



Invited Review

Return to sport following clavicle fractures: a systematic review

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Abstract

Introduction: This review aims to provide information on the return rates and return times to sport following clavicle fractures.

Sources of data: A systematic search of Medline, EMBASE, CINAHAL, Cochrane, Web of Science, PEDro, SPORTDiscus, Scopus and Google Scholar was performed using the keywords 'clavicle', 'clavicular', 'fractures', 'athletes', 'sports', 'non-operative', 'conservative', 'operative', 'return to sport'.

Areas of agreement: Twenty-three studies were included: 10 reported on mid-shaft fractures, 14 on lateral fractures. The management principles for athletic patients were to attempt non-operative management for undisplaced fractures to undertake operative intervention for displaced lateral fractures and to recommend operative intervention for displaced mid-shaft fractures.

Areas of controversy: The optimal surgical modality for mid-shaft and lateral clavicle fractures.

Growing points: Operative management of displaced mid-shaft fractures offers improved return rates and times to sport compared to non-operative management. Suture fixation and non-acromio-clavicular joint (ACJ)-spanning plate fixation of displaced lateral fractures show promising results.

Areas timely for developing research: Future prospective studies should aim to establish the optimal treatment modalities for clavicle fractures.

Key words: clavicle, fracture, return, sport, rate, time

Introduction

Acute fractures account for ~10% of all sports injuries seen by medical practitioners.¹⁻⁶ Clavicle fractures comprises up to 10% of all sport-related fractures,^{7,8} with around 30% of all clavicle fractures occurring during sport.⁸ It has previously been reported that of all sport-related fractures, clavicle fractures have the third longest return time to sport,⁹ with as many as 20% of athletes with such injuries failing to return to sport.⁹ With a growing incidence of these injuries, along with the ever-increasing participation in sporting activity, the public health impact of these injuries has been predicted to increase.^{7,8} Therefore, medical practitioners need to be able to inform patients on the predicted return rates and return times to sport after such injuries.

The management of clavicle fractures depends on the location (mid-shaft, lateral, medial) and the nature (displaced, undisplaced, comminuted) of the fracture.¹⁰ The commonest fractures locations in sporting populations are mid-shaft (70%)¹¹ and lateral (25%).¹¹ Around 45% of sport-related clavicle fractures are undisplaced.¹¹ Historically, the management of clavicle fractures has been through conservative management with sling immobilization and subsequent rehabilitation.^{10,12-14} This continues to provide satisfactory results for undisplaced fractures, remaining the recommended treatment.¹⁰ However, there is a growing appreciation that conservative management of displaced mid-shaft clavicle fractures results in increased rates of re-injury, increased return times to sport and suboptimal shoulder function, secondary to clavicular malunion and shortening, with resultant thoracoscapular dyskinesia.^{12,15,16} Similarly, conservative management of displaced lateral fractures in the athletic patient has been shown to result in high rates of non-union and subsequent impairment of shoulder function.^{10,17} As such, for the athletic individual, operative intervention is routinely performed for displaced lateral fractures^{10,17} and is recommended for mid-shaft fractures that are completely displaced, shortened >2 cm or comminuted.^{10,12} There are various methods of fracture fixation, with selection guided by the nature and location of the

fracture¹⁰: for mid-shaft fractures, techniques include plate fixation and IM (intra-medullary) nailing¹⁰; for lateral fractures, techniques include acromio-clavicular joint (ACJ)-spanning 'hook' plate fixation, non-ACJ-spanning plate fixation, suture fixation and coraco-clavicular screw fixation.¹⁰ While operative intervention of clavicle fractures can result in major complications such as neurovascular injury and infection, it is now appreciated that such techniques have acceptable margins of safety when performed by a standard orthopaedic surgeon with an interest in upper limb trauma.^{10,13,14}

Despite evolving concepts in the management of sport-related clavicle fractures, information on return to sport following clavicle fractures is limited. Examining the literature, few studies provide data on the rate and time of return to sports activity following clavicle fractures. The aim of this review is to provide an overview of the return rates and times to sport for these injuries.

Methods

Literature search

A comprehensive literature search was performed in August 2015 using Medline (PubMed), EMBASE, CINAHAL, Cochrane Collaboration Database, Web of Science, Physiotherapy Evidence Database (PEDro), SPORTDiscus, Scopus and Google Scholar. This was to identify articles published in English in peer-reviewed journals, reporting data and information on return to sports after clavicle fractures, without any distinction for type and severity of fracture, or level and type of sports activity. The search was performed using the keywords 'clavicle', 'clavicular', 'fractures', 'athletes', 'sports', 'non-operative', 'conservative', 'operative', 'return to sport' with no limit for year of publication.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines were followed.¹⁸ Two authors (G.A.R., A.M.W.) independently reviewed the abstract of each publication and deemed it suitable for inclusion on the basis of its content. The inclusion and exclusion criteria, as directed by the PRISMA protocol, are

detailed in Table 1.¹⁸ The search results and selection process are shown in the quality of reporting of meta-analyses (QUORUM) flow diagram in Figure 1.¹⁸ Literature reviews, case reports, biomechanical reports, expert opinions, instructional courses and technical notes were excluded unless they contained relevant patient data. When exclusion was not possible based on the abstract, the full-text versions were downloaded. The reference lists of the selected articles were also reviewed to identify articles not included at the electronic search.

Data on patient demographics, location and type of fracture, operative and non-operative management techniques, rate of return to sports, time to return to sports, rate of fracture union, time to fracture union, complications and predictive factors for return to sports were recorded. Primary outcome measures were rate of return to sport and time to return to sport. Secondary outcome measures were rate of return to pre-injury level of sport, rate of fracture union, time to fracture union and associated complications. The definitions used for fracture union (clinical and radiological) in each study are provided in Supplementary Appendix S1.

Time to return to sports was measured from commencement of non-operative modalities for conservatively managed patients and from primary surgical treatment for operatively management patients.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Acute clavicle fractures	No sporting outcome data reported
Elite or recreational athletes	Paediatric fractures (age under 15)
Return rate to sporting activity reported	Concomitant acromio-clavicular or sterno-clavicular joint injury
Time to return to sporting activity reported	Concomitant upper or lower limb fractures
Two or more fractures reported	Stress fractures
Peer-reviewed journals	Reviews, case reports, abstracts or anecdotal articles
English language	Animal, cadaver or in vitro studies

Quality assessment

The papers were evaluated using the modified Coleman Methodology Score (CMS), a 10-criteria validated scoring system assessing the quality of the study method, with the final score ranging from 0 to 100.¹⁹ The process and scoring system used was that described by Del Buono *et al*¹⁹ and Robertson *et al*.²⁰ The inter-observer reliability of the scores between the two investigators was assessed using intra-class correlation, achieving an intra-class correlation coefficient of 0.90 (95% confidence interval (CI) 0.88–0.92).

