Is shortening of displaced mid-shaft clavicle fractures associated with inferior clinical outcomes following non-operative management? A systematic review.

Running title: shortened displaced mid-shaft clavicle fractures

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Abstract

Background

Management of displaced mid-shaft clavicle fractures is controversial. Non-operative treatment can lead to shortening, a risk factor for non-union and poor functional outcomes. These inferior results have resulted in authors recommending surgical fixation for fractures with significant shortening. The aim of this systematic review is to analyse the effect of fracture shortening on shoulder function and non-union rate in non-operatively managed displaced mid-shaft clavicle fractures.

Methods

A review of the online databases Medline and EMBASE was conducted in accordance with the PRISMA guidelines on the 16th February 2018. The review was registered prospectively on the PROSPERO database. Clinical studies with mid-shaft clavicle fractures treated non-operatively reporting an evaluation of the degree of clavicle shortening, and either shoulder function and/or non-union were included. The studies were appraised using the Methodological index for non-randomised studies tool.

Results

The search strategy identified 16 studies eligible for inclusion. Four studies were randomised controlled trials (RCTs) and twelve were non-randomised retrospective comparative studies. Eleven of the twelve case series failed to demonstrate any correlation between shortening and shoulder outcome scores. Of the four RCTs, three reported no significant association between fracture shortening and shoulder outcome scores. The studies also failed to demonstrate a significant association between non-union and the presence of clavicle shortening.

Conclusion

There is no significant association between fracture shortening and non-union rates or shoulder outcome scores in displaced mid-shaft clavicle fractures managed non-operatively.

Level of evidence: III

Key words: mid-shaft; clavicle; fracture; displaced; short; shoulder function, non-union; outcome;

Introduction

Mid-shaft fractures account for approximately 75% of all clavicle fractures and are most common in the young active population[26, 29]. Whilst undisplaced fractures do not require surgical treatment, displaced mid-shaft clavicle fractures can be successfully treated both operatively[14, 31] and non-surgically[9, 13]. Non-surgical treatment has been associated with a non-union rate of 15-21%[8, 9, 10, 30] with fracture shortening being reported as a risk factor for non-union[10, 21, 38].

The clinical relevance of fracture shortening remains debated with some studies showing no correlation with functional outcomes[18] whilst others report poorer functional outcomes with shortening[4, 20, 21]. Biomechanical studies have demonstrated that shortening results in altered scapular kinematics[16, 17] and this has been linked to persistent pain[4, 10, 11, 30]. Similarly the extent of shortening required to affect clinical outcome remains uncertain; previous studies have considered this to be 15mm[6, 10, 38] but more recent studies have suggested that shortening of ≥ 2cm alters scapulohumeral movement and functional outcome[3, 21]. As such, some studies advocate early operative management of shortened, completely displaced mid-shaft clavicle fractures citing decreased non-union rate, low complication rate and better functional results[3, 19, 39].

The aim of this systematic review is to analyse the effect of fracture shortening on shoulder function and the non-union rate in non-operatively managed displaced mid-shaft clavicle fractures.

Methods

A systematic review of the literature was conducted in accordance with the PRISMA guidelines[22] using the online databases Medline and EMBASE. The review was registered on the PROSPERO database on 6 March 2018 (Reference number CRD42018089799). The searches were performed independently by two authors on the 16th of February 2018 and repeated on the 5th of March 2018 to ensure accuracy. Any discrepancies were resolved through discussion between these two authors, with the senior author resolving any residual differences. The Medline search strategy is illustrated in Table I.

The eligibility criteria were: clinical studies published in the English language, study population comprising adult (aged >15years old) patients with mid-shaft clavicle fractures treated non-operatively, and a requirement for the studies to reporting an evaluation of the degree of clavicle shortening, and either shoulder function and/or non-union. Only primary research was considered for review with any abstracts, comments, review articles and technique articles excluded.

The clinical studies were appraised independently by two authors and quality assessment of non-randomised studies was completed using the Methodological index for non-randomised studies (MINORS) tool[34]. MINORS is a validated scoring tool for non-randomised studies. Each of the 12 items in the MINORS criteria were given a score of 0, 1, or 2, with maximum scores of 16 and 24 for non-comparative and comparative studies, respectively (Table II). The quality of randomised studies was measured against the Consolidated Standards of Reporting Trials (CONSORT) (Table III) checklist[32].

