

Predictors requiring special attention to prevent clavicle fracture nonunion: a systematic review of literature

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ABSTRACT

Background Clavicle fracture (CF) is the tenth most prevalent fracture, accounting for an annual incidence of 37/10,000. This systematic review highlights the factors contributing to the nonunion union of the clavicular fracture.

Method A systematic search was conducted using three web-based databases up to August 12, 2022, for conducting qualitative analysis. Articles were screened for relevance, and only studies that met inclusion criteria based on PECOS; P (patients): participants diagnosed with clavicular fracture; E (exposure): nonunion, C (control): not applicable; O (outcomes): factors contributing to nonunion or delayed union; S (studies): trials and observational studies. The Newcastle-Ottawa Scale was used to assess the quality of the cohort studies. The Cochrane risk of bias tool was used to assess the bias in randomized control trials.

Results Ten studies were selected after the final literature search. Two thousand seven hundred and sixty-six adult participants who were radiologically and clinically diagnosed with nonunion clavicular fracture were included to pool the qualitative results. Fall was the most dominant cause of clavicular fracture, followed by road traffic collisions. Open reduction was widely used to treat nonunion correction. The qualitative results suggested a prominent correlation of nonunion with advancing age, female gender, high energy trauma, high Disabilities of the Arm, Shoulder, and Hand Score, smoking, fracture displacement, clavicular shortening, the callus on radiography, and fracture movement. The mid-shaft fracture was the most dominant type of fracture in the included studies; highly associated with nonunion in comparison to medial or lateral CF. The previous history of operation was an independent factor contributing to nonunion.

Conclusion The results of this systematic review suggested the predictors contributing to nonunion in the CF. Demographic factors such as advancing age with female gender are at higher risk of developing clavicular nonunion. Smoking was the most dominantly highlighted environmental factor contributing to nonunion. Diaphyseal or midshaft fracture was the most common site for nonunion. Therefore, we suggested that patients with the predictors mentioned above require special attention to prevent nonunion of the CFs. More studies should be conducted on this subject to assess the factors that pose a risk associated with the nonunion of the bone for better clinical management and outcomes of the fracture.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Clavicle fracture (CF) is the tenth most prevalent fracture with an annual incidence of 37/10,000, constituting 4% of all fractures.
- ⇒ The nonunion of clavicular fracture is not rare; the literature suggested several factors contributing to fracture nonunion.

WHAT THIS STUDY ADDS

- ⇒ We conducted this systematic review to present a collective result to identify the risk factors contributing to nonunion and malunion for the better management of patients with CF.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ The qualitative analysis presented the individual predictors contributing to a higher risk of developing nonunion of the clavicle.
- ⇒ The identification of the risk factors of nonunions can contribute to prevention of nonunions and might have a role in improvement of fracture management.

INTRODUCTION

Clavicle fracture (CF) is the tenth most prevalent fracture, accounting for an annual incidence of 37/10,000.¹ It constitutes about 4% of all fractures.^{2,3} Statistically, the most common cause of CF is falls (73.9%), followed by road traffic collisions (RTC).⁴ The midshaft of the clavicle is more prone to trauma, responsible for 80% of CF.^{3,5}

The non-operative method is dominantly employed in managing midshaft CF using a splint or figure-of-8 bandages.⁵ However, recent literature suggested a significant incidence of nonunion in conventional management methods; the nonunion ranges from 3% to 29% among the studies,¹ with an average incidence of nonunion 4.93%.⁶ Ahrens *et al* reported that radiographs taken at 3 months and 9 months of both conservatively and surgically treated patients show no evidence of nonunion at 3 months; however, findings at 9 months indicated 11% nonunion in the conservatively managed patient compared with 0.8% in a surgically managed patient.³ Wu *et al* demonstrated that age and use of wire for supplemental cerclage fixation are significantly associated with fracture nonunion. Female gender and fracture severity has no significant association with nonunion.⁷ Also, the pediatric

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population is rarely reported to have nonunion, as stated by Hughes *et al.*⁸