Statistics

With cohorts of sufficient size, meta-analysis comparisons were performed between the synthesis data. The meta-analysis was done using RevMan Version 5.3 (The Cochrane Group). Dichotomous data were analysed by odds ratios (ORs), using a random effects model. Continuous data were analysed by mean difference (MD), using a random effects model. Heterogeneity was assessed by using I^2 and judged to be significant if I^2 was >50%. The significance level was set at $P < 0.05$.

Results

Search

The details of the selection process for the included articles are listed in Figure 1. In total, 223 unique abstracts and 148 unique articles were assessed.

Patient demographics

We identified 23 relevant publications, published from 1991²¹ to 2015,¹⁴ focusing on clinical and functional outcomes of patients who returned to sports activity after clavicle fractures (Tables 2–4).^{9,13,14,16,21–39} Fifteen were retrospective studies^{9,13,16,21,22,24,26,29–33,35,36,39} and eight were prospective studies.^{14,23,25,27,28,34,37,38} There were no randomised controlled trials (RCTs).

Of the 588 patients (1 with bilateral fractures), 479 (81%) were males (1 with bilateral fractures) and 109 (19%) were females. Of the 589 fractures recorded, follow-up data was achieved for 555 (94.2%). The

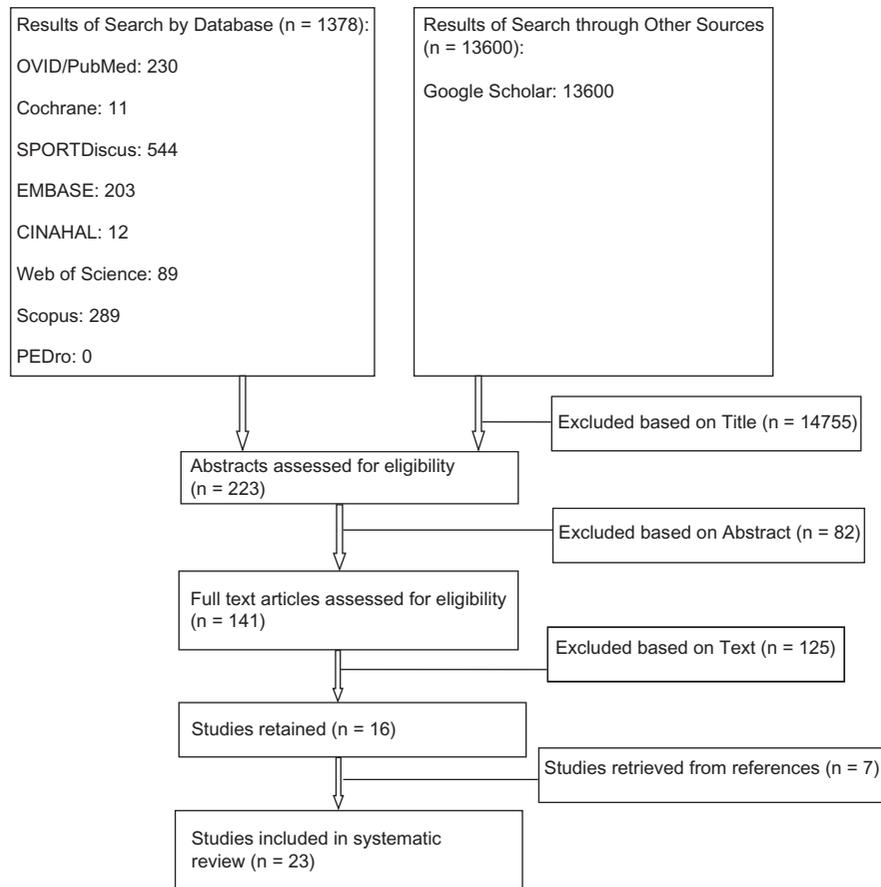


Fig. 1 Selection of articles for inclusion in the review in accordance with the PRISMA protocol.¹⁷

mean age at the time of injury ranged from 19.0 years¹³ to 44.0 years,³¹ and the sports activity commonly practised were cycling, motorcycling, horse riding, soccer, American Football, rugby, running (Tables 2–4).

Fracture location and classification

Eight studies reported on mid-shaft fractures exclusively.^{13,14,16,22–25,27} Four used the AO Classification^{14,22,23,25} to describe fracture pattern and one used the Robinson Classification.¹⁴ Seven studies reported on displaced fractures exclusively,^{13,14,22–25,27} while one reported on both displaced and undisplaced fractures (Table 2).¹⁶

Twelve studies reported on lateral fractures exclusively.^{21,28–38} Eleven used the Neer

classification,^{21,28,30–38} while one used the Robinson classification.³⁷ All studies reported on displaced fractures (Table 3).^{21,28–38}

Two studies included both mid-shaft and lateral fractures.^{9,26} These both used the AO classification and the Robinson classification.^{9,26} Both included displaced and undisplaced fractures (Tables 2 and 3).^{9,26}

One study reported on clavicle fractures but failed to specify their location (Table 4).³⁹

No studies reported on medial clavicle fractures. There were no open fractures.

There were 304 mid-shaft fractures (262 males, 42 females), with 197 being surgically managed (all displaced) and 107 being conservatively managed (85 displaced, 22 undisplaced). Thirty-seven mid-shaft fractures had concomitant injuries (Supplementary Appendix S2).

