Operative Versus Non-operative Management of Mid-diaphyseal Clavicle Fractures in the Skeletally Immature Population: A Systematic Review and Meta-analysis

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Abstract

Purpose The purpose of this study is to compare the outcomes and complications of operative vs non-operative management of mid-diaphyseal clavicle fractures in the skeletally immature population.

Recent Findings Traditionally, skeletally immature clavicle fractures have been managed non-operatively. However, there has been an increasing trend towards operative management with a lack of evidence indicating its effectiveness.

Methods Two reviewers searched three online databases (MEDLINE, EMBASE and PubMed), independently and in duplicates, for literature comparing the outcomes and complications of operative versus non-operative management in skeletally-immature patients (defined as birth to 18 years of age) with a mid-diaphyseal clavicle fracture. Where possible, risk ratios (RR) and mean differences (MD) were combined using a random effects model.

Results Seven studies, containing 522 skeletally immature patients (with 528 mid-diaphyseal clavicle fractures) with an age range of 8 to 18 years, with 148 patients undergoing operative management and 380 patients undergoing non-operative management, were included. Across the 6 studies that reported gender ($N = 444$), there were 335 males and 109 females. Patients were followed up from 2 weeks to 3.7 years across five studies ($N = 201$ patients) that reported follow-up time. There was no significant difference in the time to achieve union ($p = 0.1$), the time to return to activity ($p = 0.09$), and the overall complication rate ($p = 0.50$) between the operative and the non-operative groups.

Summary There is no significant difference between operative and non-operative management of skeletally immature mid-diaphyseal clavicle fractures. Clinical equipoise exists to study this further by means of a prospective, randomized, blinded control trial.

Level of Evidence Level IV, systematic review and meta-analysis of level II, III, and IV.

Keywords Clavicle fracture · Mid-diaphyseal · Midshaft clavicle · Skeletally immature · Pediatrics

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Introduction

Clavicle fractures represent the most common type of fracture in skeletally immature patients and account for approximately 10–15% of all fractures [1–4]. The mid-diaphyseal region is the most commonly affected region of the clavicle, accounting for 90% of clavicle fractures [4, 5]. This region is presumed most affected due to the local change in osseous shape of the clavicle in the middle region from concave to convex in the frontal plane and from round to flat on cross section [6]. The management of mid-diaphyseal clavicle fractures in skeletally immature patients is poorly investigated, and, in the absence of tenting of the skin with potential for necrosis, open/compound fractures, and/or fractures associated with polytrauma and/or neurovascular injury, there is a lack of consensus among physicians on the optimal treatment method [7].

The consideration of operative versus non-operative management has been extensively explored in the skeletally mature population, and there has been an increasing trend towards operative management due to a reported improvement in functional outcomes [7]. However, this trend has been recently mirrored onto the skeletally immature population with a lack of level I evidence supporting operative management over non-operative management [7]. Children and adolescents have excellent healing and remodeling potential due to the active adjacent physis and the increased vascular supply within the thick periosteum. The periosteum also limits the degree of displacement of the fractured clavicle, and surgical consideration is often individualized and considered only in extreme cases [8]. Furthermore, “children are not little adults” and have distinctive anatomical features of the developing clavicle making surgical indications difficult, and surgery should be considered only in extreme cases and with consultation with the patient and the patient’s families [9].

The purpose of this study was to compare the outcomes and complications of operative versus non-operative management of mid-diaphyseal clavicle fractures in the skeletally immature population.

Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and Revised Assessment of Multiple Systematic Reviews (R-AMSTAR) guidelines were used in the design of this study [10, 11]. The design and execution of this study included items such as a priori design, duplicate study selection and data extraction, scientific quality assessment of the included studies, appropriate methods for combining study findings, and assessment of publication bias [11].