The Food and Drug Administration (FDA) defines nonunion as a fracture that persists after 9 months of injury and has no signs of healing for the final 3 months. Numerous factors, that have been discovered to have an impact, contribute to nonunion. Several factors, such as inadequate blood supply, lack of mechanical stability, vertical displacement $\geq 100\%$, and deterioration of osteoconductive scaffold, contribute to nonunion.⁹ A very significant local element impacting bone healing is the intensity of the injury and soft tissue damage.^{9, 10} Five percent of nonunions are estimated to be associated with occult infection.¹⁰ Smoking adversely affects union rates in the clavicle, humerus, tibia, and femoral shaft. Clement *et al* demonstrated that DASH (Disabilities of the Arm, Shoulder, and Hand) Scores of 35 or more at 6 weeks after injury and smoking are additive risk factors for clavicular nonunion, the presence of both factors increases the rate of nonunion up to 44%; if one is present, the risk is between 17% to 20%, if neither one present risk is reduced to 2% only.^{10, 11}

Jones *et al*, in a review published in the year 2000, presented factors influencing the healing of clavicles. They found the severity of the trauma, bone displacement and shortening, soft tissue interposition, open fracture, polytrauma, inadequate mobilization, and primary open reduction and external fixation as major contributors to clavicle nonunion.¹² However, recent literature shows conflicting results regarding the nonunion of the clavicle for conventional management. In our literature, we found several cohorts on this subject; however, no published study to our knowledge presents a single result based on already available data on this subject. Therefore, we conduct this novel systematic review to present a collective result on the factors contributing to nonunion in CF.

METHOD

Data sources and search strategy

The Preferred Reporting Items for Systematic Review and Meta-analyses guidelines were adopted to conduct this systematic review and meta-analysis.¹³ An electronic search from PubMed/Medline, Cochrane Trial Register, and Google Scholar was conducted from their inception to August 12, 2022, using the search words: (clavicle OR clavicular fracture) AND (malunion OR nonunion). In addition, we manually screened the cited articles of previous meta-analyses, cohort studies, and review articles to identify any relevant studies.

Study selection

All observational studies and trials were included in the systematic review, which analyzes the factors contributing to nonunion in CF.

The literature showed an ongoing debate regarding the exact dedication of nonunion of the bone, generally regarded as an inability of the bone to heal a fracture. However, the FDA defines nonunion as “a fracture that persists for a minimum of 9 months without signs of healing in 3 months”, the definition is widely accepted, therefore, adopted in this study.^{14, 15} The authors of the selected studies have classified the patients with nonunion or union of CFs based on their radiological and clinical findings.

Online supplemental table 1 provides the demographic characteristics, site, and displacement status of the fractures. The type of operation opted for the treatment of nonunion is reported in online supplemental table 1.

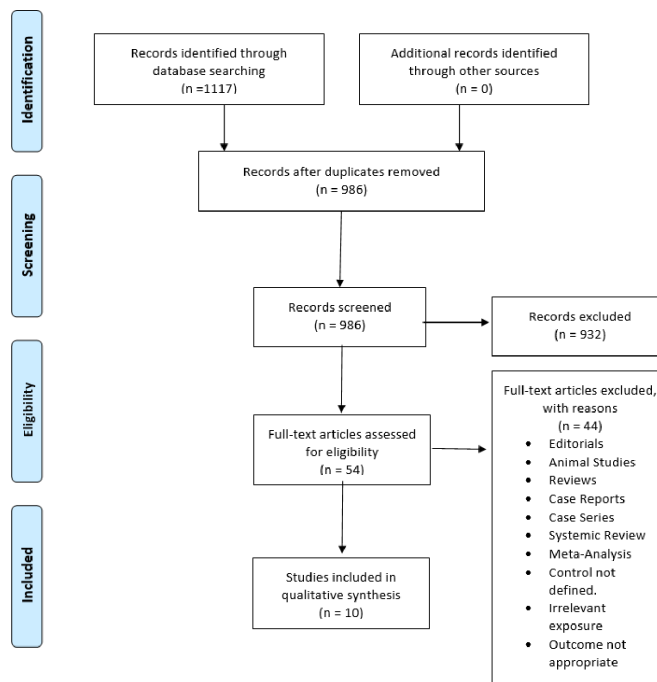


Figure 1 Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) flow diagram.