Table 2 Mid-shaft clavicle fractures—only patients with follow-up data included

Author (year)	N	Study design	Mean follow-up	Treatment (No. of displacement)	Sport activity	Coleman score	Return rate	Return rate by treatment modality	Return rate to same level of sport	Return time (range)	Return time (range) by treatment modality	Time to union (range)	Rate of union
Grassi <i>et al.</i> (2001) ²²	80	RCS	63.7 mo	Conservative (displaced) (40) IM nail (40)	NA	76	79/80	Cons (D): 40/40 IMN: 39/40	NA	13.1 (5–36) wks	Cons (D): 11.7 (5–36) wks IMN: 14.4 (5–32) wks	NA	Cons (D): 40/40 IMN: 38/40
Jubel <i>et al.</i> (2003) ²³	12	PCS	19.2 mo	IM Nail (12)	Motorcross (6), Horse riding (2), Triathlon (1), Soccer (1), Rollerskating (1) Rowing (1)	65	12/12	IMN: 12/12	IMN: 12/12	2.4 (1–4) wks	IMN: 2.4 (1–4) wks	NA	IMN: 12/12
McKee <i>et al.</i> (2006) ²⁴	30	RCS	5.5 mo	Conservative (displaced) (30)	NA	54	26/30	Cons (D): 26/30	Cons (D): 18/30	NA	NA	NA	NA
Meier <i>et al.</i> (2006) ²⁵	13	PCS	17 mo	IM Nail (13)	Cycling (6), Snowboard (2), Skiing (2), Soccer (2), Running (2), Motocross (1), Climbing (1), Gymnastics (1), Marital arts (1), Dancing (1).	74	13/13	IMN: 13/13	NA	By 4 wks	IMN: by 4 wks	IMN: 7.7 (6–12) wks	IMN: 13/13

Continued

Table 2 Continued

Author (year)	N	Study design	Mean follow-up	Treatment (No. of displacement)	Sport activity	Coleman score	Return rate	Return rate By treatment modality	Return rate to same level of sport	Return time (range)	Return time (range) by treatment modality	Time to union (range)	Rate of union
Meisterling <i>et al.</i> (2013) ¹³	30	RCS	21 mo	ORIF (30)	American Football (16), Soccer (3), Motorsport (3), Baseball (2), Basketball (2), Skiing (2), MTB (1), Softball (1), Lacrosse (1)	75	30/30	ORIF: 30/30	ORIF: 30/30	11.9 (2-40) wks	ORIF: 11.9 (2-40) wks	11.4 (5-60) wks	ORIF: 19/19
Morgan <i>et al.</i> (2010) ¹⁶	19	RCS	Min 16 mo	Cons (undisplaced) (6) ORIF (3) IMN (3) Cons (displaced) (7)	American Football (19)	52	19/19	Cons (U): 6/6 ORIF: 3/3 IMN: 3/3 Cons (D): 7/7	Cons (U): 6/6 ORIF: 3/3 IMN: 3/3 Cons (D): 7/7	NA	Cons (U): 10 wks ORIF: 8 wks IMN: 8 wks Cons (D): 78 wks	Cons (U): 7/7 (U):7.3 wks ORIF: 9 wks IMN: 8.7 wks Cons (D): 14.1 wks	Cons (U): 6/6 ORIF: 3/3 3 IMN: 3/3 Cons (D): 7/7
Ranalletta <i>et al.</i> (2015) ¹⁴	54	PCS	22.4 mo	ORIF (54)	Sports	85	53/54	ORIF: 53/54	ORIF: 50/54	9.7 (1-26) wks	ORIF: 9.7 (1-26) wks	NA	ORIF: 53/54
Robertson <i>et al.</i> (2012) ⁹	10	RCS	30 mo	Cons (undisplaced) 5 Cons (displaced) 4 ORIF (1)	Soccer	44	7/10	Cons (U): 4/5 Cons (D): 2/4 ORIF: 1/1	Cons (U): 4/5 Cons (D): 2/4 ORIF: 1/1	14.1 wks	Cons (U): 12.5 wks Cons (D): 29 wks ORIF: 24 wks	NA	Cons (U): 5/5 Cons (D): 4/4 ORIF: 1/1

Robertson <i>et al.</i> (2014) ²⁶	17	RCS	40 mo	Cons (Undis) (11) Cons (Dis) (4) ORIF (2)	Rugby	44	16/17	Cons (U): 11/11 Cons (D): 4/4 ORIF: 1/2	Cons (U): 11/11 Cons (D): 4/4 ORIF: 1/	15.5 wks	Cons (U): 10.2 wks Cons (D): 17.5 wks ORIF: 18 wks	NA	Cons (U): 11/11 Cons (D): 4/4 ORIF: 1/
Verborgt <i>et al.</i> (2005) ²⁷	39	PCS	64 mo	ORIF (39)	MTB, Motocross, Soccer Cycling Swimming	77	39/39	ORIF: 39/ 39	ORIF: 39/ 39	6.4 (0– 30) wks	ORIF: 6.4 (0–30) wks	NA	ORIF: 37/39

Mean values unless otherwise stated. RCS, Retrospective Cohort Study; PCS, Prospective Cohort Study; ORIF, open reduction internal fixation; Cons, conservative; NA, no data available; Dis/D, displaced; Undis/U, undisplaced; MTB, mountainbiking; mo, months; wks, weeks.

There were 210 lateral fractures (153 males, 57 females) with 204 being managed surgically (all displaced) and 6 being managed conservatively (all undisplaced). Twelve lateral fractures had concomitant injuries (Supplementary Appendix S2).

Study design

The mean CMS for all the studies was 63.5 (range 44–85).^{9,13,14,16,21–39} For the ‘mid-shaft fracture’ studies, the mean CMS was 64.6 (range 44–85) (Table 2).^{9,13,14,16,22–27} For the ‘lateral fracture’ studies, the mean CMS was 60.5 (range 44–76) (Table 3).^{9,21,26,28–38}

Management

Mid-shaft clavicle fractures

The general principles for the management of mid-shaft clavicle fractures were to employ conservative management for undisplaced fractures, in the form of modified rest with sling immobilization, for a period for between 2 and 4 weeks.¹⁰ For displaced fractures, primary surgical intervention is now recommended, either with plate fixation or IM Nail, as this has shown to provide improved return of shoulder function, increased return to pre-injury sporting levels and reduced return time to sport.^{12,16} The surgical procedures are listed in Table 2. Post-operative rehabilitation generally comprised sling immobilization for 2–4 weeks, with immediate ROM exercises as able.^{13,14,22,25,27} This was followed by graduated physiotherapy and return to sports between 4 and 6 weeks post-operatively.^{13,14,22,25,27} One study recommended no post-operative immobilization and immediate return to sports as able.²³ Routine removal of metalwork was recommended for IM Nail but not for plate fixation.^{9,13,14,16,22,23,25–27}