Design and Eligibility Criteria

The research questions, inclusion, and exclusion criteria were established a priori and agreed upon by two reviewers (XX and XX). The included literature studies followed the following criteria: (1) original research articles, (2) all levels of evidence, (3) articles in English language, (4) published after January 1, 1999, (5) looking at skeletally immature patients (between birth and 18 years of age), (6) with mid-diaphyseal clavicle fractures and (7) comparing operative versus non-operative management. The exclusion criteria included (1) non-original articles such as opinion articles, editorials, abstracts, commentaries, case studies, conference papers and systematic reviews, (2) studies looking at distal or medial clavicle fractures, (3) studies with patients that have medical comorbidities that preclude surgery or any genetic abnormalities, and (4) open fractures, displaced fractures with tenting of the skin with impending skin compromise, or neurovascular injury.

Search Strategy

Two reviewers searched three online databases (MEDLINE, EMBASE, and PubMed); additionally, further studies were extracted following a full reference screen of the relevant articles. The databases were searched on December 17, 2018, for the literature related to management of mid-diaphyseal clavicle fractures in skeletally immature patients. The search terms are presented in the [Appendix](#).

Study Screening

The studies were screened by two reviewers (XX and XX) independently in all stages (title, abstract, and full-text screen). All inconsistencies in the criteria during the title and abstract screening stages were carried on to the next screening stage and were discussed between reviewers during the full-text stage to settle any discrepancies.

Quality Assessment of Included Studies

Methodological Index for Non-Randomized Studies (MINORS) was used to assess the quality of the included papers [12]. The assessment tool contained 12 items, the last 4 being specifically for comparative studies. Items adequately reported were at *low risk* and given a score of 2, items not reported represented a *high risk* and were given a score of 0, and items that were unclear were given a score of 1. The maximum achievable score is 24.

Interviewer Agreement

Kappa scores were calculated to determine the reviewer’s agreement at each stage of the screening process [13]. In

general, $k > 0.6$ represents substantial agreement, a k value between 0.1 and 0.6 represents moderate agreement, and a $k < 0.2$ represents weak agreement [13]. The kappa values of this study were all above the 0.6 k value threshold representing a substantial agreement between the reviewers.

Data Abstraction

Data was collected and recorded into predetermined tables independently by the reviewers (XX and XX), in Excel 2016 (Microsoft, Redmond, WA, USA). The following information, if available, was extracted from the studies: primary author and year, study design, patient age, number of male versus female patients, number of operative versus non-operative patients, management techniques, outcomes (including time to achieve union, time to return to activity, DASH, and other functional scores), and complications. Pooling of the overall complication rate was performed similar to a meta-analysis conducted in the skeletally mature population [14] and included complications such as the incidence of malunion, delayed union, nonunion, refracture, implant failure, additional/secondary requirement for surgical intervention, and cosmetic deformity.

Data Analysis

Synthesis of quantitative results and the pooled analysis was performed using RevMan [15]. To compare the effects of treatments, the mean difference (MD) with 95% confidence intervals (CI) was used for continuous data, and the risk ratio (RR) with 95% CI was used for dichotomous variables. A priori decision was made between reviewers that a minimum of three trials would be required for pooling of an outcome. For studies not reporting the standard deviation (SD), the *Cochrane Handbook for Systematic Reviews* was used to estimate the SD [16]. The differences of study methods as well as the definition of complications/outcomes were expected to yield heterogeneity among the studies used. Heterogeneity was assessed using the I^2 test [16]. I^2 values between 0 and 0.4 represent low heterogeneity, between 0.3 and 0.6 represent moderate heterogeneity, and above 0.5 represent substantial/high heterogeneity [16]. The studies were weighted based on the inverse variance, and pooling was done using a random effects model. The results from outcomes not viable for pooling were summarized for each study in a narrative fashion.

Results

Search Strategy and Study Characteristics

The results of the search strategy are depicted in Fig. 1. Initially 981 studies were identified across all three databases.

Finally, seven studies were deemed eligible for the synthesis of the quantitative data [1, 3, 4, 17–20]. The seven studies included a total of 522 patients (with 528 mid-diaphyseal clavicle fractures) with an age range of 8 to 18 years, 148 underwent operative management, and 380 underwent non-operative management. The study characteristics are depicted in Table 1. Across the 6 studies that reported gender, there were 335 males and 109 females [3, 4, 17–20]. Patients were followed up from 2 weeks to 3.7 years across five studies that reported follow-up time [1, 3, 4, 19, 20]. Across the 6 studies reporting displacement, all fractures were displaced in the operative group, and 221 out of 369 fractures were displaced in the non-operative group [1, 3, 4, 17, 18, 20]. The degree of displacement and/or shortening reported by each study is represented in Table 2.