Results

The search strategy identified 16 out of 128 studies eligible for inclusion[5, 6, 7, 8, 9, 10, 12, 21, 23, 25, 27, 28, 33, 35, 36, 37]. Four studies were randomised controlled trials and twelve were non-randomised retrospective comparative studies. A flow chart of the search strategy is shown in Figure I. Study characteristics are summarised in Table IV. Table V and VI details the relation of clavicle shortening to shoulder function and the rate of non-union respectively.

Shortening

All studies determined clavicle shortening on plain radiographs, except for one study that used 3D CT scan9. The most frequently used radiographic views for this calculation were anteroposterior (AP) and cephalad tilted views ranging from 20 degrees to 45 degrees in addition to an AP view[3, 7, 8, 21, 23, 25, 27, 36]. Five studies relied on AP radiographs[5, 8, 9, 12, 35] whilst three had not reported on the type of radiographs used[28, 33, 37]. The amount of mean shortening in the studies ranged from 7.7mm (SD 3)[5] to 25mm (SD 16)[35].

Outcome Scores

Shoulder outcomes were assessed objectively either using the Disability of Arm, Shoulder and Hand (DASH) score or the Constant-Murley score (Table V). Three studies reported the DASH score only[7, 36, 37] and seven studies reported the Constant score only[5, 7, 12, 23, 25, 27, 28]. Five studies reported both the DASH and Constant scores[3, 8, 9, 21, 35].

The mean Constant score ranged from 78.28[33] to 96.75[5]. There were 3 RCTs that reported the Constant score[5, 9, 36]. Two of these RCTs[5, 9] did not demonstrate any correlation between shortening and inferior outcome scores. Goudie et al.,[9] found that shortening of ≤1cm or ≥2cm has no effect on the Constant score. Ersen et al.,[5] reported upon 11 patients with >15mm of shortening in their RCT and also reported no association with shoulder outcome scores. The third RCT[3] showed a mean Constant score of approximately 91 but did not comment on any correlation with fracture shortening.
There were nine non-randomised comparative studies reporting Constant scores[8, 12, 21, 23, 25, 27, 28, 33, 35]. Seven of these studies[8, 21, 23, 25, 27, 28, 35] did not demonstrate any statistically significant correlation between shortening and the Constant score.

However Lazarides et al.[12] reported that shortening of >18mm in males, or >14mm in females, was associated with significantly inferior patient satisfaction, and a Constant score defined as <70, as a subjectively unsatisfactory result in both genders (χ^2 test $p<0.05$). The final study[33] did not comment on the correlation of shortening and shoulder function.

The mean DASH score ranged from 2.3[37] to 24.6[21]. There were 3 RCTs[3, 9, 36] that reported the DASH score. Two RCTs[9, 36] showed shortening does not affect outcome scores with Goudie et al.,[9] showing that shortening of ≤1cm or ≥2cm has no effect on the DASH score. Whereas the third RCT from the Canadian Orthopaedic Trauma

Society, showed increased shortening was associated with higher DASH scores (r=0.326, p=0.05)[3].

There were 5 comparative studies reporting the DASH score[7, 8, 21, 35, 37], and all five showed no correlation between shortening and the DASH score. McKee et al.[21] did report that a higher DASH score (>30 points) was recorded for patients with shortening of ≥2cm but this was not statistically significant (p=0.11).

Non-unions

Eleven studies (Table VI) reported the rate of non-union[3, 7, 8, 9, 10, 23, 25, 27, 33, 36, 37], which ranged from 0% to 17%[9, 23]. The rate of non-union in the non-operative group was over 14% in all three RCTs[3, 9, 36] reporting on non-union rate. None of the RCTs provided an analysis of correlation between shortening and non-union rate.

Of the eight non-randomised comparative studies reporting non-unions[7, 8, 10, 23, 25, 27, 33, 37], only three[7, 8, 10] commented on non-union rate and shortening. Fuglesang et al.,[8] reported a non-union rate of 15% (9 cases) but they found no difference in initial shortening in patients who went on to non-union fractures versus those that had fractures united. Figueiredo et al.[7] reported a non-union rate of 11.1% (6 cases) and all 6 non-unions had less than 1cm of shortening. In contrast Hill et al.,[10] reported 7 non-unions (15%) of which 6 had shortening of >2cm. Hill et al.[10] concluded that initial shortening of >2cm was significantly associated with the development of non-union (Fisher's exact test p<0.0001).

A funnel plot of all eleven studies[3, 7, 8, 9, 10, 23, 25, 27, 33, 36, 37] reporting non-union rate demonstrated a symmetrical spread of data points suggesting no significant bias was present (Figure II).