Lateral clavicle fractures

For management of lateral clavicle fractures, the general principles were to employ conservative management for undisplaced fractures in the form of modified rest with sling immobilization for between 2 and 4 weeks.¹⁰ For displaced fractures, routine management was to undertake surgical reduction of the fracture with associated

Table 3 Lateral clavicle fractures – only patients with follow-up data included

Author (year)	N	Study design	Mean follow-up	Treatment	Sport activity	Coleman score	Return rate	Return by treatment modality	Return rate to same level of sport	Return time (range)	Return (range) by treatment modality	Time to union	Rate of union
Badhe <i>et al.</i> (2008) ²⁸	10	PCS	18 mo	Suture (10)	NA	59	10/10	Sut: 10/10	NA	NA	NA	Sut: 9.2 (6–16) weeks	Sut: 10/10
Ballmer and Gerber (1991) ²¹	5	RCS	12 mo	Screw (5)	NA	52	5/5	Scr: 5/5	Scr: 5/5	36 (18–77) week	Scr: 36 (18–77) weeks	Scr: all within 6 to 9 weeks	Scr: 5/5
Bhatia and Page (2012) ²⁹	15	RCS	26.1 mo	Hook Plate (10) Non-ACJ Plate (5)	Cycling (8)	54	12/15	HP: 7/10 NACJP: 5/5	HP: 7/10 NACJP: 5/5	NA	NA	NA	HP: 9/10 NACJP: 5/5
Chen <i>et al.</i> (2002) ³⁰	11	RCS	27 mo	Cerclage (11)	Motocross (5)	71	10/11	Cer: 10/11	Cer: NA	NA	NA	NA	Cer: 11/11
Fleming <i>et al.</i> (2015) ³¹	15	RCS	25 mo	Non-ACJ Plate (15)	NA	54	12/15	NACJP: 12/15	NACJP: 12/15	NA	NA	NACJP: median 12 (6–16) weeks	NACJP: 15/15
Goldberg <i>et al.</i> (1997) ³²	7	RCS	36 mo	Suture (7)	Cycling (3) Soccer (2)	56	7/7	Sut: 7/7	NA	11 (6–16) weeks	Sut: 11 (6–16) weeks	Sut: 16 (5–52) weeks	Sut: 7/7
Lee <i>et al.</i> (2009) ³³	52	RCS	24.3 mo	Hook Plate (32) TBW (20)	NA	61	34/52	HP: 26/32 TBW: 8/20	HP: NA TBW: 26/32 8/20	NA	NA	NA	HP: 32/32 TBW: 19/20
Levy (2003) ³⁴	12	PCS	>2 years	Suture (12)	NA	73	12/12	Sut: 12/12	NA	12 (8–24) weeks	Sut: 12 (8–24) weeks	Sut: all by 12 weeks	Sut: 12/12
Loriaut <i>et al.</i> (2015) ³⁵	21	RCS	35 mo	Arthroscopic endobutton (21)	Sports	72	17/21	Arthro: 17/21	Arthro: 14/21	17 weeks	Arthro: 17 weeks	Arthro: all by 14 weeks	Arthro: 20/21

Author	RCS	Median mo	Non-ACJ plate (30)	NA	63	30/30	NACJP: 30/30	NACJP: NA 24/30	NA	NACJP: all within 6 to 10 weeks	NACJP: 30/30
Martetschlager <i>et al.</i> (2013) ³⁶	30	12.2 mo									
Robertson <i>et al.</i> (2012) ⁹	7	30 mo	Cons (Undis) (4) Suture (3)	Soccer (7)	44	6/7	Cons (U): 4/4 Sut: 2/3	Cons (U): 21.3 weeks Sut: 21.5 weeks	Cons (U): 15 weeks Sut: 21.5 weeks	NA	Cons (U): 4/4 Sut: 3/3
Robertson <i>et al.</i> (2014) ²⁶	2	40 mo	Cons (Undis) (2)	Rugby (2)	44	2/2	Cons (U): 2/2	Cons (U): 15.5 weeks (U): 2/2	Cons (U): NA 14 weeks	NA	Cons (U): 2/2
Robinson <i>et al.</i> (2010) ³⁷	12	12 mo	Suture	Sport	76	12/12	Sut: 12/12	Sut: NA 11/12	NA	NA	Sut: 11/12
Yamaguchi <i>et al.</i> (1998) ³⁸	11	68 mo	Screw	Cycling (3) Motocross (3)	68	11/11	Scr: 11/11	Scr: all by 36 wks 11/11	Scr: all by 36 wks 36 wks	Scr: 7 (6-10) week	Scr: 11/11

Mean values unless otherwise stated. RCS, Retrospective Cohort Study; PCS, Prospective Cohort Study; ORIF, open reduction internal fixation; Cons, conservative; NA, no data available;

Dis/D, displaced; Undis/U, undisplaced; hook plate/HP, hook plate fixation; Non-ACJ plate/NACJP, non-acromio-clavicular-joint-spanning plate fixation; Suture/Sut, suture fixation; Screw/Scr, coraco-clavicular screw fixation; Cerclage/Cer, cerclage fixation; arthroscopic endobutton/arthro, arthroscopic endobutton fixation; TBW, tension band wire fixation. ; mo, months; wks, weeks.

Table 4 Miscellaneous clavicle fractures—only patients with follow-up data included

Author (year)	N	Study design	Mean follow-up	Treatment	Sport activity	Coleman score	Return rate	Return rate by treatment modality	Return rate to same level of sport	Return time (range)	Return time to union	Rate of union
Davies <i>et al.</i> (2009) ³⁹	41	RCS	18 mo	Conservative (41)	NA	56	37/41	Cons: 37/41	Cons: 18/41	NA	NA	NA

Mean values unless otherwise stated. RCS, Retrospective Cohort Study; Cons, Conservative; NA, no data available; mo, months.

