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REVIEW ARTICLE

Cast selection and non-union rates for acute scaphoid fractures treated conservatively: a systematic review and meta-analysis

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ABSTRACT

Cast selection for conservatively treated acute scaphoid fractures remains controversial. Cast options include short arm versus long arm, and those that include the thumb or leave it free. We sought to investigate the role of how cast choice affects nonunion rates after conservative management of scaphoid fractures. We searched PubMed, Embase, and Google Scholar from inception through July 14, 2020, according to the Preferred Reporting Items for Systematic Review and Meta-Analyses guidelines. We extracted information of interest, including cast type, and non-union rates at the end of the treatment period. We then performed a meta-analysis using the random-effects model. We identified seven relevant studies. Non-union was observed in 15 out of 156 (9.6%) with short-arm cast and 13 out of the 124 (10.5%) with long-arm cast (OR = 0.79, 95% CI [0.19, 3.26], p = 0.74). Non-union was observed in 18 out of 174 (10.3%) with thumb immobilization cast and 18 out of the 179 (10.1%) without thumb immobilization (OR = 0.97, 95% CI [0.49, 1.94], p = 0.69). In our study, short arm casting was proven non-inferior to long arm casting. Similarly, casts without thumb immobilization were equally as effective as casts with thumb immobilization in terms of non-union rates for acute scaphoid fractures treated non-operatively.

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Introduction

Controversy exists regarding the optimal treatment options for scaphoid fractures with no or minimal displacement. Although conservative management with long term casting has been a mainstay of treatment, open reduction and internal fixation has been strongly advocated by other hand surgeons [1,2]. Each method has its own advantages and disadvantages [3–6]. Several options exist for nonoperative management in particular. These include casting above the elbow, or below the elbow, with or without thumb immobilization, and with wrist extension or wrist flexion.

Significant disagreement exists about the ideal cast and previous studies have been inconclusive regarding the impact of the cast type on union rates [7–9]. Initially long or above the elbow cast was used to prevent motion at the fracture site due to forearm rotation, although the degree of motion instability necessary to disrupt healing was not established. In addition, and considering patients' comfort and compliance, the short arm cast was introduced. Similarly, thumb immobilization cast was employed to prevent motion at the carpometacarpal and metacarpophalangeal joint that in theory would prevent movement at the fracture site in risk of thumb stiffness. However, anecdotally, surgeons' preference is considered to affect the cast type choice.

In this systematic review and meta-analysis, we sought to investigate the impact of cast type on non-union rates for scaphoid fractures treated non-operatively. We hypothesized that the non-union rate will be similar among above versus below arm cast, and similar for casts with or without thumb immobilization.

Methods

Literature search

The present study is a systematic review and meta-analysis of the literature based on the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines [10]. A review protocol was not submitted before the completion of the study. We searched PubMed, Scopus, Embase, Cochrane, and Web of Science from inception to 14 July 2020. The initial database search was performed by a qualified librarian [SMS] using predetermined search terms and strategies. We included comparative experimental or observation studies with union, non-union outcomes for pediatric or adult patients with scaphoid fractures treated non-operatively with different types of casts. We did not enforce language or date restrictions. Non-comparative studies, cadaveric studies, conference proceedings, letters to the editors, and experts' opinions were excluded from our study. Two authors [CS, JL] independently screened the titles and abstracts based on the selected eligibility criteria. The selected studies were further screened based on the content of the full-text article. The list of references of the included papers were also assessed for other relevant studies.