Data extraction

Two reviewers independently searched all three electronic databases. Studies searched were exported to the EndNote Reference Library software V.20.0.1 (Clarivate Analytics), and duplicates were screened and removed.

Three investigators independently extracted data entering them on a computer spreadsheet. Discrepancies were resolved through consensus discussions among investigators.

Quality assessment of studies

Three investigators independently assessed the quality of each included study. The Newcastle-Ottawa Scale (NOS) was used to assess the quality of the cohort studies. An NOS Score < 6 was considered a high risk for bias, 6–7 was moderate, and a score > 7 was considered a low risk of bias. The Cochrane risk of bias tool was used to assess the bias in randomized controlled trials.

RESULTS

Literature search results

The initial search of the three electronic databases yielded 1117 potential studies. After exclusions based on titles and abstracts, the full texts of 54 studies were read for possible inclusion. A total of 10 studies remained for quantitative analysis.^{1, 16–24} Figure 1 summarizes the results of our literature search.

Study characteristics

We included nine published observational studies and one randomized controlled trial. Two thousand seven hundred and sixty-six adult participants with radiologically and clinically diagnosed nonunion CF were included to pool the qualitative results. Fall was the most dominant cause of CF, followed by RTCs. Open reduction was widely used to treat nonunion correction. Online supplemental table 1 demonstrates the demographic and clinical characteristics of the included participants.

Quality assessment

Online supplemental tables 2 and 3 showed the results for the quality assessment of included cohorts and randomized controlled trials, respectively. Low bias was reported in all the observational cohorts. A moderate level of risk of bias was associated with Robinson *et al.*²⁴

Qualitative analysis

A qualitative analysis of 10 studies involving 2766 patients was conducted to analyze the independent risk factors for nonunion of CFs after either operative or non-operative techniques.^{1,16-24}

Demographic factors

Advancing age

Shoulder function can be severely compromised by nonunion of the clavicle. Robinson *et al* analyzed the risk of nonunion after non-operative management was analyzed in 868 patients having a gender distribution of 638 men and 230 women with a median age of 29.5 years for 51 months. According to the multivariate analysis, at the end of the 24-week period, to assess the prevalence of nonunion, advancing age (relative risk=0.99; 95% CI 0.99 to 1.00) remained an independent predictor of nonunion.¹⁶

Moreover, 263 fractures were clinically and radiologically reported in the lateral fifth of the clavicle; however, at the end of the 24-week period, advancing age (relative risk=0.98; 95% CI 0.97 to 0.99) remained a significant predictor, and a risk factor for nonunion.¹⁶

Lim *et al* include 34 patients in retrospective analysis having a mean age of 40.8 ± 13.7 years, showing a negative correlation between advancing age and nonunion with a value of $p=0.617$ and OR=1.0; 95% CI 0.9 to 1.1.¹⁷ Hence, it is concluded that advancing age and nonunion are positively correlated in the setting of non-operative treatment.

Gender distribution

Robinson *et al* analyzed the risk of nonunion after non-operative management was analyzed in 868 patients having a gender distribution of 638 men and 230 women with a median age of 29.5 years during 51 months. According to the multivariate analysis, at the end of the 24-week period, to assess the prevalence of nonunion, the female gender (relative risk=0.70; 95% CI 0.55 to 0.89) remained an independent predictor of nonunion.¹⁶

Lim *et al* include 34 patients (22 men and 12 women) in retrospective analysis; however, on multivariate analysis, a negative correlation is established between gender and nonunion with a value of $p=0.838$ and OR 1.4; 95% CI 0.1 to 25.3.¹⁷ The disparities among the results of included studies were reported; however, qualitative analysis suggested gender as an independent risk factor for nonunion derived from the results of Robinson *et al* due to larger participants and multivariate results.