Discussion

The main finding of this systematic review was that there is no clear effect of fracture shortening on shoulder outcome scores [5, 7, 8, 9, 13, 21, 23, 25, 27, 28, 33, 35, 36, 37]. Of the four RCTs reviewed, which provided the highest level of available evidence, three reported no significant association between fracture shortening and functional outcome[5, 9, 36]. Although the COTS study[3] did report increased shortening to be associated with significantly higher DASH scores, the validity of these findings are questioned by the failure to reproduce these results either within the study using the Constant score or in any of the other more recent RCTs reviewed[5, 9, 36]. This main finding is further supported by eleven of the twelve case series, which failed to demonstrate any correlation between shortening and shoulder function[7, 8, 12, 21, 23, 25, 27, 28, 33, 35, 37].

Neither of the two studies[3, 10] reporting inferior shoulder function with clavicle shortening were able to define an absolute value of shortening acceptable for a good shoulder function. In addition, these two studies had limitations that may explain this discrepancy in results. This included heterogeneity in the way shortening was measured as well as the method of immobilisation of the fractured clavicle, which varied in different studies. Hill et al.[10] reported that final shortening of ≥2cm was associated with unsatisfactory results ($p < 0.0001$). However this study had significant limitations as demonstrated by the methodological items for non-randomised (MINORS) score of 8, which is the lowest score attributed to any of the clinical studies included in this systematic review. The main weakness was the failure to provide an objective way of assessing shoulder function to validate these conclusions.

Although eleven studies reported the non-union rate (mean ranged from 0 to 17%), only three studies[7, 8, 10] specifically analysed for correlation between fracture shortening and union rate. These three studies were all case series thus providing a lower level of evidence for review. Fuglesang et al.[8] performed multivariate logistic regression analysis and reported that the odds ratio for the risk of non-union more than doubled for every 10 years increase in patient age ($p=0.04$) and was five times higher in females but no correlation with fracture shortening was demonstrated. The other two studies[7, 10] did not perform a multivariate analysis to account for other known risk factors predisposing to non-union. Results varied with Hill et al.[10] demonstrating significant association between shortening and non-union ($p<0.0001$) and Figueiredo et al.[7] reporting higher non-union rate in those with shortening <1cm. Therefore, the studies reviewed provide limited data and contrasting results on the association between non-union and clavicle shortening in non-operatively managed fractures.

Clavicle shortening was calculated using (AP) radiographs in all but one study in this SR. Shortening measurements taken on radiographs depend on the views taken and can be subject to error depending on the estimates made if the film is not calibrated.

Malik et al.[15] demonstrated significant changes ($p < 0.001$) in fracture shortening measurement by altering patient position; in the supine position shortening was −0.41mm (95% CI, −2.53 to 1.70mm) whilst in the upright position it was 4.86mm (95% CI, 1.66–8.06mm). Only one included study measured shortening using CT scans which has been demonstrated to be a more accurate method of assessing fracture shortening than plain radiographs.[1,24] The increased radiation dose associated with CT imaging would be a concern if introducing CT as the routine imaging modality to measure fracture shortening for mid shaft clavicle fractures. The radiation dose for a CT scan of the shoulder (2.06s mSv)[2] is higher than that of a plain chest radiograph (0.1mSv). As this systematic review has failed to demonstrate any correlation between fracture shortening and either outcome scores or non-union, routine CT imaging to enable accurate measurement with the subsequent risk of radiation exposure cannot be recommended at the present time. It is a limitation of this review that there was considerable variability between studies with respect to the methods used to calculate shortening and also that none of the included studies attempted to evaluate malrotation at the fracture site. It is plausible that malrotation may be of greater clinical importance than shortening because it more profoundly affects scapula position. Further study of this aspect is required.

Appraisal of the Randomised studies were found to be CONSORT compliant (Table III) with scores ranging between 22 and 25 (maximum score 25). Appraisal of the non-randomised clinical studies using the Methodological index for non-randomised studies (MINORS) tool demonstrated a variety of limitations, which are summarised in Table II. The MINORS scores ranged from 8 to 14 for non-comparative studies (maximum score 16), and from 16 to 18 for comparative studies (maximum score 24).

