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Operative versus Conservative Treatment of Clavicular and Scapular Fractures

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Abstract

Background: Clavicle fractures and scapula fractures represent up to 4% and 1% of all fractures, respectively.[1-4,9-11] Historically, both fracture types have been treated conservatively with acceptable outcomes. The surgical correction of these fractures is currently being investigated as a viable alternative to conservative management.

Method: A systematic search of PubMed was performed to identify articles comparing open reduction and internal fixation (ORIF) with conservative treatment for both clavicular and scapular fractures. Specific outcomes of interest were shoulder function, pain, strength, range of motion, and risk of nonunion.

Results: ORIF of midshaft clavicular fractures results in increased shoulder function within six weeks following treatment and a decreased risk of nonunion. After one year, there was no longer a difference in shoulder function between groups. There was no difference in pain between treatment groups. Both ORIF and conservative treatment of extraarticular scapular fractures yield comparable results in shoulder function, range of motion, and strength following treatment.

Conclusions: Both conservative and operative treatment of midshaft clavicular fractures yield acceptable, long-term outcomes in shoulder function and pain, although conservative treatment has a higher risk of nonunion. More randomized clinical trials are needed to address the high heterogeneity between studies, which is limiting the strength of the current evidence. The lack of randomized clinical trials comparing operative and conservative treatment of extraarticular scapular fractures does not allow for specific conclusions to be made regarding superiority of treatment; only that both treatment options produce acceptable results. Therefore, additional studies are warranted.

Introduction

Clavicle fractures account for up to 4% of all fractures.[1-4] Up to 80% of clavicular fractures occur in the middle third of the bone, and roughly 73% of those are displaced.[1-3,5] Historically, it has been common practice to treat clavicular fractures conservatively with either a simple sling or figure 8 bandage.[1-3,6] However, studies have shown that malunion of clavicular fractures following conservative treatment can alter glenohumeral joint kinematics, resulting in a loss of function and strength.[5,7,8] Furthermore, recent studies have shown that nonunion rates are higher than expected.[7] This has led to an increase in the number of cases being treated surgically via open reduction and internal fixation (ORIF) with either metal plates or intermedullary pins to prevent malunion complications. While it is generally accepted that nondisplaced clavicular fractures don't require operative treatment, no firm guidelines have been established for displaced clavicular fractures and their management remains controversial.[7]

Scapula fractures are quite rare, accounting for 1% of all fractures.[9-11] Extraarticular fractures are the most common type of scapula fractures, representing up to 90% of cases.[12] Most often, scapula fractures are caused by high energy trauma, and therefore, very rarely exist in isolation.[9-11] Much like clavicular fractures, conservative treatment has been the mainstay for scapular fractures.[9,10] However, conservative management of severely displaced scapular fractures can result in shoulder girdle dysfunction secondary to malalignment, dysfunction of the rotator cuff muscles, scapulothoracic dyskinesis, and impingement-type pain.[9,10] Recent improvements in surgical techniques and hardware have led to increased interest in utilizing operative management as an alternative to treating scapular fractures.[10,11]

The purpose of this literature review was to compare operative and conservative management of clavicular and scapular fractures and conclude which has superior treatment outcomes. Specific outcomes investigated were shoulder function, pain, and risk of nonunion or malunion. Since midshaft clavicular fractures and extraarticular scapular fractures are the most common fractures reported for each bone, this review will focus on the differences in treatment outcomes of those types exclusively. It was hypothesized that operative treatment of both clavicular and scapular fractures would result in better shoulder function, decreased pain, and a decreased risk of nonunion/malunion compared to conservative treatment.

Normal Function of the Clavicle

The clavicle is responsible for connecting the scapula to the thorax, thus increasing stability for the shoulder girdle.[13] It allows for additional motion when the arm is raised by elevating and rotating, keeping the scapula in proper alignment over the humeral head and preventing anterior displacement.[14] Additionally, it serves as an origin/insertion site for muscles and protects important neurovascular anatomy.[13] Lastly, the clavicle also helps support respiratory function.[13] It's possible that a clavicle fracture could result in serious complications regarding glenohumeral joint mechanics.