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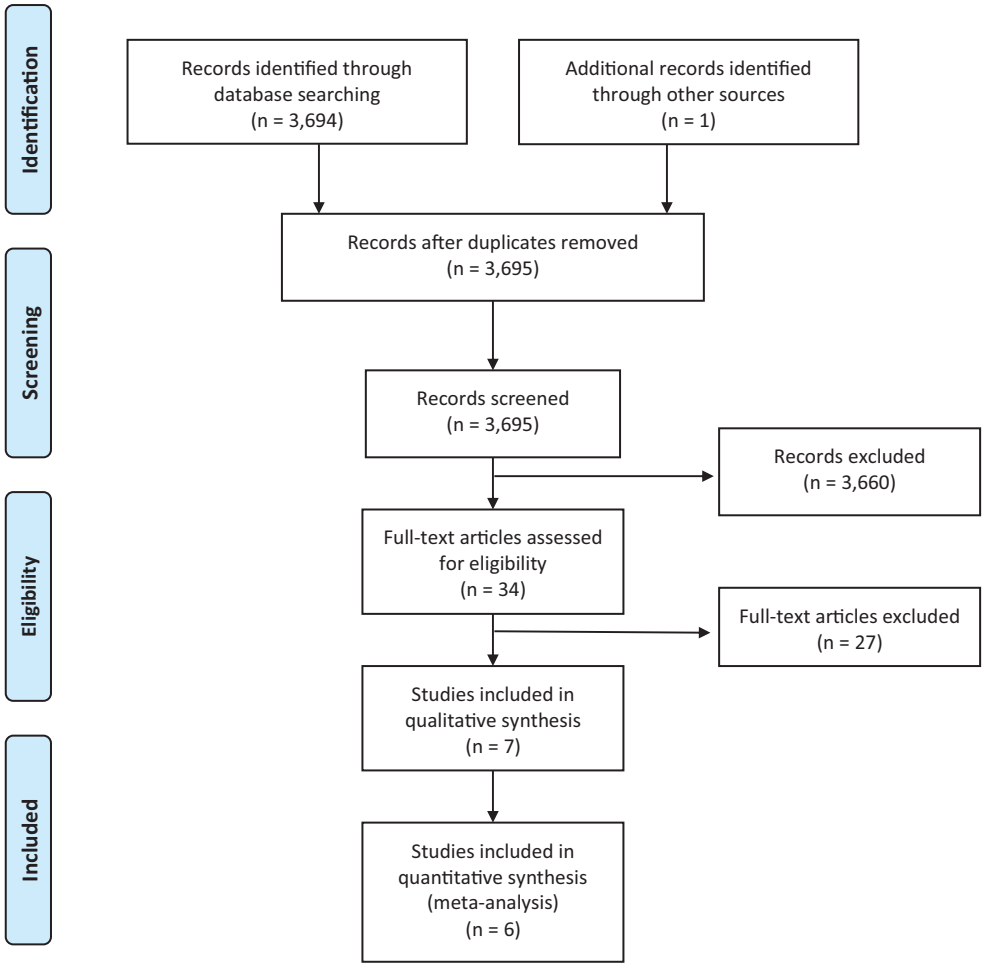

Figure 1. PRIMSA flow diagram.

Data extraction and quality assessment

For the relevant studies we extracted the following information of interest; year of publication, location, study design, sample size of each cohort, fracture characteristics, cast used, duration of immobilization, and non-union rates. We anticipated non-union definition to be heterogenous among the different studies, but the definition of each individual study was accepted and presented in our results.

The first author [CS] evaluated the quality of the included studies based on the Methodological Index for Non-Randomized Studies (MINORS) criteria [11] for the observation studies and the Jadad Scale [12] for the experimental studies. The evaluator was blinded to the author's names and hospital affiliations of the included studies.

Statistical analysis

We performed our meta-analysis on the Review Manager 5.3 software (The Cochrane Collaboration, Copenhagen, Denmark). We used the Random Effects Model using the Mantel-Haenszel method [13] due to perceived clinical heterogeneity among the participants of each individual study. We calculated Odds Ratio (OR) and 95% Confidence Intervals (CI) for our binary outcomes. We assessed statistical heterogeneity across the studies using the Q statistic, generated by the χ^2 (chi-square) test. We calculated the size of the heterogeneity based on the I^2 measurement. We considered I^2 values less than 50% to represent low, values between 50% and 75% medium, and greater than 75% high heterogeneity [14].

Results

Literature search

Following exclusion of duplicate articles, we found 3694 studies. We initially screened these studies based on their title and abstract and we excluded 3660 irrelevant studies. We then screened the full text article of the remaining 34 studies and included 7 in our systematic review and meta-analysis (Figure 1) [7,8,15–19]. Characteristics and quality scores of the included studies are presented in Table 1.

Non-union definition

As expected, non-union definition was not identical among the different studies, however similar principles were employed by all authors in order to establish the diagnosis of non-union. Alho et al. [15], Clay et al. [7], Gellman et al. [17], Terkelsen et al. [18], and Hambidge et al. [19] used both clinical information, such as presence of tenderness at anatomic snuffbox, and radiographic evidence, such as persistent fracture line to diagnose non-union at different follow up times as described in Table 1. Buijze et al. [8] measured the extent of union radiographically with computed tomography. We considered non-union when union extend was less than 50%. Cooney et al. [16] used only radiographic

Table 1. Characteristics and quality assessment of included studies.