Intensity of trauma

In 34 patients included for retrospective analysis, Lim *et al* outline the independent risk factors for bone nonunion at 12 weeks postoperatively (operative procedure consisted of plate osteosynthesis with autologous cortical and cancellous bone graft for nonunion of midshaft CF). The patients were categorized into motor vehicle collisions ($n=16$), falls ($n=11$), and sports-related injuries ($n=7$). Six patients were categorized as having high-energy trauma (five multiple traumas, one subclavian vascular injury).¹⁷

According to the multivariate analysis, high-energy trauma OR=19.2; 95% CI 1.2 to 308.7 and value of $p=0.037$ correlated positively with nonunion.

DASH scoring

To decipher a correlation between the 6-week DASH Score and the risk of nonunion after midshaft CF, Clement *et al* retrospectively analyzed 88 patients. On multivariate analysis, increasing DASH Score emerged as an independent risk factor for nonunion (OR 1.11; 95% CI 1.01 to 1.22).¹

Nicholas *et al* included 200 patients in the retrospective analysis for displaced midshaft CF. The QuickDASH (the abbreviated version of the DASH Questionnaire) was used to assess the patients. According to the multivariate regression model, a score of ≥ 40 was reported for 20 and < 40 for 7 of the total nonunion patients ($n=27$), thus showing a positive correlation between increasing DASH Scores and nonunion OR=6.0; 95% CI 2.0 to 17.4 and value of $p=0.001$ as analyzed by both the forward stepwise conditioning method entry (Nagelkerke $R^2=0.45$) and the backward stepwise conditioning method entry ($R^2=0.47$).¹⁸

Hence increasing QuickDASH Scores are an independent risk factor for increasing the incidence of nonunion in events of CFs, especially in non-operative treatment interventions.

Smoking

In a retrospective analysis, Jearvis *et al.* studied 82 patients who had undergone clavicle osteosynthesis with either locking or non-locking plates, performed by 11 different surgeons. On univariate analysis, it was found that smoking was the only high-risk factor ($Pp=0.02$) that showed a positive correlation with nonunion after midshaft clavicular osteosynthesis.¹⁹

Ban *et al* retrospectively analyzed 55 nonunions from 729 CFs, approximately half of whom (27/55) were active smokers. On univariate analysis, smoking correlates positively with nonunion.²⁰

Nicholson *et al* analyze the association between smoking and the accuracy of CT scans to predict the type of callus formation, hence the associated risk of nonunion. From a total of 184, 99 CT scans were reported to show nonunion after either atrophic (57/99) or hypertrophic callus formation. On univariate analysis, smoking emerged to be the only identifiable risk factor showing a positive correlation with nonunion in the setting of atrophic callus formation ($p<0.001$, OR=4.1).²¹

Murray *et al* retrospectively analyzed nonunion in 941 patients after non-operative treatment of displaced midshaft fractures of the clavicle. According to the multivariate analysis, as 219 patients were smokers, smoking correlated positively with nonunion of the clavicle.²²

Lim *et al* include 14 smokers in the retrospective frame of 34 patients. On multivariate analysis, smoking correlates negatively with nonunion after operative intervention value of $p=0.353$, OR=3.2; 95% CI 0.3 to 38.5.¹⁷

To decipher a positive correlation between smoking and the risk of nonunion after midshaft CF, Clement *et al* retrospectively analyzed 88 patients. On multivariate analysis, smoking emerges as an independent risk factor for nonunion (OR=40.76; 95% CIs 1.38 to 120.30).¹

Hence it can be concluded that smoking remains an independent risk factor for nonunion only after non-operative treatment.

Fractures

Lack of cortical apposition (complete displacement of a fracture)

Robinson *et al* analyzed the risk of nonunion after non-operative management in 868 patients. Accordingly, the lack of cortical apposition correlated positively with nonunion (relative risk=0.69; 95% CI 0.52 to 0.91). Even for lateral fractures of the clavicle, a positive correlation was reported between lack of

cortical apposition and nonunion apposition (relative risk=0.38; 95% CI 0.25 to 0.57).¹⁶

Moreover, Murray *et al* also show a positive correlation between fracture displacement and nonunion (OR=1.75).²² Thus, a positive correlation is reported between decreasing cortical apposition and nonunion, thus emerging as an independent risk factor for nonunion.