MINORS Score

Results of the MINORS assessment of the seven included studies, completed in duplicates among reviewers (XX and XX), are depicted in Table 1. The scores of the included studies ranged from 16 to 20. All studies adequately reported items such as a clearly stated aim, inclusion of consecutive patients, and prospective calculation of the study size. All studies did not report unbiased assessment of the study endpoint item.

Time to Achieve Union

Four of the included studies reported the radiographic time to achieve union [1, 3, 4, 20]. Union was defined in the studies as follows: bony bridging [3], the healing of at least three cortices [4], the formation of a complete bridging callus with the elimination of the fracture lines [20], or by the attending surgeon [1]. Two studies indicated a significantly earlier time to achieve union in the operative groups vs the non-operative group (7.3 ± 1.0 vs 10.4 ± 1.0 mean weeks; $p = 0.001$ and 7.39 ± 1.58 vs 9.50 ± 3.246 mean weeks; $p = 0.0259$) [3, 4]. The two other studies did not report a significant increase in time to union between operative vs non-operative groups [1, 20]. Overall the pooled results did not demonstrate a significant difference between the operative ($N = 106$) and the non-operative groups ($N = 77$) ($p = 0.10$) (Fig. 2).

Time to Return to Activity

Three of the included studies reported the time to return to activity [1, 3, 4]. The three studies defined time to activity as the time to return to full activities [1, 3, 4]. The decision regarding when to return to activity was not clearly stated across the included studies, with the exception of one, which was if radiographic evidence was present and the clavicle was not tender [4]. Two studies reported a significantly earlier time to return to activity in the operative group vs the non-operative

Fig. 1 PRISMA flow diagram outlining the screening process and the included/excluded studies at each screening stage

group (9.2 ± 1.2 vs 16.6 ± 1.3 mean weeks; $p = 0.001$) [4] (9.44 ± 1.65 vs 16.0 ± 5.61 mean weeks; $p = 0.0001$) [3]. One study reported no change in time to return to activity between the operative vs non-operative group [1]. Overall the pooled results showed no significant difference between the operative ($N = 88$) and the non-operative group ($N = 54$) ($p = 0.09$) (Fig. 3).

Functional Outcome Scores

Functional outcome scores reported by the studies are represented in Table 3. One study reported Quick-DASH and the Oxford Shoulder score indicating that 95% of patients that responded ($N = 122$) to the questionnaires in the non-operative group reported good to excellent outcomes, with no reports of such scores in the operative group [17]. Two studies reported Constant-Murley Shoulder Scores (CSS),

with one showing that no significant differences exist between the interventions (mean CSS was 97.1 in the operative group and 97.0 in the non-operative group; $p = 0.993$) [17] and the other significantly favoring operative management (mean CSS was 97.8 in the operative group and 94.7 in the non-operative group; $p = 0.001$) [4]; however the results were not clinically relevant.

Complications

The number and type of complication, reported by each study, are outlined in Table 4. In one study, symptomatic malunion was defined as fracture union with shortening/angulation and asymmetry as well as subjective complaints [3], and in another study, it was defined as 10 mm shortening with subjective complaints [20]. The incidence of malunion was not significantly different between operative (incidence = 0 out of 45