	Study location	Recruitment period	Study design	Age (years)	Immobilization protocol details	Type/location of fracture	Rate of non-union per protocol	Diagnosis of non-union	Quality assessment score
Alho, 1979	Helsinki, Finland	January 1971 to November 1972	Prospective randomized study	mean 31 (range: 16–71)	53 – below elbow cast for average 48 days	Nondisplaced: 18 Transverse displacement: 10 Axial displacement: 23 Fragmented: 2 Distal: 3 Middle: 42 Oblique: 4 Proximal: 4	2/53	By clinical exam and X-ray findings up to 3 months following injury.	3*
					47 – above elbow cast for average 49 days (changed to below elbow at 6 weeks when required)	Nondisplaced: 18 Transverse displacement: 7 Axial displacement: 20 Fragmented: 2 Distal: 4 Middle: 41 Oblique: 1 Proximal: 1	6/47		
Buijze, 2013	United States, The Netherlands	July 2007 to January 2012	Prospective randomized study	With thumb: 33 +/− 14 years Without thumb: 42 +/− 18	31 below elbow cast with thumb cast for 10 weeks	Waist: 27 Distal: 4	4/31	By measuring extend of union at 10 weeks with computed tomography. We considered non-union when union $n < 50\%$.	5*
					31 below elbow cast with no thumb cast for 10 weeks	Waist: 28 Distal: 3	3/31		
Clay, 1991	United Kingdom	January 1986 to December 1988	Prospective non-randomized study	mean 29.7 (range 16–71)	143 below elbow cast with thumb cast for 10 weeks for 8 weeks on average	Transverse: 81 Horizontal oblique: 29 Distal pole: 15 Vertical oblique: 6 Proximal pole: 9 Unclassified: 4	14/143	By clinical exam and X-ray findings up to 6 months following injury.	15
					148 below elbow cast with no thumb cast for 10 weeks for 8 weeks on average	Transverse: 98 Horizontal oblique: 28 Distal pole: 10 Vertical oblique: 7 Proximal pole: 2 Unclassified: 3	15/148		
Cooney, 1980	United States	January 1976 to December 1978	Prospective non-randomized study	N/S	38 below elbow cast	Nondisplaced: 30	8/38	By X-ray or trispiral tomography. Timeframe undisclosed.	12
					7 above elbow cast	Nondisplaced: 2	0/7		
Gellman, 1989	United States	January 1986 to January 1988	Prospective randomized study	mean 30 (range: 14–57)	23 below the elbow cast	Proximal third: 3 Middle third: 18 Distal third: 2 Tuberosity: 0	2/23	By clinical exam and X-ray findings up to 6 months following injury.	4*
					28 above the elbow cast for 6 weeks followed by short arm cast	Proximal third: 2 Middle third: 22 Distal third: 3 Tuberosity: 1	0/28		
Hambidge, 1999	United Kingdom	N/S	Prospective randomized study	N/S	63 in wrist extension for8–12 weeks	Waist: 57 Distal pole: 6	8/63	By clinical exam and X-ray findings up to 4 months following injury.	12
					58 in wrist flexion for8–12 weeks	Waist: 54 Distal pole: 4	5/58		
Terkelsen, 1988	Denmark	July 1978 to January 1984	Retrospective study	Short arm: mean 31 (range 19–50) Long-arm: mean 26 (range 16–33)	44 below the elbow cast until clinical and radiographic union were found	Proximal: 2 Waist: 31 Distal: 7 Tubercle: 4	3/44	By clinical exam and X-ray findings up to 12 months following injury.	14
					48 above the elbow cast until clinical and radiographic union were found	Proximal: 3 Waist: 33 Distal: 6 Tubercle: 6	7/48		

*Jadad quality assessment score for clinical trials was used (Range of scores: 0–5).
MINORS criteria for quality assessment of observation studies was used (Range of scores: 0–24).
N/S: Not specified.