Presence of comminution

Robinson *et al* analyzed the risk of nonunion after non-operative management in 868 patients. Accordingly, the presence of comminution correlated positively with nonunion (relative risk=0.43; 95% CI 0.34 to 0.54).¹⁶ Moreover, Murray *et al* also show a positive correlation between the presence of comminution and nonunion (OR=1.17).²² A positive correlation is reported between the presence of comminution and nonunion, thus emerging as an independent risk factor for nonunion.

Callus on radiographs

According to Nicholas *et al*, at 6 months, a follow-up was completed by 200 patients after midshaft CF. To analyze nonunion and associated risk, the regression model predicted no callus on radiographs as a positive correlator with nonunion (OR=4.9; 95% CI 1.6 to 14.3) and value of $p=0.004$ as analyzed by both the forward stepwise conditioning method entry (Nagelkerke $R^2=0.45$) and the backward stepwise conditioning method entry ($R^2=0.47$).¹⁸

Thus, the absence of callus on radiography is an independent risk factor for nonunion in non-operative treatment.

Anatomic site

Ban *et al* retrospectively analyzed 55 nonunions from a total of 729 CFs. A positive correlation between a specific anatomic site of fracture and nonunion was identified as 0%, 9.7 %, and 2.9% nonunion rates were identified for medial, diaphyseal, and lateral fractures, respectively. The greatest nonunion rate (15 %) was reportedly related to type 2B2 (Diaphyseal, displaced, isolated, or comminuted segmental) fractures.²⁰ Hence, it can be concluded that the risk of nonunion is increased in terms of diaphyseal fractures compared with other anatomic sites.

Clavicular shortening

Wick *et al* retrospectively analyzed 39 patients with nonunion. According to the Allman classification, out of 33 Allman I fractures (middle third of the clavicle), 30 reported a shortening of more than 2 cm, concluding a positive correlation between the length of clavicle shortening and delayed union or nonunion.²³ Conclusively, the length/degree of clavicular shortening emerges as an independent risk factor for nonunion after midshaft CFs.

Fracture movement on examination

Nicholas *et al* show fracture movement on examination in $n=14$ of the total nonunion patients ($n=27$). A positive correlation is reported between fracture movement on examination and nonunion (OR=6.1; 95% CI 2.0 to 18.3, $p=0.001$) as analyzed by both the forward stepwise conditioning method entry (Nagelkerke $R^2=0.45$) and the backward stepwise conditioning method entry ($R^2=0.47$).¹⁸ Hence fracture movement present on examination is an independent risk factor for nonunion in non-operative interventions.

Treatment group allocation

In the study by Robinson *et al*, 200 patients between 16 years and 60 years of age were randomized to receive either primary open reduction and plate fixation or non-operative treatment. The risk of nonunion was significantly less in the open reduction and plate fixation group, with a 93% reduction in the risk when the comparison is drawn with non-operative treatment ($p=0.007$).²⁴ Hence, treatment group allocation independently predicted nonunion on multivariate analysis ($p=0.0001$).