Common limitations of the non-comparative studies included assessment of endpoints, an acceptable loss to follow-up rate (<5%), and prospective sample size calculation. Common weaknesses of the comparative studies were failure to demonstrate baseline equivalence between groups, and how the shortening was measured on radiographs depending on the type of the radiograph views taken. Furthermore, not all studies had looked at a cut-off point of shortening affecting shoulder function and those that did consider 15mm or 2cm had a very small number of patients within these groups potentially skewing results. Another weakness is the length of follow-up time in these studies, which varied from 50 days to 8.7 years.

This systemic review has analysed clinical studies including RCTs that evaluated displaced mid-shaft clavicle fractures and the effect of shortening on shoulder outcome scores. The SR overall shows that shortening in mid-shaft displaced clavicle fractures managed non-operatively does not have an effect on outcome scores. We therefore recommend that shortening should not be routinely used to predict outcome after non-operative management of displaced mid-shaft clavicle fractures.

Conclusion

There is no significant association between fracture shortening and non-union rates or shoulder outcome scores in displaced mid-shaft clavicle fractures managed non-operatively.

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Table legends

Table I – Search strategy for Ovid MEDLINE

Table II – Methodological items for non-randomised studies (MINORS) Scores for clinical studies

Table III – The Consolidated Standards of Reporting Trials (CONSORT) for randomized controlled trials (RCTs)

Table IV – Summary of 16 clinical studies

Table V – Summary of clinical studies and functional outcomes in relation to shortening.

Table VI. Summary of clinical studies and non-union.

Shortened, displaced mid-shaft clavicle fractures

Figure Legend

Figure I: Flow diagram of review process

Figure II: Funnel plot showing the Non-union rates in included studies

Figure (No.I)