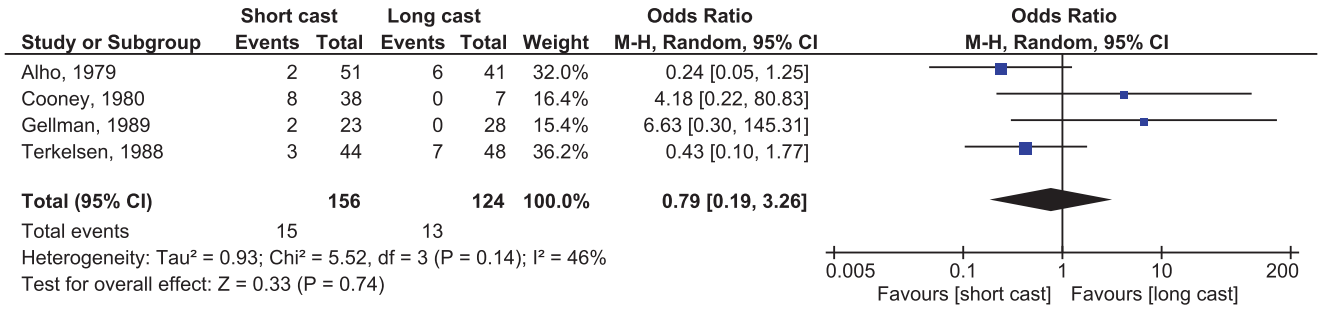

Figure 2. Forest plot for the comparison of short (below the elbow) versus long (above the elbow) cast.

information produced by X-rays or trispiral tomography, however no additional details were available.

Meta-analysis

We first performed a meta-analysis on non-union rates following conservative management with short-arm (below the elbow) cast versus long-arm (above the elbow) cast. We included 5 studies [15–18]. Non-union was observed in 15 out of 156 (9.6%) with short-arm casting and 13 out of the 124 (10.5%) with long-arm casting. Our meta-analysis showed a non-statistically significant 21% lower odds for non-union rates with short-arm cast (OR = 0.79, 95% CI [0.19, 3.26], $p = 0.74$, I^2=46%, Figure 2).

We then performed a meta-analysis on non-union rates following conservative management with a cast with thumb immobilization versus without. We included two studies [7,8]. Non-union was observed in 18 out of 174 (10.3%) with thumb immobilization cast and 18 out of the 179 (10.1%) without thumb immobilization. Our meta-analysis showed a non-statistically significant difference in non-union rates among the two modalities (OR = 0.97, 95% CI [0.49, 1.94], $p = 0.69$, I^2=0%, Figure 3).

We attempted to perform meta-analysis on the effect of wrist flexion versus wrist extension on union outcomes, but only one relevant study [19] was found and no meta-analysis was able to be performed for that outcome. In that particular study by Hambidge et al. position of the wrist was not found to affect the outcomes. (OR = 1.54, 95% CI [0.47, 5.01], $p = 0.47$, Figure 4).

Discussion

Scaphoid fractures are the most common carpal fractures [20,21]. Non-displaced or minimally displaced scaphoid fractures have been successfully treated non-operatively with short or long arm casting and with or without thumb immobilization [7,9,16,22]. It has been reported that 10% of conservatively treating patients may develop nonunion following immobilization [8,9,23]. We sought to investigate the role of cast choice in nonunion rates following non-operative management of scaphoid fractures.

After an extensive search of the literature, we identified seven relevant studies that fit our study criteria. Our meta-analysis showed that the use of the short arm cast was associated with lower rates of nonunion, however this difference was not statistically significant. We also found similar rates of non-union with or without thumb immobilization. We only identified one report by Hambidge et al. which studied the difference on outcomes between casts with wrist flexion or extension and found no difference in outcomes [19].

One of the most important factors in decreasing morbidity of non-displaced or minimally displaced scaphoid fractures, including the rate of nonunion, carpal collapse and avascular necrosis, is prompt diagnosis and casting [8,24,25]. The recommended timeframe for cast immobilization following injury is anywhere from 9–12 weeks to allow adequate healing and fracture union [17,26–28]. The type of cast immobilization may play a significant role in the management of scaphoid fracture. In general, patients desire minimal joint immobilization, pain and joint stiffness, maintenance of grip strength and early return to normal activity [29].

Among advocates of the long arm cast, is believed that the inhibition of pronation and supination with the long arm cast early on could potentially eliminate the shear forces across the fracture site [17,30]. In an early biomechanical study assessing the impact of forearm rotation on scaphoid fracture motion, displacement was seen in all specimens following pronation/supination, and thus immobilization with a long-arm cast was recommended [31]. However, more recent studies have contradicted these findings. One study that focused exclusively on short arm spica casts showed no significant fracture movement with this treatment and therefore concluded that this type of cast would be adequate for scaphoid fracture immobilization [22]. Additionally, an *in vivo* study by Kawanishi et al. that compared scaphoid fracture movement in short arm cast with and without thumb immobilization, showed non-significant or no scaphoid displacement, respectively [32]. In an optoelectronic motion analysis of wrist movement in patients with short arm casts with and without thumb immobilization, no benefit was seen in using a scaphoid cast over a Colles cast. These results mirror recent study of distal radius fracture treatment, which demonstrated no significant difference in reduction maintenance and clinical outcomes comparing short and long arm casts [33].