Clavicle Fractures and Their Effects on Glenohumeral Joint Kinematics

Numerous studies have shown that clavicular fractures, specifically those that are displaced at least 15 mm, create a cascade of changes that can result in decreased shoulder function and strength.[5] The shortened malunion of the clavicle changes the length-tension relationship of the musculature of the shoulder.[5,8] Those muscles lose mechanical efficiency, which decreases strength.[5] The loss of strength specifically affects shoulder extension, internal rotation, and adduction.[5] Furthermore, since the clavicle is the conduit through which the scapula attaches to the axial skeleton, shortened clavicular malunion increases anterior scapular tilt.[5,8] This also has the potential to alter glenohumeral and scapulothoracic kinematics.[5,8]

One cadaver study investigated clavicular malunion and its effects on the center of rotation of the glenohumeral joint. Rosso et al. reported significant increases in posterior and superior translation of the rotational center of the shoulder throughout the range of abduction.[5] Interestingly, alterations in the center of rotation were still present even after plate fixation. While plate fixation corrected the posterior and superior translations found in malunion at lower abduction angles, there was excessive anterior and inferior translation at overhead angles.[5] It must be noted, however, that this study was unable to simulate dynamic muscle forces involved in shoulder function/stability.[5] This is an important sticking point, because perhaps these forces can compensate for the changes in osseous anatomy and negate the impact on shoulder function following clavicular fracture.

Classification of Clavicular Fractures

There are multiple, documented classification systems that are used to categorize clavicle fractures. Allman was the first to propose categorizing clavicular fractures based on the location of the fracture in 1967.[1,6,13] According to his system, fractures that occur in the middle third of the clavicle are considered group I.[1,6,13] They are the most common clavicle fracture, representing up to 80% of cases.[1-3,5] Up to 73% of midshaft clavicular fractures have some degree of displacement.[5] Group II clavicular fractures occur in the lateral third, and group III fractures occur in the medial third.[1,6,13] Allman's classification system was a good starting point, but it lacked important information like the degree of displacement or comminution.

The *Arbeitsgemeinschaft für Osteosynthesefragen*/Orthopedic Trauma Association (AO/OTA) classification is commonly used in clavicle fracture literature and it addresses more than just location of the fracture (see figure 1).[4,15] In this system, a number is assigned to each bone. The number that represents the clavicle is 15.[4,15] Then, numbers 1, 2, or 3 are assigned to indicate fractures in the medial, midshaft, or lateral regions of the clavicle respectively.[4,15] Finally, the letters A, B, or C correspond to either a simple, wedge, or comminuted fracture respectively.[4,15] For an example using this system, the notation to describe a simple, midshaft clavicular fracture would be recorded as 15.2A.

Lastly, the Robinson classification system is simpler, yet just as descriptive, as the AO/OTA method. It is also commonly used in the literature. Much like the Allman system, the Robinson groups clavicular fractures based on location. Type 1 fractures occur in the medial fifth, type 2 occur in the middle three-fifths, and type 3 occur in the lateral fifth.[4] Next, the modifiers A or B are added to indicate degree of displacement. The letter A correlates to fractures that are displaced less than 100%, while the letter B is reserved for fractures that are displaced more than 100%.[4] Finally, the numbers 1 or 2 are used to indicate articular involvement for type 1 and 3 fractures or comminution in type 2 fractures.[4] The number 1 means no articular involvement/no comminution, while the number 2 indicates articular involvement/comminution. Therefore, the same simple, midshaft clavicular fracture used for the AO/OTA example would have a Robinson notation of type 2A1.