Table 1 Characteristics of the seven included studies

Study	Country	Study design (level of evidence)	Total number of patients (operative/non-operative)	Age (range)	Gender (males/females)	Operative technique (N)	Non-operative technique (N)	MINORS score (out of 24)	Follow-up
Vander Have ^d , 2010 [3]	United States	Retrospective cohort (III)	31 (17/14)	15.4 (12 to 17)	26/5	Plate ORIF ^b (17)	Sling (12) Figure of eight brace (2)	16	2 weeks and 6 weeks. Fractures not healed were also seen biweekly until union, at 6 months and at 1 year
Randsborg, 2014 [17]	Norway	Retrospective case series (IV)	172 (9/163)	14.4 (10 to 18)	137/35	Plate ORIF ^b (9)	NR ^a	16	NR ^a
Hagstrom, 2015 [1]	United States	Retrospective cohort (III)	78 (46/32)	12.2 (8 to 18)	NR ^a	Plate ORIF ^b (46)	NR ^a	18	Mean follow-up was 54 months in the non-operative and 41 months in the operative
Luo ^c , 2015 [18]	United States	Retrospective cohort (III)	149 (23/130)	15.5 (14 to 17)	103/46	Plate ORIF ^b (19) IM nail ^c (4)	Sling (NR ^a) Figure of eight brace (NR ^a)	18	NR ^a (patients followed until union)
Herzog, 2017 [19]	United States	Retrospective cohort (III)	20 (10/10)	14.4 (12 to 18)	18/2	Plate ORIF ^b (2) IM nail ^c (8)	Sling (10)	17	Median follow-up was 2.6 years
Mukhtar, 2018 [4]	Qatar	Prospective cohort (II)	31 (24/7)	10.5 (8 to 16)	20/11	Flexible IM nail ^c (24)	Figure of eight brace (7)	20	Patient followed at 2 weeks, 1 month, 2 months, and 6 months
Song, 2019 [20]	Korea	Retrospective cohort (III)	41 (18/23)	13.4 (10 to 16)	31/10	Plate ORIF ^b (18)	Figure of eight brace (23)	19	Mean follow-up was 3.7 years. All Patients were seen every 2 weeks for the first month following injury and every month until achieving union

All studies reported mean age except for Ransborg et al., 2014 which reported median age

^aNR = Data not reported

^bPlate ORIF = Open reduction and internal fixation (surgical technique)

^cIM nail = Intramedullary nail fixation (surgical technique)

^dThis study contained 17 patients with 18 mid-diaphyseal clavicle fractures in the operative group and 14 patients with 15 mid-diaphyseal clavicle fractures in the non-operative group

^eThis study contained a total of 149 patients with 153 mid-diaphyseal clavicle fractures

Table 2 Degree/level of displacement and/or shortening within the operative and non-operative groups of each study

Study	Operative	Non-operative
Vander Have, 2010 [3]	All fractures were displaced. Mean shortening 27.5 mm (19 mm to 36 mm)	All fractures were displaced. Mean shortening 18.8 mm (10 to 32 mm)
Randsborg ^a , 2014 [17]	All 9 fractures were displaced. Median shortening 16 mm (5 mm to 30 mm)	56 of the 163 fractures were displaced
Hagstrom ^b , 2015 [1]	All fractures were displaced	All fractures were displaced
Luo, 2015 [18]	All fractures were displaced. Mean shortening 2 cm (0.6 cm to 3.4 cm)	89 of the 130 fractures were displaced. Mean shortening 0.9 cm (0 cm to 3.0 cm)
Herzog ^c , 2017 [19]	Shortening 17.2 ± 3.5 mm	Shortening 17.8 ± 3.5 mm
Mukhtar ^d , 2018 [4]	All fractures were displaced	All fractures were displaced
Song ^e , 2019 [20]	Mean vertical displacement 167.9% (73% to 304%). Mean shortening 20.9 mm (15 mm to 31 mm)	Mean vertical displacement 124.4% (80% to 244%). Mean shortening 18.7 mm (15 mm to 29 mm)

^a No shortening was reported in the non-operative group exclusively, but shortening was not statistically significant between the two groups ($p = 0.1$)

^b This study did not report the shortening in each group. The inclusion criteria was displaced fractures with >1.5 cm of shortening

^c Shortening between the two groups was not statistically significant ($p = 0.53$)

