wedging differed based on patient's age and fracture localisation. The improvement in coronal (i.e. anteroposterior (AP)) alignment was 4.4° to 8.3°, 3.0° to 4.7° and 4.1° for forearm, distal radius and lower leg fractures, respectively. The improvement in sagittal (i.e. lateral) alignment was 6.3° to 12.1°, 13.9° to 15.7° and 1.8° for forearm, distal radius and lower leg fractures, respectively.

Samora et al[18] also reported the following complications after cast wedging: three out of 61 patients suffered from pain following wedging and one patient showed transient finger numbness. Kattan et al[16] did not face any complications due to cast wedging and Keenan and Clegg[17] did not mention their complications.

Effectiveness of cast wedging

A forest plot was used to summarise and visualise the results of the meta-analysis (Fig. 2). Since the test for heterogeneity was not significant (p = 0.50), results from the fixed effects model were used. Overall, cast wedge failure (necessitating re-wedging, re-manipulation and/or surgery, or resulting in a healed deformity) occurred in 4.4% of patients. The 95% CI for the overall proportion was in the range of 2 to 6.

Overall, a funnel plot (Fig. 3) did not show evidence for publication bias.

Discussion

Cast wedging reflects a non-invasive method to align secondary displaced long-bone fractures in the paediatric population. Typical localisations of paediatric fractures treated with cast wedging are the forearm shaft, the tibial shaft and the distal radius. Despite being first described more than 75 years ago, the available literature about cast wedging is sparse.[10-12] This meta-analysis intended to summarise all the available data about cast wedging. Overall, only three studies including 325 patients were identified. Cast wedge failures occurred in 14 of 316 (4.4%) patients. Three patients needed surgical fixation and 11 patients ended up with a healed deformity. Furthermore, eight of 316 (2.5%) patients needed remanipulation and cast change.

Cast wedging was performed due to incomplete correction of fracture, unacceptable primary alignment, secondary loss of reduction and intention to improve alignment in angulation and rotation in included studies. Authors were contacted to evaluate their study design and complete missing values and data and to achieve better comparability between the studies, but no answers were obtained.

Whereas traditional casts were made of plaster of Paris, modern synthetic casts are built on a polypropylene basis and are aimed to be light, thin-walled and comfortable. Interestingly, the effectiveness of cast wedging was shown to be independent of the cast material (i.e. plaster of Paris *versus* synthetic) used evaluating cast wedging with a laser supported forearm model.[19] Whereas the oldest included study (i.e. published in 1995 by Keenan and Clegg[17]) used plaster of Paris for casts, Samora et al[18] probably used synthetic material (as visible on printed pictures) and Kattan et al[16] gave no insight on the cast material used.

Three different types of cast wedging are given in the literature: (i) opening, reflecting the distraction facing the concave site of the angulation; (ii) closing, reflecting the compression facing the convex site of the angulation and; (iii) balanced techniques, combining opening and closing of the cast. In the first two techniques, the pivot point lies outside the limb, while in the balanced technique it lies at the site of the fracture. Nevertheless, opening reflects the most commonly performed technique due to its simple implementation.[11] Accordingly, all included studies used opening as the cast wedge technique. The location of cast wedging in relation to the fracture site is still a matter
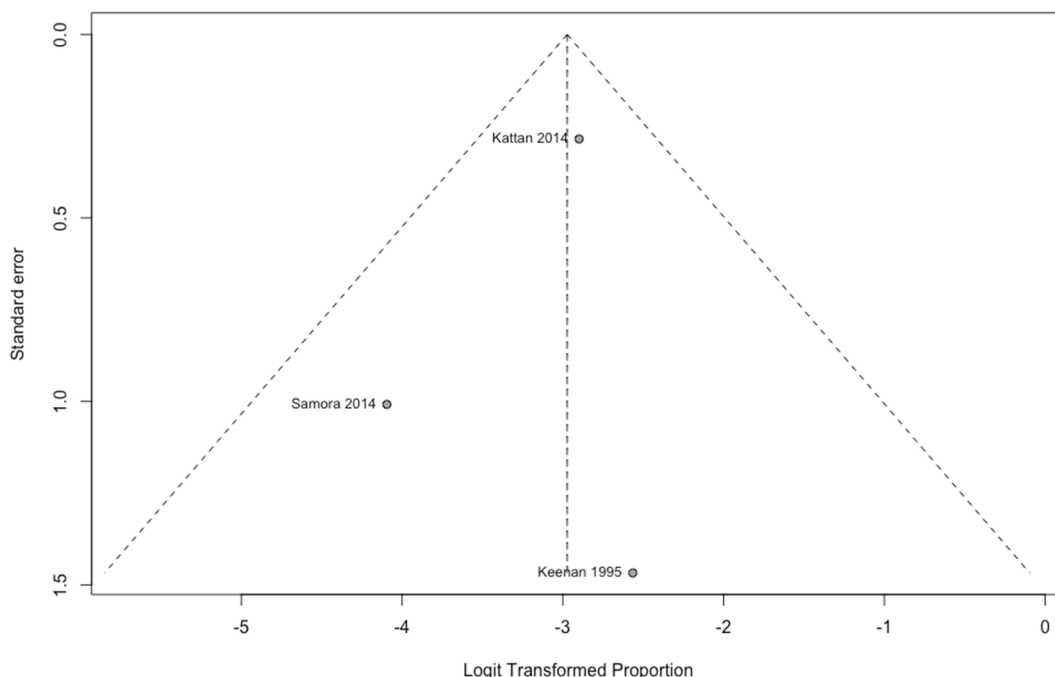
Fig. 3 Funnel plot of association between study size (y-axis) and study result (x-axis): no evidence for publication bias is shown.