Figure I: Flow diagram of review process

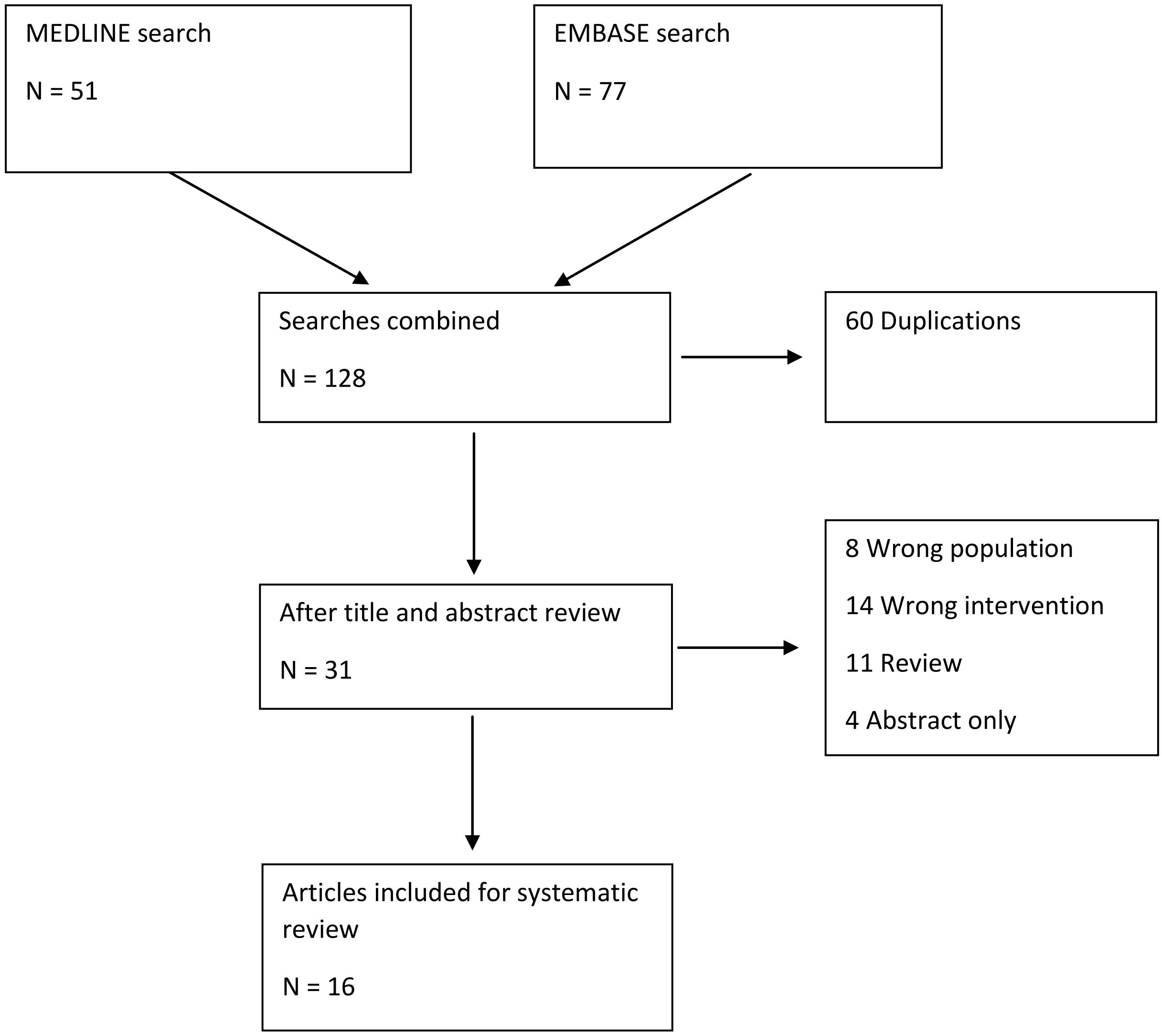

Figure (No.2)

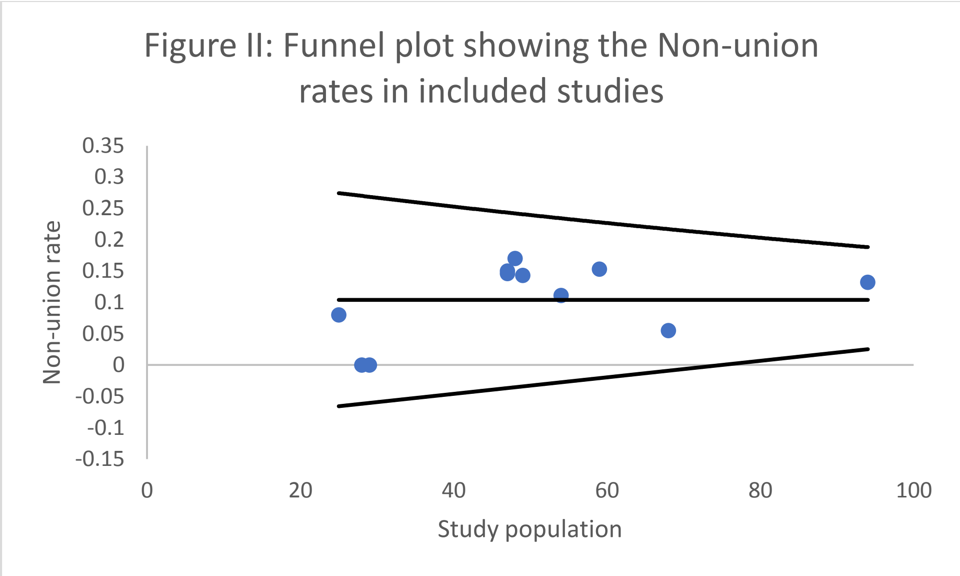

Figure II: Funnel plot showing the Non-union rates in included studies
Non-union rate
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
20
40
60
80
100
Study population

Table I: Search strategy for Ovid MEDLINE

Search Number	Search Term	Results
1	"Clavicle"[tw] OR "clavicular"[tw] OR "clavicula"[tw]	9255
2	"fractures, bone"[MeSH] OR "fractures"[tw] OR "fracture"[tw]	269298
3	"midshaft"[tw] OR "mid-shaft"[tw] OR "mid shaft"[tw] OR "middle third"[tw] OR "middle-third"[tw]	5906
4	"Shortening"[tw] OR "Shortenings"[tw] OR "shortened"[tw]	84405
5	"conservative"[tw] OR "conservatively"[tw] OR "nonoperative"[tw] OR "nonoperatively"[tw] OR "non-operative"[tw] OR "non-operatively"[tw] OR "nonsurgical"[tw] OR "nonsurgically"[tw] OR "non-surgical"[tw] OR "non-surgically"[tw]	142964
6	"sling"[tw] OR "immobilisation"[tw] OR "immobilization"[MeSH Terms] OR "immobilization"[tw] OR "bandages"[MeSH] OR "bandages"[tw] OR "bandage"[tw]	93110
7	1 AND 2 AND 3 AND 4 AND 5 AND 6	55
8	Limit 7 to “English” AND “Human”	51

Tables (No. 2)

Table II. Methodological items for non-randomised studies (MINORS) Scores for clinical studies