^d Mean clavicle displacement was 19.5 mm (16 mm to 25 mm) in both groups

^e Vertical displacement was significantly greater in the operative group ($p = 0.023$). Shortening between the two groups was not statistically significant ($p = 0.163$)

patients) and non-operative (incidence = 7 out of 201 patients) management ($p = 0.60$) (Fig. 4A). In one study, delayed union was defined as more than 7 months to radiographic union [1] and in another study as more than 4 months to radiographic union [20]. The incidence of delayed union was not significantly different between operative (incidence = 2 out of 96 patients) and non-operative (incidence = 7 out of 348 patients) management ($p = 0.92$) (Fig. 4B). The rate of refractures was not significantly different between operative (incidence = 8 out of 111 patients) and non-operative (incidence = 2 out of 192 patients) management ($p = 0.18$) (Fig. 4C). The additional/secondary requirement for surgical intervention was not significantly different between operative (incidence = 11 out of 138 patients) and non-operative (incidence = 6 out of 372 patients) management ($p = 0.23$) (Fig. 4D). The overall complication rate was not significantly different between operative (incidence = 25 out of 148 patients) and non-operative (incidence = 26 out of 382 patients) management ($p = 0.50$) (Fig. 4E). Moreover, within the operative group, there were patients who elected for implant removal, although not associated with any complication. Elective implant removal was

performed in four different studies (only one study mentioned the reason behind the removal [3]): 23 of 24 patients [4], 3 of 18 patients (due to local prominence of the implant) [3], 12 of 18 patients [20], and 1 of 10 patients [19].

Discussion

The most important result of this systematic review and meta-analysis is that there is no significant statistical difference between the operative and the non-operative management of skeletally immature mid-diaphyseal clavicle fractures with respect to time to union and time to return to activity. Furthermore, there were no differences regarding complications including malunion, delayed union, nonunion, refracture, implant failure, additional/secondary requirement for surgical intervention, and cosmetic deformity.

Across the studies reporting functional outcome scores, such as DASH and CSS scores, patients demonstrated a high level of satisfaction with low difficulty in both treatment groups. One of the included studies [4] found a statistically significant

Fig. 2 Comparison in the meantime to achieve union, in weeks, between operative and non-operative management. IV represents inverse variance; df represents degrees of freedom

Fig. 3 Comparison in the meantime to return to activity, in weeks, between operative and non-operative management. IV represents inverse variance; df represents degrees of freedom

difference in CSS scores favoring operative fixation; however, both scores in the operative and non-operative groups were deemed excellent and may not be of clinical significance. The minimal clinical important difference is at least 10.83 points for DASH, at least 15.91 points for Quick DASH [21], and at least 10 points for CSS scores [22]. Similarly, DASH scores throughout the examined studies represented a substantial level of satisfaction with no statistical or clinical significance.

Children from birth to 18 years are traditionally treated using non-operative techniques due to the remarkable growth potential among the skeletally immature population [23, 24]. In his text about skeletally immature fractures, Mercer Rang stated, “if the two ends of the clavicle are in the same room they will heal and remodel adequately” [23]. A cross-sectional study of 961 individuals between birth and 18 years of age found that 80% of clavicular length is reached by 9 years among females and by 12 years among males [24]. Early studies have also demonstrated a low rate of patients developing nonunion following non-operative techniques, with one study assessing 2,235 clavicle fractures reporting only 3 patients with nonunion [25]. The current study supports this as only one patient with a nonunion was identified in the non-operative group. Other reviews also support that nonunion is rare in this patient population [26].

The last decade has seen a shift towards operative management in skeletally mature patients, mainly due to the low rate of nonunion and symptomatic malunion that operative fixation had in comparison to non-operative management

[27–30]. Furthermore, patient-reported outcomes in some studies have demonstrated a high rate of poor patient-satisfaction scores, of approximately 25 to 31%, following non-operative management [27, 30–32]. A multitude of prospective trials has also identified the nonunion rate to increase by approximately 21% compared to the earlier reports [24]. Malunited fractures are not only of pure radiographic interest as some are associated with increase in patient-reported neurological and functional cosmetic deficits (described as “difficulty wearing backpacks, straps etc.”) [24]. However, the enthusiasm for surgery must take into account the significant complications such as brachial plexus or subclavian vessel injuries, pneumothorax[33], and infection[34, 35] that have been reported following surgical intervention.