DISCUSSION

In this systematic review, we included 10 studies to identify the independent risk factors for nonunion in mid-shaft CFs treated with either surgical or non-surgical methods. To assess whether there was any positive or negative correlation between nonunion after surgical or non-surgical procedures, 13 risk factors were considered. According to Robinson *et al*, advancing age is an autonomous risk factor for nonunion in the context of non-operative treatment. However, Lim *et al* conducted a retrospective analysis and reported a negative correlation between advancing age and nonunion.^{16 17} Likewise, with regard to the distribution of gender, Robinson *et al* and Lim *et al* have reported that the female gender is an independent predictor of nonunion, particularly in non-operative techniques.^{16 17} In their retrospective analysis, Lim *et al* divided patients with various types of injuries into groups, and they discovered that high-energy trauma was positively connected with nonunion after surgical intervention.¹⁷ Clement *et al* identified increasing DASH Scores as an independent nonunion risk factor.¹ Nicholson *et al* obtained comparable results.¹⁸ The association between smoking and nonunion was examined through multivariate and univariate analyses, with smoking being a significant risk factor. In their univariate analysis, Ban *et al* discovered a positive correlation between smoking and nonunion.²⁰ Similarly, in their study, Nicholson *et al* conducted a univariate analysis. They analyzed that smoking was the sole identifiable risk factor that exhibited a positive correlation with nonunion in the context of atrophic callus formation.¹⁸ Murrey *et al*, Lim *et al*, and Clement *et al* conducted multivariate analysis and discovered a significant correlation between smoking and nonunion.^{1 17 22} The included studies have identified various risk factors associated with fractures, including but not limited to lack of cortical apposition, comminution, presence of callus on the radiograph, anatomic site, clavicular shortening, fracture movement on examination, and previous operation. These factors have been analyzed to be independent risk factors for nonunion.

Our systematic review yielded various independent risk factors for nonunion in midclavicular fractures. Several other studies have identified comparable independent risk factors for nonunion in various bones. Sengab *et al* conducted a meta-analysis and identified that the occurrence of a both-bone fracture, complete displacement of the distal radius, and non-anatomic reduction are significant risk factors for re-displacement after the reduction of an initially displaced distal radius fracture in children with such a condition.²⁵

In their systematic review and meta-analysis, Tian *et al* identified 15 factors significantly influencing fracture unions. These factors included being over 60 years old, male, a tobacco smoker, having a body mass index greater than 40, having diabetes, being a user of non-steroidal anti-inflammatory drugs or opioids, having a fracture of the middle or distal tibia, experiencing a high-energy fracture, having an open fracture, being classified as Gustilo-Anderson grade IIIB or IIIC, being classified according

to the Müller AO Classification of Fractures as C, undergoing open reduction, having a specific fixation model, and experiencing an infection.⁶ According to Tian *et al*, there are 14 potential risk factors for the prevalence of nonunion in patients with tibia fractures. However, close reduction and minimally invasive percutaneous plate osteosynthesis pose a low risk for nonunion in patients with tibial fracture.⁶ According to a meta-analysis conducted by Mahajan *et al*, smoking has been identified as a significant risk factor for nonunion and delayed union in patients with tibial fracture. This finding is comparable to the results we obtained.²⁶ CFs are mainly treated conservatively despite the availability of several surgical procedures. The subsequent surgical techniques employed are as follows: classic compression plate osteosynthesis, minimally invasive plate osteosynthesis using angle-stable implants, and minimally invasive elastic stable intramedullary nailing.²⁷ Implementing surgical fixation for a dislocated fracture of the clavicular shaft leads to enhanced functional outcomes and a reduced incidence of nonunion compared with non-surgical treatment after a 1-year follow-up period.²⁸

Our study has identified smoking as an independent risk factor, consistent with a prior study's findings.¹ The precise mechanism of smoking leads to nonunion needs to be more adequately comprehended.²⁹ The impact of smoking on nonunion is significant, although the increased risk may be relatively minor unless accompanied by other risk factors.²⁹ Aging was also identified as an independent risk factor in our study. Nonunion pathogenesis in elderly individuals is complex and not entirely comprehended from a pathophysiological perspective. Several factors have been identified as potential contributors to nonunion in the elderly population. The aging process correlates with bone density reduction and escalated susceptibility to osteoporosis. Low bone mineral density in elderly people is associated with fracture nonunion.³⁰ The incidence of chronic conditions such as diabetes, hypertension, and osteoarthritis, tends to be higher among the elderly population, potentially elevating the likelihood of nonunion.³¹ Similar to the effect of increasing age, our study has identified a positive correlation between the female gender and nonunion. Several proposed mechanisms explain the association between female gender and nonunion after bone fractures. Hormonal differences between men and women may be a factor. It has been shown that estrogen plays a role in bone metabolism and fracture repair, with lower estrogen levels being associated with impaired bone healing.³² Furthermore, certain research indicates that progesterone could potentially impede the process of bone regeneration.³³