fixation.^{10,17} Methods of fixation included ‘hook’ plate fixation,^{29,33} non-ACJ-spanning plate fixation with ligament reconstruction,^{29,31,36} open suture fixation,^{9,28,32,34,37} arthroscopic endobutton fixation,³⁵ coraco-clavicular screw fixation,^{21,38} cerclage wire fixation³⁰ and tension band wire fixation³³ (Table 3). Post-operative rehabilitation generally comprised sling immobilization for 2–4 weeks, with immediate ROM exercise as able.^{21,28,30–38} This was followed by graduated physiotherapy and return to sports between 4 and 6 weeks post-operatively.^{21,28,30–38} Routine removal of metalwork was performed for ‘hook’ plate fixation,^{29,33} screw fixation,^{21,38} cerclage wire fixation³⁰ and tension band wire fixation³³ but not for ‘non-ACJ-spanning’ plate fixation^{29,31,36} and suture fixation.^{9,28,32,34,35,37}

Functional assessment

Seventeen studies used validated measures to assess post-intervention functional status.^{13,14,22–25,27–31,33–37,39}

Of the ‘mid-shaft’ studies, seven reported formal outcome measures with one reporting Quick DASH scores,¹³ two reporting Constant and Quick DASH Scores,^{14,24} two reporting Constant and VAS scores^{23,27} and two reporting Constant Scores alone.^{22,25}

Of the ‘lateral’ studies, nine reported formal outcome measures with one reporting a combination of Constant, Simple Shoulder Test and Walch ACJ scores,²⁹ one reporting Short Form-36, DASH and Constant scores,³⁷ two reporting Constant, DASH and VAS scores,^{35,36} three reporting Constant Scores alone,^{28,33,34} one reporting Oxford Shoulder Scores³¹ and one reporting a modified shoulder rating scale.³⁰

Return rates to sports

Mid-shaft fractures

The return rates for the surgical and non-surgical cohorts are provided in Table 5 and Figure 2a.

There was no significant difference between the return rates for the conservatively managed undisplaced mid-shaft fractures and the surgically managed fractures (OR 0.32: 95% CI 0.03–3.26,

Table 5 Summary of the return times to sport, return rates to union and rates of union by treatment modality

Mode of treatment	n (total)	Return rates to sport	Mean return times to sport	Return rate to pre-injury level	Rates of union	Mean times to union
All ^{9,13,14,16,21-39}	555	511/555 (92%) ^{9,13,14,16,21-39}	13.7 weeks ^{9,13,14,16,21-23,25-27,32-38}	348/431 (81%) ^{9,13,14,16,21,23,24,26-38}	463/472 (98%) ^{9,13,14,16,21-23,25-38}	10.4 wks ^{13,16,21,25,28,31,32,34-36,38}
Mid-shaft ^{9,13,14,16,22-27}	304	294/304 (97%) ^{9,13,14,16,22-27}	11.7 wks ^{9,13,14,16,22,23,25-27}	191/211 (91%) ^{9,13,14,16,23,24,26,27}	257/262 (98%) ^{9,13,14,16,22,23,25-27}	10.3 wks ^{13,16,25}
Lateral ^{9,21,26,28-38}	210	180/210 (86%) ^{9,21,26,28-38}	19.2 wks ^{9,21,26,32,34,35,38}	139/179 (78%) ^{9,21,26,29-31,33,35-38}	206/210 (98%) ^{9,21,26,28-38}	10.4 wks ^{21,28,31,32,34-36,38}
Miscellaneous ³⁹	41	37/41 (90%) ³⁹	NA ³⁹	18/41 (44%) ³⁹	NA ³⁹	NA ³⁹
Mid-Shaft						
Surgical ^{9,13,14,16,22,23,25-27}	197	194/197 (98%) ^{9,13,14,16,22,23,25-27}	9.4 wks ^{9,13,14,16,22,23,25-27}	139/144 (97%) ^{9,13,14,16,23,26,27}	181/186 (97%) ^{9,13,14,16,22,23,25-27}	10.1 wks ^{13,16,25}
IM Nail ^{16,22,23,25}	68	67/68 (99%) ^{16,22,23,25}	9.9 wks ^{16,22,23,25}	15/15 (100%) ^{16,23}	66/68 (97%) ^{16,22,23,25}	7.9 wks ^{16,25}
ORIF ^{9,13,14,16,26,27}	129	127/129 (98%) ^{9,13,14,16,26,27}	9.3 wks ^{9,13,14,16,26,27}	124/129 (96%) ^{9,13,14,16,26,27}	115/118 (97%) ^{9,13,14,16,26,27}	11.2 wks ^{13,16}
Non-Surgical ^{9,16,22,24,26}	107	100/107 (93%) ^{9,16,22,24,26}	17.7 wks ^{9,16,22,26}	52/67 (78%) ^{9,16,24,26}	76/76 (100%) ^{9,16,22,26}	11.0 wks ¹⁶
Undisplaced ^{9,16,26}	22	21/22 (95%) ^{9,16,26}	10.6 wks ^{9,16,26}	21/22 (95%) ^{9,16,26}	21/21 (100%) ^{9,16,26}	7.3 wks ¹⁶
Displaced ^{9,16,22,24,26}	85	79/85 (93%) ^{9,16,22,24,26}	21.5 wks ^{9,16,22,26}	31/45 (69%) ^{9,16,24,26}	55/55 (100%) ^{9,16,22,26}	14.1 wks ¹⁶
Lateral ^{9,21,26,28-38}						
Surgical ^{9,21,28-38}	204	174/204 (85%) ^{9,21,28-38}	19.4 wks ^{9,21,32,34,35,38}	135/175 (77%) ^{9,21,29-31,33,35-38}	200/204 (98%) ^{9,21,28-38}	10.4 wks ^{21,28,31,32,34-36,38}
Non-ACJ plate ^{29,31,36}	50	47/50 (96%) ^{29,31,36}	NA ^{29,31,36}	41/50 (82%) ^{29,31,36}	50/50 (100%) ^{29,31,36}	9.3 wks ^{31,36}
Hook plate ^{29,33}	42	33/42 (79%) ^{29,33}	NA ^{29,33}	33/42 (79%) ^{29,33}	41/42 (98%) ^{29,33}	NA ^{29,33}
Suture ^{9,28,32,34,37}	44	43/44 (98%) ^{9,28,32,34,37}	12.6 wks ^{9,32,34}	13/15 (87%) ^{9,37}	43/44 (98%) ^{9,28,32,34,37}	12 wks ^{28,32,34}
Screw ^{21,38}	16	16/16 (100%) ^{21,38}	3.6 wks ^{21,38}	16/16 (100%) ^{21,38}	16/16 (100%) ^{21,38}	7 wks ^{21,38}
TBW ³³	20	8/20 (40%) ³³	NA ³³	8/20 (40%) ³³	19/20 (95%) ³³	NA ³³
Cerclage ³⁰	11	10/11 (91%) ³⁰	NA ³⁰	10/11 (91%) ³⁰	11/11 (100%) ³⁰	NA ³⁰
Arthroscopic endobutton ³⁵	21	17/21 (81%) ³⁵	1.7 wks ³⁵	14/21 (67%) ³⁵	20/21 (95%) ³⁵	13.5 wks ³⁵
Non-surgical ^{9,26}	6	6/6 (100%) ^{9,26}	14.7 wks ^{9,26}	6/6 (100%) ^{9,26}	6/6 (100%) ^{9,26}	NA ^{9,26}
Undisplaced ^{9,26}	6	6/6 (100%) ^{9,26}	14.7 wks ^{9,26}	6/6 (100%) ^{9,26}	6/6 (100%) ^{9,26}	NA ^{9,26}