Conservative Treatment for Clavicular Fractures

Historically, conservative treatment has been the norm for midshaft clavicular fractures.[1-3,6,16-18] Conservative management involves the use of simple slings or figure 8 bandages followed by physical therapy. The simple sling provides support as the fracture heals.[6] However, the sling does not realign displaced fractures which could result in clavicular shortening or malunion.[6] The logic behind the use of the figure 8 bandage is that it keeps the shoulders retracted, which aims to realign displaced fractures, thus decreasing the chance of clavicular shortening or malunion.[6] Those benefits come with an increased risk of nonunion, and patients generally find figure 8 bandages to be cumbersome and inconvenient.[6]

Current literature fails to identify the best conservative management for middle third clavicle fractures.[6] Therefore, the use of a simple sling over a figure 8 bandage and vice versa is heavily provider dependent. For example, 94% of US surgeons opt to use a simple sling over the figure 8 bandage, while 88% of their German counterparts prefer the opposite.[6] Additionally, there is currently no documented optimal duration of use for either the sling or figure 8 bandage, however one study has suggested a period of 2-6 weeks.[6]

Most studies have their nonoperative patients start physical therapy once the use of the sling or figure 8 bandage is discontinued by the treating clinician, sometime during the range previously mentioned. Specific physical therapy protocols and exercises are scantly reported in the literature, as they can vary between patients. Instead, studies note vague timelines and types of exercises used for nonoperative treatment of clavicular fractures. For example, Robinson et al. had their nonoperative patients wear a sling for three weeks followed by range of motion exercises with a physical therapist.[16] At six weeks post-injury, patients could begin strength exercises.[16] While the timelines may vary slightly between studies, the progression from sling, to range of motion, to strength exercises is repeated throughout the literature in nonoperatively treated clavicle fractures.

Operative Treatment for Clavicular Fractures

There are several surgical techniques utilized to manage clavicular fractures. The two most commonly performed techniques are open reduction and internal fixation (ORIF) with plates or the insertion of intermedullary pins.[19] A variety of plates have been used with the ORIF approach, including tubular plates, dynamic compression plates, and reconstruction plates.[19] Additionally, the use of pre-contoured locking plates is being investigated for the treatment of clavicular fractures.[19] A Cochrane review from 2015 concluded that, "the evidence regarding the effectiveness of different methods of surgical interventions for treating fracture and nonunion of the collarbone is very limited and that further studies are justified.[13]" Therefore, there isn't an established first line surgical procedure to manage clavicular fractures.

Indications for operative treatment of clavicular fractures include the following: open fractures, severe displacement secondary to comminution, an imminent skin lesion by a sharp edge of the clavicle, and neurovascular compromise.[13] Complicating matters, there is currently no set definition for the term "severe displacement." Some studies define it as more than 15 mm, while others use 20 mm. Symptomatic malunion and non-union are only considered relative indications for surgery.[13] This means that patients with these complications do not necessarily require surgical management, and that it's up to the patient and the surgeon to utilize shared decision making when planning course of treatment.

For those patients who do decide to undergo operative treatment, the literature shows that this option is not without its own inherent risks. A Cochrane review published in 2019 reported that infection and dehiscence were found to occur after surgery exclusively. Data from eleven included studies showed that 22 out of 686 patients (3.2%) treated surgically experienced either infection, dehiscence, or both.[1] None of the 641 patients (0%) treated conservatively experienced these complications.[1] This equates to operatively managed patients being 5.62 (95% CI 1.95 to 16.15) times more likely to have infection or dehiscence complicate their recovery.[1]

Furthermore, the same Cochrane review noted that skin and nerve problems were also more commonly observed in the operative group.[1] Data from six included studies showed that of 338 patients treated operatively, 75 of them (22.2%) complained of either skin or nerve issues after treatment.[1] Only 5.5% (17/310) of their conservatively treated counterparts reported either issue.[1] Therefore, patients treated operatively were 4.86 (95% CI 1.85 to 12.76) times more likely to have skin or nerve complaints following treatment.[1]

Lastly, a few studies included in this review report on implant-related irritation requiring hardware removal. Frima et al. notes that the occurrence of implant-related irritation can affect as many as 70% of patients after operative treatment.[4] Data from 9 studies included in the Cochrane review showed that 52 out of 508 patients (10.2%) treated operatively experienced hardware irritation that required subsequent removal (RR 9.75, 95% CI 3.91 to 24.31).[1] Therefore, the risks and benefits of surgical treatment for midshaft clavicular fractures should be discussed with prospective patients prior to determining treatment course.