Our study found a positive correlation between a high intensity of trauma and nonunion too. Fractures that exhibit high-energy characteristics have been observed to be linked with an increased likelihood of nonunion. This may be attributed to the severity of soft tissue damage, fragmentation of bone, or restricted blood flow to the location of the fracture. According to Hak *et al*, delayed union or nonunion can be predicted significantly by the injury's severity and the fracture's location.³³ The DASH Score is a widely employed instrument for evaluating the functional outcome of upper extremity injuries, encompassing nonunion. Our study identified it as an independent risk factor. Research has indicated that individuals who experience nonunion exhibit low DASH Scores compared with those who have recovered from fractures, indicating the adverse effects of nonunion on the functionality of the upper limb.³⁴

Two included studies reported the data on CF treated primarily with surgical intervention in comparison to eight studies based their findings on conservatively or both surgically or conservatively managed CF. Jarvis *et al* included patients who underwent

surgical fixation for midshaft CF, using locking and non-locking plates; the author reported the characteristics of plate such as length, proximal or distal screw position, and osteosynthesis has no effect on the nonunion of the bone, identifying smoking as the only statistically significant risk factor for nonunion.¹⁹ Unlike Jarvis *et al*, Lim *et al* identify previous operation as a significant factor contributing to clavicle nonunion. According to the author, open reduction can decelerate the biological healing potential. However, due to lack of significant evidence, and high limitation to the study, it is not possible to assess the impact of previous operation on nonunion, considering a substantial ongoing debate on this subject in literature.³⁵ However, the results of systematic review suggest uncertainty on previous surgical intervention effecting the nonunion; the other identified risk factors are independent of the previous operation.

The qualitative analysis suggested that individual demographic factors such as age and female gender are at a higher risk of developing nonunion of the clavicle. Fracture site, displacement, clavicular shortening, or fracture movement can independently contribute to the nonunion or delayed union of the clavicle. DASH Score and intensity of trauma are also major contributors to nonunion. Therefore, we suggested that patients with the abovementioned predictors require special attention to prevent nonunion of the clavicle. More studies should be conducted on this subject to evaluate the risk factors associated with the nonunion of the bone for better clinical management and outcomes of the fracture. With little data, future research must focus on this to distinguish between individuals who would benefit from operation and those who would not.

Limitation

Despite the novelty of this study for predicting the risk factors contributing to the nonunion of fracture for better management of CF, the need for more consistency among included studies was a drawback, producing some heterogeneity in the study. The clinical and radiological identification of nonunion and adopted definitions of the author of the selected studies might differ, therefore producing heterogeneity in the included population. The patients who were managed conservatively as well as surgically for CF were included in the study, therefore, we were unable to separate the outcomes leading to nonunion in surgically managed CF in comparison to conservatively managed CF; however, low evidence on the impact of previous surgical intervention was present. In addition to the management, we were also unable to present stronger evidence of the factors contributing to nonunion based on the site of fracture and methods for assessing the displacement or shortening in the CF. Despite the available evidence reporting more risk of nonunion at diaphyseal, displaced, isolated, or comminuted segmental fractures, we think more data on isolated fracture based on the specific site are needed. Due to a lack of significant data, we could not present a quantitative result which is a major limitation of our study. Although 10 studies were included in the qualitative analysis, only some of the included studies presented data on each predictor. The lack of statistical analysis, limited sample size, and unavailability of data can affect the quality of our results. Therefore, we suggest larger studies to assess the predictors for better management of CFs.

CONCLUSION

Several independent risk factors for nonunion and the success of operative or non-operative techniques in mid-shaft clavicle fractures have been identified. These include advancing age, gender,

high DASH score, smoking, lack of cortical apposition, degree of clavicular shortening, anatomical site of the fracture, presence of comminution, callus on radiographs, and fracture movement on examination.

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