The trend towards surgery in the skeletally immature population has taken place despite the absence of level 1 evidence demonstrating its effectiveness [7, 36, 37]. Two studies (both with an $N = 16$) looking at conservative treatment of skeletally immature mid-diaphyseal clavicle fractures with 100% displacement and > 2 cm of shortening had a 100% union rate; however all fractures developed malunion [38, 39]. These fractures were not symptomatic, and no significant difference in strength or range of motion was observed with most patients reporting low pain scores [38, 39]. In the current manuscript, one study had five patients in the non-operative group that developed malunion, four of which underwent corrective osteotomy with plate fixation[3], and another study had two patients initially treated non-operatively that underwent

Table 3 Comparison of the functional outcome score for each of the seven included studies

Study	Outcome score reported	Operative	Non-operative	p value
Randsborg, 2014 [17]	Quick DASH ^b	Not performed in operative group	2.8	NR ^c
	Oxford Shoulder Score	Not performed in operative group	47.5	NR ^c
Hagstrom, 2015 [1]	DASH ^a	1.17	0.04	(NR ^c) Not statistically significant
Herzog, 2017 [19]	DASH ^a	1.7	0	0.08
Mukhtar, 2018 [4]	Constant-Murley Shoulder Score	97.8	94.7	0.0001
Song, 2019 [20]	DASH ^a	0	0	(NR ^c) Not statistically significant
	Constant-Murley Shoulder Score	97.1	97.0	0.993

^a DASH = Disability of arm, shoulder, and hand questionnaire

^b Quick DASH = Shortened version of the DASH questionnaire

^c NR = Data not reported

Table 4 Individual complications reported by each of the seven included studies

Study	Complication	Operative management (N/N total)	Non-operative management (N/N total)	Total number of patients
Vander Have ^a , 2010 [3]	Malunion	0/18	5/15	31
	Secondary surgical intervention	0/18	4/15	
Randsborg ^b , 2014 [17]	Malunion	0/9	1/163	172
	Delayed union	0/9	1/163	
	Secondary surgical intervention	6/9	2/165	
	Nonunion	0/9	1/165	
	Cosmetic deformity	1/9	0/163	
Hagstrom, 2015 [1]	Delayed union	0/46	2/32	78
	Refracture	3/46	2/32	
	Secondary surgical intervention	2/46	0/32	
Luo ^c , 2015 [18]	Delayed union	0/23	1/130	149
	Refracture	2/23	0/130	
	Secondary surgical intervention	1/23	0/130	
	Nonunion	1/23	0/130	
Herzog, 2017 [19]	Cosmetic deformity	2/10	9/10	20
	Refracture	2/24	0/7	31
Mukhtar, 2018 [4]	Secondary surgical intervention	1/24	0/7	
Song, 2019 [20]	Malunion	0/18	1/23	41
	Delayed union	2/18	3/23	
	Refracture	1/18	0/23	
	Discomfort over the hypertrophic scar lesion	1/18	0/23	
	Secondary surgical intervention	1/18	0/23	

^a In this study, four patients with malunited fractures in the non-operative group underwent surgical intervention (corrective osteotomy)

^b In this study, two of the nine operatively treated fractures were initially treated non-operatively (initially, N of non-operative = 165) but underwent surgical intervention due to complications. Moreover, the patient who developed a delayed union in the non-operative group also developed a malunion, revealed by a CT-scan 12 months after injury

^c The patient with the nonunion in the operative group underwent another surgery

operative fixation due to increasing pain and displacement 23 days following injury (one patient) and a nonunion (one patient)[17]. This indicates that the decision to treat non-operatively was valid, yielding satisfactory outcomes with low complication rate.

One factor which should be taken into account when considering operative management is the requirement for second surgery for implant removal. Within the assessed studies, 40 out of the 148 patients treated operatively had underwent elective implant removal. Multiple studies have documented the need for a second surgery to remove implant as well [40, 41]. Although, not a formal complication, the additional intervention should be considered when surgical options are offered to patients.