of debate. Whereas some authors argue that the wedge should be placed directly at the fracture site (i), others prefer the wedge placement proximal to the fracture site (especially in distal fractures to ensure a sufficient lever arm distal to the fracture) (ii) or at the intersection point of the axes of the two long-bone fragments (iii).[11] The location of the wedge was only given by Kattan et al[16] and was at the fracture site in proximal and middle third shaft fractures and 5 cm proximal to the fracture in distal third shaft fractures. As shown using a laser supported forearm model, the optimal position of wedge placement was on the concave site (i.e. cast opening) at the fracture level.[19] Wedges may consist of different materials including wood blocks, pieces of cork, plastic, etc. Whereas Kattan et al[16] used radiolucent plastic wedges sized 22.9 mm and 21 mm on average for forearm and lower leg fractures, respectively, the wedge size and material were not given by the other authors. The effects of cast wedge type (i.e. opening versus closing versus balanced), location of the wedge, cast material and wedge material on the incidence of cast wedge failure was not assessed. Due to the limited amount of published data, the present meta-analysis could not assess the impact of these putative risk factors on cast wedge failure.

The range of correction following cast wedging differed based on patient's age and fracture localisation. The improvement in coronal (i.e. AP) alignment was 4.4° to 8.3°, 3.0° to 4.7° and 4.1° for forearm, distal radius and lower leg fractures, respectively. The improvement in sagittal (i.e. lateral) alignment was 6.3°

to 12.1°, 13.9° to 15.7° and 1.8° for forearm, distal radius and lower leg fractures, respectively. Together with the age and fracture localisation dependent natural remodelling potential of the juvenile bone, possible correction grades should be considered when applying cast wedging. However, it is important to note that these findings are based on results from single studies, not from meta-analysed data and must therefore be considered with caution. Individual patient outcomes as well as correction grades at specific patient ages cannot be reported in detail due to the lack of data published in the three included studies.

Radiological follow-ups of the remaining patients showed significant improvements in angulation for both-bone forearm (Samora et al),[18] radius (Samora et al,[18] Kattan et al[16]) and ulnar fractures (Samora et al)[18] as well as in tibial fractures (Kattan et al).[16]

Only Samora et al[18] reported complications occurring after cast wedging including pain, muscle spasm and temporary numbness.

Cast wedging reflects one possible treatment option for secondary displaced long-bone paediatric fractures, which is successful in about 96% of cases. Complications occur rarely and can be corrected easily. The correction grade following cast wedging seems to be greatest in distal radius fracture in the sagittal plane (about 15°) and lowest in lower leg fractures in the sagittal plane (about 2°). Due to the limited amount of available data, further studies assessing the outcome following cast wedging are necessary. These studies should include the following

information: age and gender of included patients; fracture localisation; cast type (i.e. plaster of Paris *versus* synthetic); technique of cast wedging (i.e. opening *versus* closing versus balanced); wedge placement relative to fracture location; wedge material; timing of wedging (i.e. days after trauma); duration of wedging; degrees of angulation corrected by wedging; complications occurring due to cast wedging and; finally the incidence of cast wedge failure.

COMPLIANCE WITH ETHICAL STANDARDS

FUNDING STATEMENT

OA LICENCE TEXT

ETHICAL STATEMENT
Ethical Approval: The research involved human data from previously published studies only.
Informed Consent: No informed consent needed.

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