	Clearly stated aim	Inclusion of consecutive patients	Prospective data collection	Endpoints appropriate to study aim	Unbiased assessment of study endpoint	Follow-up period appropriate to study aim	<5% lost to follow-up	Prospective calculation of study size	Adequate control group	Contemporary groups	Baseline equivalence of groups	Adequate statistical analyses	Total
Tutuhatunewa et al., [37] n=94	2	2	1	1	1	1	1	0	2	2	1	2	16/24
Nordqvist et al., [23] n=29	2	2	1	2	0	2	1	0	n/a	n/a	n/a	n/a	10/16
Stegeman et al., [35] n=32	2	0	2	2	1	0	2	0	n/a	n/a	n/a	n/a	9/16
Hill et al., [10] n=47	0	2	2	1	0	2	1	0	n/a	n/a	n/a	n/a	8/16
Fuglesang et al., [8] n=59	2	2	2	2	1	2	1	0	n/a	n/a	n/a	n/a	12/16
Lazarides S & Zafiropoulos G [12] n=132	2	2	2	2	1	2	1	0	n/a	n/a	n/a	n/a	12/16
Oroko et al., [25] n=28	2	0	2	2	0	1	2	0	n/a	n/a	n/a	n/a	9/16
McKee et al ., [21] n=30	2	2	2	2	2	2	2	0	n/a	n/a	n/a	n/a	14/16
Postacchini et al., [27] n=68	2	2	2	2	2	2	1	0	n/a	n/a	n/a	n/a	13/16
Figueiredo et	2	2	2	2	0	2	1	0	n/a	n/a	n/a	n/a	11/16

al., [7] n=54													
Shukla et al. [33] n=25	2	2	2	2	0	1	2	0	2	2	1	1	17/24
Rasmussen et al., [28] n=136	2	2	2	2	0	2	2	0	2	2	0	2	18/24

The items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The global ideal score being 16 for non-comparative studies and 24 for comparative studies.

Tables (No. 3)

Table III. The Consolidated Standards of Reporting Trials (CONSORT) for randomized controlled trials (RCTs)

	Item no	Goudie et al., [9] n=48	Tamaoki et al., [36] n=47	Ersen et al. [5] n=51	COTS. [3] n=49
Title and abstract	1a, 1b	Y	Y	Y	Y
Introduction					
Background and objectives	2a, 2b	Y	Y	Y	Y
Methods					
Trial design	3a, 3b	Y	Y	Y	Y
Participants	4a, 4b	Y	Y	Y	Y
Interventions	5	Y	Y	Y	Y
Outcomes	6a, 6b	Y	Y	Y	Y
Sample size	7a, 7b	Y	Y	Y	Y
Randomisation: Sequence generation Allocation concealment mechanism	 8a, 8b 9	 Y N	 Y Y	 Y Y	 Y Y
Implementation	10	N	Y	Y	N
Blinding	11a, 11b	N	Y	N	N
Statistical methods	12a, 12b	Y	Y	Y	Y
Results					
Participant flow (a diagram is strongly recommended)	13a, 13b	Y	Y	Y	Y
Recruitment	14a, 14b	Y	Y	Y	Y
Baseline data	15	Y	Y	Y	Y
Numbers analysed	16	Y	Y	Y	Y
Outcomes and estimation	17a, 17b	Y	Y	Y	Y
Ancillary analyses	18	Y	Y	Y	Y
Harms	19	Y	Y	Y	Y
Discussion					
Limitations	20	Y	Y	Y	Y
Generalisability	21	Y	Y	Y	Y
Interpretation	22	Y	Y	Y	Y
Other information					
Registration	23	Y	Y	Y	Y
Protocol	24	Y	Y	N	N
Funding	25	Y	Y	Y	Y
Total	25	22/25	25/25	23/25	22/25