ORIF, open reduction internal fixation; TBW, tension band wire; ACJ, acromio-clavicular joint; NA, no data available; wks, weeks.

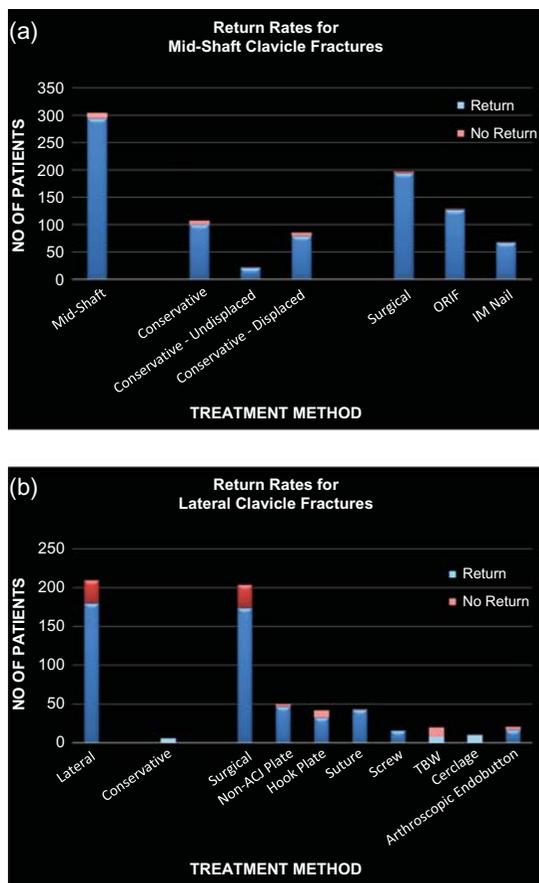


Fig. 2 (a) Return rates to sport for mid-shaft clavicle fractures; (b) return rates to sport for lateral clavicle fractures. ORIF, open reduction internal fixation; TBW, tension band wire.

$P = 0.339$; $I^2 = 12\%$, $P = 0.32$). However, the return rates for the conservatively managed displaced mid-shaft fractures were significantly lower than those for the surgically managed fractures (OR 0.20: 95% CI 0.05–0.83, $P < 0.027$; $I^2 = 0\%$, $P = 0.68$). For the surgical cohort, there was no significant difference between the return rates for those managed with plate fixation compared to those managed with IM nailing (OR 0.95: 95% CI 0.08–10.64, $P = 0.965$; $I^2 = 16\%$, $P = 0.30$).

The return rates to pre-injury level sport for the surgical and non-surgical cohorts are provided in Table 5.

There was no significant difference between the return rates to pre-injury level of sport for the conservatively managed undisplaced mid-shaft fractures

and the surgically managed fractures (OR 0.60: 95% CI 0.06–5.67, $P = 0.659$; $I^2 = 0\%$, $P = 1.00$). The return rates to pre-injury level of sport for the conservatively managed displaced mid-shaft fractures were significantly lower than those for the surgically managed fractures (OR 0.08: 95% CI 0.03–0.24, $P < 0.001$; $I^2 = 35\%$, $P = 0.21$).

For the surgical cohort, there was no significant difference between the return rates to pre-injury level of sport for those managed with plate fixation compared to those managed with IM Nailing (OR 0.73: 95% CI 0.04–13.85, $P = 0.834$; $I^2 = 24\%$, $P = 0.26$).

Lateral clavicle fractures

The return rates for the surgical and non-surgical cohorts are provided in Table 5 and Figure 2b.

Among the surgical techniques, the numbers were insufficient to allow statistical testing.

Return times to sports

Mid-shaft clavicle fractures

The return times to sport for the surgical and non-surgical cohorts are provided in Table 5 and Figure 3a.

There was no significant difference between the return times for the conservatively managed undisplaced mid-shaft fractures and the surgically managed fractures (MD 1.2 weeks: 95% CI 0.53–1.87, $P = 0.151$). However, the return times for the conservatively managed displaced mid-shaft fractures were significantly longer than those for the surgically managed fractures (MD 12.1 weeks: 95% CI 5.58–18.62, $P < 0.001$).

For the surgical cohort, there was no significant difference between the return times for those treated with plate fixation compared to those treated with IM Nailing (MD 0.6 weeks: 95% CI –1.97 to 0.77, $P = 0.295$).

Lateral clavicle fractures

The return times to sport for the surgical and non-surgical cohorts are provided in Table 5 and Figure 3b.

Among the surgical techniques, the numbers were insufficient to allow statistical testing.