Limitations

This review has common limitations to all meta-analyses and few specific limitations to the studies. First, the findings of this review are based on the quality of the selected studies on mid-diaphyseal clavicle fractures among the skeletally immature

population. Therefore, the findings are only as unbiased and accurate as the data that are entered. Second, the reliability of the conclusions described in this review depends on the consistency of the patients in the analyzed studies, the treatments used, the complication stated, and the outcomes reported. Third, the quality of data depends on the level of evidence prescribed in this study, which in most cases was retrospective and non-randomized, therefore lacking higher quality evidence on this topic. Fourth, the functional outcome scores used in this review may not be a reliable assessment of patient-reported outcomes because they have not been validated for the skeletally immature patients. Another major methodological limitation of this study is the presence of heterogeneity among the reported studies. Reasons for heterogeneity include clinical differences such as patient age, methods of fixation and differences in the implants used, study design and quality of evidence, and outcomes and complication measured. To account for this, the studies were weighted based on the inverse variance, and pooling was done using a random effects model.

Fig. 4 Comparison of (A) the rate of malunion, (B) the rate of delayed union, (C) the rate of refractures, (D) the secondary requirement for surgical intervention, and (E) the overall rate of complications between

operative and non-operative management. IV represents inverse variance; df represents degrees of freedom

Conclusions and Future Directions

The pooled results indicate that there is no significant difference between operative and non-operative management

of skeletally immature mid-diaphyseal clavicle fractures. In light of the current best available level of evidence and no apparent differences in this meta-analysis across several subjective and objective outcomes, clinical equipoise

exists to study this further by means of a prospective, randomized, blinded control trial. Consequently, families and caregivers may benefit following the identification of the optimal and most cost-efficient treatment. Non-operative management should remain the gold standard when treating skeletally immature patients, and operative management is to be considered in extreme cases and in accordance with the patient's needs.

Compliance with Ethical Standards

Conflict of Interest Khaled Nawar, Yousif Eliya, Sarah Burrow, Devin Peterson, Olufemi Ayeni, and Darren de SA declare that they have no conflict of interest. Olufemi Ayeni has reported that he is the speaker's bureau for Conmed which might give the appearance of a potential conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Appendix

Search strategy

Date: December 17, 2018

OVID MEDLINE	PUBMED	EMBASE	Other
<p>1. (Clavicle fracture or clavicular fracture or clavicular fractures or clavicle fractures or mid-shaft clavicle or midshaft clavicle or mid-shaft clavicular or midshaft clavicular or collarbone).mp. [mp = title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]</p> <p>Result: 1182</p> <p>2. Pediatric.mp or exp. Pediatrics/</p> <p>Results: 200721</p> <p>3. Adolescence.mp or exp. Adolescent/</p> <p>Results: 1195226</p> <p>4. Skeletally immature.mp.</p> <p>Results: 1083</p> <p>5. 2 or 3 or 4</p> <p>6. 1 and 5</p> <p>7. Limit 6 to (English language and yr = "1999-Current" and ("all infant (birth to 23 months)" or "newborn infant (birth to 1 month)" or "infant (1 to 23 months)" or "preschool child (2 to 5 years)" or "child (6 to 12 years)" or "adolescent (13 to 18 years)")) Results: 271</p> <p>Total = 271</p>	<p>1. (((((((((((clavicle fracture) OR clavicular fracture) or clavicular fractures) or midshaft clavicle) or clavicle fractures) or midshaft clavicle) or mid-shaft clavicle) or mid-shaft clavicular) or midshaft clavicular) or collarbone) and pediatric</p> <p>Result: 264</p> <p>Total = 264</p>	<p>2. (Clavicle fracture or clavicular fracture or clavicular fractures or clavicle fractures or mid-shaft clavicle or midshaft clavicle or mid-shaft clavicular or midshaft clavicular or collarbone).mp. [mp = title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]</p> <p>Result: 3264</p> <p>3. Pediatric.mp or exp. Pediatrics/</p> <p>Results: 408306</p> <p>4. Adolescence.mp or exp. Adolescent/</p> <p>Results: 1092360</p> <p>5. Skeletally immature.mp.</p> <p>Results: 1630</p> <p>6. 2 or 3 or 4</p> <p>7. 1 and 5</p> <p>8. Limit 6 to (English language and yr = "1999-Current" and ("all infant (birth to 23 months)" or "newborn infant (birth to 1 month)" or "infant (1 to 23 months)" or "preschool child (2 to 5 years)" or "child (6 to 12 years)" or "adolescent (13 to 18 years)")) Results: 441</p> <p>Total = 441</p>	<p>Results: 5</p> <p>Total = 5</p>

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