Table IV – Summary of 16 clinical studies

Study	Study Design	Population	Intervention (s)	Comparator	Follow up	Outcome	Results
Goudie et al., [9] n=48	RCT	33 years (SD12.5)	Collar & cuff		12months	DASH Constant Score SF-12	Mean shortening 11.3mm (SD 7.6mm)
Tamaoki et al., [36] n=47	RCT	34.6 years (SD 12.6) 81% male	Figure of eight		12months	DASH VAS - Pain	Mean shortening 9.3mm (SD 6.6) Mean VAS (pain) = 0.38 No restriction in the range of shoulder movement
Ersen et al., [5] n=51	RCT	31.6 years (15-75)	Figure of eight *vs* Sling		8.3m (6-12)	Constant score ASES VAS - Pain	Mean shortening = 9mm (SD; figure of eight) ; 7.7 (SD 3: broad arm sling). Maximum shortening 24mm in broad arm sling. VAS at day 21 = 0.6 in figure of eight, and 0.5 for sling p=0.9
COTS [3] n=49	RCT	33.5 years	Sling		52 weeks	DASH Constant	Mean shortening = 14.3 mm
Tutuhatunewa et al., [37] n=94	Retrospective Observational study	42.4 years (25.6-55.8) 78% male	Sling or Collar and cuff		50 days (25.8-106.8)*	QuickDASH VAS – pain Health-related quality of life (Eq-5D-5L),	Average shortening = 24.7mm (SD 15.6) Median VAS 0 (10.0-1.4)
Nordqvist et al., [23] n=29	Retrospective case series	>15years	Not stated		5 years	Constant score Non-union ROM	Shortening = 11.1mm (CI 8.2-14.0) There was no statistically significant difference in active ROM (p-value not given).
Stegeman et al., [35]	Retrospective	31 years (21-62)	Not stated		Not stated	Constant score	Mean shortening = 25mm (SD 16)

n=32	Observ ational study	84% male				DASH	
Hill et al., [10] n=47	Retros pective case series	34years (18-59 years) 71.1 % men	Figure of eight *vs* Sling *vs* No treatment		38months (15-68 months)	Non-union Pain Paraesthesi a	Mean shortening 11.8mm (0-22mm) Final shortening of ≥2cm associated with unsatisfactory results.
Fuglesang et al., [8] n=59	Retros pective case series	39.1 years (SD 12.3) 83% male	Sling for 2 weeks		2.7 years	Constant score DASH VAS Non-union	Mean initial shortening =15mm (12-20mm) Mean shortening in united fractures = 15mm (7.8-18.3) Median VAS (pain) = 1.3
Lazarides S & Zafiropoulos G [12] n=132	Retros pective	M = 25.4 years (16-72) F = 34.2 years (15-77)	Broad arm sling		30months (12-43)	Constant score Pain ROM	Shortening in male = 14.4mm (SD 8.5) Shortening in females = 11.2mm (SD 7.3) ROM impairment =18 (13.6%) Pain = 40 (30.3%)
Oroko et al., [25] n=28	Retros pective case series	40 years (13-83) 76% male	Broad arm sling or Polysling or Collar & cuff		38 weeks (16wk – 3 years)	Constant score Non-union	Median shortening = 10mm (range 0-30mm)
McKee et al., [21] n=30	Retros pective	37years (19-67)	Sling		55months (12-72)	DASH Constant score ROM	Mean shortening = 14.1mm (SD 8.9)
Postacchini et al., [27] n=68	Retros pective case series	36.9 years	Figure of eight or sling		8.7 years	Constant Score Non-union	Shortening in males = 14.1mm (SD 8.9) & Shortening in females = 10.9mm (SD 7.8) Overall the mean OV and DS were 12% and 1.6 cm respectively.
Rasmussen et	Retros	35 years	Figure of eight		55month	Constant	Average shortening = 11.6m (SD 9.0)

al., [28] n=136	pective case series	(15-70 years) male 79%	or sling or collar & cuff		(24-83)	score	Shortening in Sling = 10.9mm (SD 7.3) Shortening in figure of eight = 12mm (SD 7.3) Mean difference in shortening = 1.2mm (95% CI -1.9 – 4.2) p=0.45
Shukla et al., [33] n=25	Case control series	32.6 years (SD 6 .43)	Clavicle brace		6months	Constant Score Union time	Mean shortening = 19.36 mm Mean radiographic union time was 23.45 +/- 1.40 weeks
Figueiredo et al., [7] n=54	Prospe ctive cohort study	34 years (17-64) SD12.73 81.4% male	Figure of eight		1 year	DASH VAS (pain)	Mean shortening = 9.2 mm (0-30mm) SD 6.4 VAS = 0.34 (0-5) SD 0.98

* data presented as median (first quartile - third quartile)

RCT – Randomised control trial; DASH - The Disabilities of the Arm, Shoulder and Hand; VAS - Visual Analogue Scale; ROM – range of impairment

Table V – Summary of clinical studies and functional outcomes in relation to shortening.