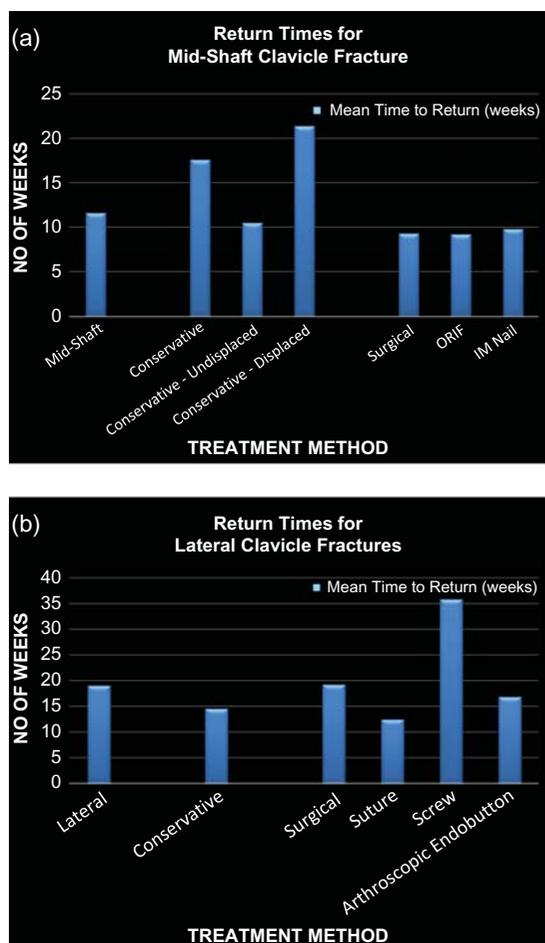


Fig. 3 (a) Return Times to sport for mid-shaft clavicle fractures; (b) return times to sport for lateral clavicle fractures. ORIF, open reduction internal fixation; IM Nail, intra-medullary nail.

Fracture union

Mid-shaft clavicle fractures

For the mid-shaft fractures, union rates ranged from 95% to 100% (mean 98%),^{9,13,14,16,22,23,25-27} and mean times to union ranged from 7.3 to 14.1 weeks (mean 10.3 weeks)^{13,16,25} (Table 5).

Lateral clavicle fractures

For the lateral fractures, union rates ranged from 90% to 100% (mean 98%),^{9,21,26,28-38} and mean times to fracture union ranged from 7.3 to 14.1 weeks (mean 11.0 weeks)^{21,28,31,32,34-36,38} (Table 5).

Only one study specified the difference between clinical and radiological union³⁴ with the majority stating combined figures for both.^{9,13,14,16,21,23,25-33,35,36,38}

Complications

Mid-shaft clavicle fractures

Conservative management. For the undisplaced mid-shaft fractures, there were no reported complications.^{9,16,26}

For the conservatively managed displaced mid-shaft fractures, reported complications included refracture (up to 57%)¹⁶ and temporary upper limb paraesthesia (7.5%).²² The rate of further intervention ranged from 0% to 29%.^{9,16,22,24,26}

Surgical management For the mid-shaft fractures managed with plate fixation,^{9,13,14,16,26,27} reported complications included wound infection (3%,¹³ 18%²⁷), painful metalwork requiring removal (3%,¹³ 9%¹⁴), transient neuropraxia of peripheral nerves (3%,¹³ 8%²⁷), non-union requiring revision fixation with bone grafting (2%,¹⁴ 5%²⁷); hardware loosening with loss of fracture reduction requiring revision fixation (2%¹⁴); subclavian vein compression requiring plate removal (2%¹⁴); hypertrophic scarring (2%¹⁴) and refracture requiring revision (5%²⁷). The rate of re-intervention ranged from 0%^{9,16,26} to 18%,²⁷ with the rate of removal of metalwork ranging from 0%^{9,16,26} to 9%.¹⁴

For mid-shaft fractures managed with IM nail,^{16,22,23,25} reported complications included wound infections (20%²²), refractures after metalwork removal (8%²²), non-unions requiring revision fixation with bone graft (2.5%²²), fracture displacement (8%²⁵), skin perforation from hardware displacement (8%²⁵) and skin irritation from protruding metalwork requiring removal of metalwork (15%²⁵). The rate of re-intervention ranged from 67%¹⁶ to 100%,^{22,23} largely comprising routine removal of metalwork.^{16,22,23}

Lateral clavicle fractures

Conservative management For undisplaced clavicle fractures, there were no reported complications.^{9,26}

Surgical management For the lateral fractures managed with non-ACJ-spanning plate fixation,^{29,31,36} reported complications included symptomatic metalwork (40%,³⁶ 27%³¹) and ACJ subluxation (60%²⁹). The rate of re-intervention ranged from 0%^{29,31} to 40%.³⁶ The rate of removal of metalwork ranged from 0%^{29,31} to 40%.³⁶

For lateral fractures managed with 'hook' plate fixation,^{29,33} reported complications included symptomatic metalwork (34%³³), metalwork loosening with fracture displacement (3%,³³ 30%²⁹), non-union (10%²⁹), ACJ subluxation (10%²⁹), and subacromial osteolysis with hook migration (50%²⁹). The rate of re-intervention ranged from 90%²⁹ to 100%³³: this was all for removal of metalwork.

For lateral fractures managed with open suture fixation,^{9,28,32,34,37} reported complications included fibrous union (8%³⁷) and post-operative shoulder stiffness (11%,³² 8%³⁷). The rate of re-intervention was 0%.^{9,28,32,34,37} The rate of removal of metalwork was 0%.^{9,28,32,34,37}

For the lateral fractures managed with screw fixation,^{21,38} there were no reported complications. The rate of re-intervention was 100%, with routine removal of metalwork performed in both.^{21,38}

Predictive factors

Mid-shaft clavicle fractures

One study found that the incidence of complications was significantly higher for operative management of displaced mid-shaft fractures with IM Nail compared to conservative management of displaced mid-shaft fractures ($P < 0.003$).²² Thirty-five per cent of those treated with IM nail suffered adverse events, while only 10% of those treated conservatively suffered adverse events.²²

Another study found that in displaced mid-shaft fractures treated with plate fixation, the return times for different sports were similar¹³ (mean 12 weeks for American Football, mean 12 weeks for basketball, mean 11.7 weeks for other sports). It was also found that an early return to sports (<6 weeks) did not result in an increased rate of complications.¹³

Lateral clavicle fractures

In a study comparing ACJ-spanning to non-ACJ-spanning plate fixation, it was found that all patients in the non-ACJ-spanning group returned to sport, while only two-thirds of patient returned in the ACJ-spanning group.²⁹ Reoperation rates for implant removal were also significantly higher in the ACJ-spanning group (90%) as compared to the non-ACJ-spanning group (0%).²⁹

Factors found to have no significant influence on functional outcome following surgical management of displaced lateral fractures included gender,³⁶ hand dominance,^{36,37} age at surgery,³⁶ delay of surgery³⁶ and degree of fracture displacement.³⁶