Clinically, Buijze et al. [8] found no detrimental effect on healing outcomes following use of Colles cast. Clay et al. [7] and Buijze et al. [8] demonstrated 18 (10.06%) nonunions in the thumb free group versus 18 (10.34%) in the thumb immobilization group ($p = 0.69$). Hambidge et al. [19] further strengthened the support for Colles casting with no difference in outcomes among those with wrist flexion or extension. One of the known disadvantages of the long arm cast is that it hinders the ability to participate in normal daily living activities, which may contribute to noncompliance with its consequences. This becomes extremely problematic in young adult laborers and athletes.

Interestingly, in the older studies included in our study, some authors decided to treat few displaced fractures conservatively. Although the severity of the displacement is not always clear, some useful information can be obtained. In one of them, the author found longer immobilization time for transversely displaced fractures [15]. Clay et al. identified that fractures displaced at the waist were more likely to have persistent radiologic findings of the fracture line, but no definitive non-union [7]. Similarly, Cooney at al. found lower union rates for displaced fractures versus non-displaced (65% versus 85%) [16]. Finally, Terkelsen et al.

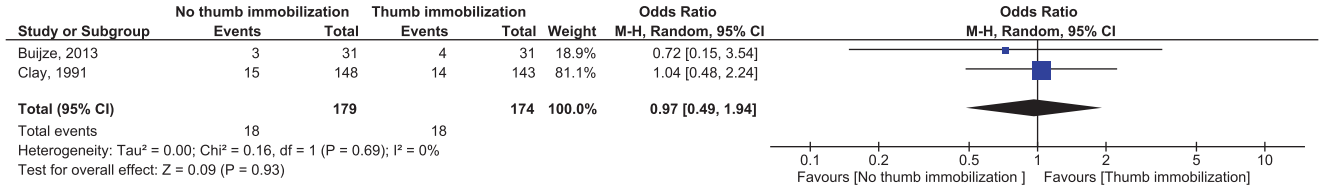

Figure 3. Forest plot for the comparison of cast with no thumb immobilization versus cast with thumb immobilization.

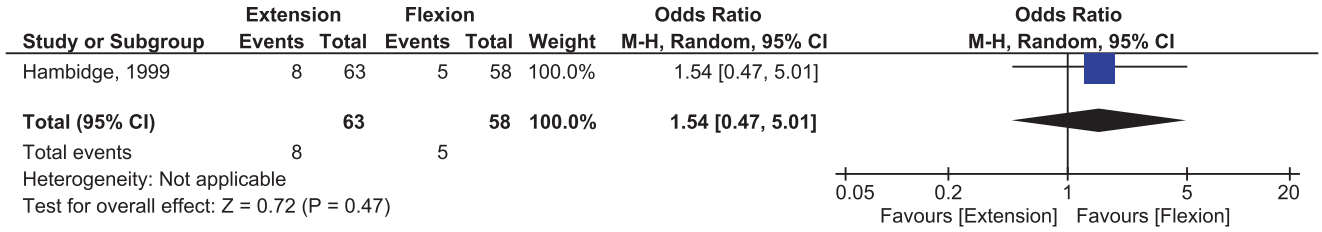

Figure 4. Forest plot for the comparison of short arm cast with wrist extension versus wrist flexion.

reported that of the 10 total non-unions in their study, only four of them were initially displaced [18].

Strengths-limitations

For our systematic review we performed a meticulous search of the literature. The Random Effects Statistical Model was used in order to minimize the effect of heterogeneity among the studies on our results. One source of heterogeneity is the discrepancy among the types of scaphoid fractures evaluated by the individual studies, including location, comminution, and amount and type displacement of the fracture. Another issue we faced was the heterogeneity among the way non-union was diagnosed among the different studies. Although similar principles were followed, differences exist which may introduce bias in our analyses. Additional high-quality trials that would standardize the definition of minimally displaced fractures, and the necessary diagnostic procedures (e.g. use of computed tomography) are warranted. Randomization of the patients based on the fracture type, other covariates, such as age, and comorbidities should also be considered by future studies [34].

Conclusion

Our systematic review and meta-analysis indicate that for the non-displaced or minimally displaced scaphoid fractures there is no significant difference in nonunion rates with the use of a long arm cast versus a short arm cast, or with or without thumb immobilization.

Ethical approval

This study conforms to the Declaration of Helsinki ethical principles for medical research. The study is exempt from IRB.

Author contribution

All of the authors have made substantial contributions to the following areas: 1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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