Study	Mean Shortening (mm)	Mean Constant Score	Mean DASH score	Correlation between shortening and function
Goudie et al., [9] n=48	11.3 mm (SD 7.6mm)	88.7 (12.3)	4.9 (SD 10.5)	Shortening of ≤1cm or ≥2cm has no effect on DASH or Constant Score.
Tamaoki et al., [36] n=47	9.3 mm (SD 6.6)	-	3 (SD 9.4)	Shortening does not have an affect on shoulder function
Ersen et al. [5] n=51	9mm (SD 3) in figure of eight 7.7 mm (SD 3) in broad arm sling	96 (80-100) for figure of eight 96.75 (75-100) for sling	-	Shortening not associated with lower functional results.
COTS [3] n=49	14.3 mm	91*	14*	Increased shortening leads to higher DSAH scores (r=0.326, p=0.05).
Tutuhatunewa et al., [37] n=94	24.7mm (SD 15.6)	-	2.3 (0 – 14.2)#	No disadvantage with shortening on overall shoulder function.
Nordqvist et al., [23] n=29	11.1mm	93 Injured v 93 contralateral shoulder	-	No statistically significant difference between shortening and Constant score (Stepwise Regression analysis)
Stegeman et al., [35] n=32	25mm (SD 16)	96 (SD 5.3)	5.2 (SD 6.3)	Constant score & DASH were not affected by clavicle shortening.
Fuglesang et al., [8] n=59	15mm	81 (69-90)	6.7 (0.8-19)	No correlation demonstrated DASH p=0.1 Constant score p=0.5
Lazarides S & Zafiropoulos G [12] n=132	14.4mm in males 11.2mm in females	84 (62 -100)	-	Constant score <70 significantly associated with a subjectively unsatisfactory result in both genders (X^2 -test, P <0.05) Patient dissatisfaction if shortening >18mm in males

				(X^2 test, p <.001) and >14mm in females (Fisher exact test, p < .001)
Oroko et al., [25] n=28	10mm (range 0-30mm)	90 (44-100) injured v 100 (66-100) contralateral shoulder	-	No correlation between shortening and Constant score.
McKee et al., [21] n=30	14.5 (SD 8.6) <20mm n=19 (63%) ≥20mm n=11 (37%)	71	24.6	No correlation between shortening and the DASH score (r = 0.315, p = 0.11) or the Constant score (r = −0.196, p = 0.44)
Postacchini et al., [27] n=68	14.1mm (SD 8.9) male 10.9mm (SD 7.8) female	87.1% 1b 85.6% 1c for 1b & 1c CS ≥90% (n=55) OV 7.7% CS ≤80 (n=9) OV 13.2%	-	If overlap is 7.7% (11.6mm), CS is ≥90%, If overlap was 12%, Constant score was between 81-89%.
Rasmussen et al., [28] n=136	11.6m (SD 8.2) ≥20mm n=20	86.3 (29-100) 93.7 (81–100) contralateral shoulder		No correlation between shortening of the clavicle and the clinical outcome (r = 0.14, P> 0.05).
Shukla et al., [33] n=25	19.36mm	78.28	-	-
Figueiredo et al., [7] n=54	9.2 mm (0-30mm) SD 0.64	-	3.38 (0-58) SD 9.21	No correlation between the shortening and the DASH score at six weeks or one year (p = 0.073 and 0.706 respectively). Setting a minimum threshold of 2 cm shortening did not improve the correlation.

*figures taken from graph as not mentioned in the text.
data presented as median (first quartile - third quartile)
DASH - The Disabilities of the Arm, Shoulder and Hand; CS – Constant score; SD – standard deviation

Table VI – Summary of clinical studies and non-union.

Study	**Number of patients**	**No of non-unions (%)**	**Correlation between shortening and non-union, where recorded.**
Goudie et al., [9]	48	16 (17%)	Non-unions excluded form the results to avoid skewness
Tamaoki et al., [36]	47	7 (14.9%)	5 patients remained asymptomatic.
COTS [3]	49	7 (14.3%)	-
Tutuhatunewa et al., [37]	94	20 (13.2%)	Delayed union and non-union grouped together
Nordqvist et al., [23]	29	0	-
Hill et al., [10]	47	7 (15%)	6 had shortening >20mm. Shortening of >20mm significantly associated with non-union (Fisher's exact test, $p < 0.0001$).
Fuglesang et al., [8]	59	9 (15.3%)	No difference in initial shortening of non-unions versus to those that united.
Oroko et al., [25]	28	0	-
Postacchini et al., [26]	68	5 (5.5%)	-
Shukla et al. [33]	25	2 (8%)	-
Figueiredo et al., [7]	54	6 (11.1%)	All 6 non-unions had less than 1cm of shortening.