Discussion

The main findings of this review are that most patients with an acute clavicle fracture will return to sports activity, with around four-fifths of all patients able to return to their pre-injury level of sports activity. Those with displaced mid-shaft fractures treated conservatively demonstrate decreased return rates and increased return times to sport compared to those managed surgically: this is confirmed by meta-analysis of the study results. However, clinicians must remember that surgical management exposes the patient to the risk of surgical complications, which include neurovascular injury and infection.¹⁰

In comparison to previous similar systematic reviews, the methodological quality of the studies in this review was improved, with a mean modified CMS of 64.^{19,20,40} However, there were no RCTs, with the majority of studies comprising Level 2 or 3 evidence. Thus, despite established management principles for clavicle fractures, the optimal modalities for management of these injuries have yet to be determined.¹⁰

For the mid-shaft fractures, conservative management remains the recommended treatment for undisplaced fractures, with a favourable side-effect profile.¹⁰ For displaced fractures, while non-surgical management can be considered, refracture can occur in over half of cases and delayed surgical intervention in over a quarter.¹⁶ In contrast, primary surgical intervention offers improved return

rates and return times to sport, particularly with regards to returning to pre-injury level of sport.^{10,12}

This however exposes the patient to the risks of surgical complications that include major neurovascular injury and infection.¹⁰ Clinicians should always counsel patients as such when guiding management.

Regarding the preferred surgical technique for mid-shaft fractures, both plate fixation^{9,13,14,16,26,27} and IM Nail^{16,22,23,25} demonstrated near complete return rates and similar return times. However, clinicians should remain aware that the optimal method of fixation is dependent on the nature of the fracture pattern.^{10,25} Simple, transverse and oblique, two-part fractures are suitable for either form of fixation, and in such instances, the authors advise that clinicians should use the technique that they are experienced with and feel comfortable performing.^{10,16,25} Clinicians should inform patients undergoing IM nail of the recommended requirement for subsequent removal of metalwork.^{16,22,23,25} Complex, comminuted fractures, however, are not suitable for IM nailing, with recorded difficulties in achieving and securing accurate reduction.^{10,25,27} In such instances, clinicians should employ plate fixation.^{10,25,27}

With lateral fractures, in the athletic patient, conservative management remains the standard management for undisplaced fractures, while surgical management remains the standard management for displaced fractures.¹⁰

Regarding the preferred surgical modality, given the wide variety of techniques available and limited numbers per cohort, it was not possible to define the optimal technique.¹⁷ From the results available, non-ACJ-spanning plate fixation and open suture fixation appears to offer better sporting outcomes than 'hook' plate fixation and coraco-clavicular screw fixation. This is likely due to the preservation of ACJ function with the former techniques, providing improved resultant shoulder biomechanics and function.^{10,17,29} However, clinicians should remain aware that the choice of fixation should also be directed by the severity of fracture pattern, with the more complex unstable fracture patterns often requiring concomitant ACJ stabilisation.^{10,29} While the rates of major complications were similar among the various techniques, non-ACJ-spanning plate fixation and suture

fixation had much lower rates of secondary intervention, as routine removal of metalwork was not required for these techniques. Further studies are required to determine the optimal method of fixation.

In comparison to previous studies, there was an improvement in the reporting of rehabilitation methods and functional outcome scores.^{19,20,40} Seventeen studies reported rehabilitation protocols,^{13,14,21–23,25,27,28,30–38} and a further 17 studies reported formal functional outcome scores.^{13,14,22–25,27–31,33–37,39} However, the descriptions of the rehabilitation protocols were often limited.^{13,14,21,22,25,27,28,30–38} While one study noted that an early return to sport (<6 weeks) did not result in an increased complications rate,¹³ there was no other data comparing the effects of differing protocols. As such, the evidence to guide the selection of rehabilitation modality for these injuries remains limited, and future studies should focus on establishing the optimal rehabilitation methods.

As with previous similar reviews,^{19,20,40} the studies from this review often provided limited descriptions of return rates and return times to sport, limiting the ability to compare outcomes from different treatment modalities.^{9,13,14,16,21–39} This is further confounded by the heterogeneity of the included cohorts as well as the limited quality of scientific evidence provided.^{9,13,14,16,21–39} Authors should be encouraged to provide comprehensive descriptions on the level of sport returned to as well as the timing of return, both to training and full-level sport, thus allowing future studies to provide clear comprehensive data on return rates and return times to sport. The design of prospective studies employing validated functional outcome scores should be encouraged to provide high-quality evidence on this topic.

There are several limitations to this review. First, the included studies provided a diversity of data, such that it was not possible to stratify the synthesis data, to assess the effects of fracture severity, fracture classification or level of sporting activity on sporting outcome. Given that the interval from injury to return to sports is dependent on such factors, with the return rates and times for high-risk contact sports being less favourable than for non-contact sports, the generalized data can be of

limited value for the individual athlete. However, to improve the applicability of such data, the causative sports for the individual studies have been included to better illustrate the individual outcomes of different sports. Second, the recording of sporting outcome was limited throughout most of the included studies, with the majority making brief reference to this, failing to provide comprehensive, level-specific definitions regarding return to sport. This significantly impaired our ability to objectively assess final sporting function achieved, and so impaired our ability to compare outcomes from different modalities. Additionally, for the lateral fractures, with multiple treatment modalities employed and limited cohorts, it was not possible to draw definite conclusions on the optimal treatment methods for this fracture type.^{9,21,26,28–38} Furthermore, for the mid-shaft fractures, due to the limited cohorts, it was not possible to assess the link between fracture configuration and choice of surgical technique.^{9,13,14,16,22–27} Finally, due to the heterogeneity of the studies included, it was only feasible to perform a meta-analysis on the data relating to the mid-shaft fractures^{9,13,14,16,22–27}; this was not possible for the lateral fractures.^{9,21,26,28–38}

Conclusion

Most athletes, who suffer an acute clavicle fracture, can expect to return to sport. Non-surgical management forms the first-line treatment for undisplaced fractures. In the athlete, surgical management is the routine treatment for displaced lateral fractures and the recommended treatment for displaced mid-shaft fractures, offering improved return rates and return times over conservative management. However, before recommending surgical intervention, clinicians must warn patients of the potential complications that include neurovascular injury and infection. The optimal surgical technique, for both mid-shaft and lateral fractures, are yet to be established.

Supplementary material

Supplementary material is available at *BRIMED* online.

Conflict of interest statement

The authors have no potential conflicts of interest.

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