Operative versus Conservative Treatment of Clavicular Fractures

Effects on Shoulder Function

Shoulder function following operative or conservative treatment is frequently the primary outcome measured in the literature. Most commonly, it is measured using the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire or the Constant score. The DASH score is a validated patient-reported measurement of upper limb function.[1,6,13] It ranges from a score of 0, indicating best function, to a score of 100, indicating worst function.[1] In contrast, the Constant score is a composite score for shoulder function that includes both subjective and objective measures.[6,13] For example, it includes patient rated pain and activities of daily living along with objective measurements of range of motion and strength.[6,13] Like the DASH questionnaire, it is graded from 0 to 100, although 100 is associated with best function while 0 indicates worst function.[1] To clarify, patients with acceptable shoulder function will have low DASH scores and high Constant scores. Conversely, patients with poor shoulder function will have high DASH scores and low Constant scores.

Multiple randomized clinical trials (RCTs) and cohort studies show an earlier improvement in shoulder function following surgical intervention compared to conservative treatment. Qvist et al. reported mean DASH scores at six weeks' and three months' follow-up were significantly better in the intervention group ($p<0.001$ and $p = 0.02$ respectively).[17] Median DASH scores at three months' follow-up were 1.7 in the operative group and 8.3 in the conservative group ($p = 0.02$, see figure 2).[17] Furthermore, mean Constant scores were also significantly better in the intervention group at both six weeks' and three months' follow-up ($p<0.001$ and $p = 0.02$ respectively). Median Constant scores at three months' follow-up were 97 in the operative group and 90 in the conservative group ($p = 0.02$, see figure 3).[17] After six months, however, the difference in DASH and Constant scores between the groups was no longer significant.[17] Therefore, while surgical intervention provides an earlier improvement in shoulder function, the conservative treatment group eventually catches up.

Ahrens et al. reported similar findings in their multicenter RCT from 2017. The operative group had significantly better DASH and Constant scores at both six weeks and three months (see figures 4 and 5).[2] Unadjusted median DASH scores were 13.33 points (19.60 to 7.07, $p <0.001$, $n = 218$) lower (better) in the operative group at six weeks.[2] Similarly, unadjusted median Constant scores at six weeks were 12.37 points (6.59 to 18.14, $p < 0.001$, n = 209) higher (better) in the operative group.[2] However at nine months, the difference was no longer significant.[2] Unadjusted median DASH and Constant scores were only 0.83 points (0.54 points worse to 2.20 points better, p = 0.231, n = 204) and 2.13 points (1.12 points worse to 5.38 points better, p = 0.197, n = 164) better respectively for the operative group at nine months.[2]

Another multicenter RCT conducted in 2013 by Robinson et al. supports the notion that surgical treatment yields an earlier improvement in shoulder function with one important caveat. They found that mean functional scores were better in the operative group than the conservative group at all assessments (p values of 0.01-0.04) except for the Constant score at six weeks and six months and the DASH score at six months (see figures 6 and 7).[16] Even at the one year follow-up, DASH and Constant scores were still significantly better in the operative group; 3.4 versus 6.1 (p = 0.04) and 92.0 versus 87.8 (p = 0.01) respectively (see figure 8).[16] Interestingly though, the aforementioned important caveat was that once patients with nonunion were excluded from analysis, the differences in DASH and Constant scores were no longer statistically significant at any time point.[16] This means that shoulder function was roughly equivalent for both groups at one year of follow-up. Therefore, this study reinforces previously discussed RCTs' findings that even though surgical intervention yields earlier improvements in shoulder function, ultimately the conservative group's function improves to match it.

One cohort study conducted in 2015 by van der Ven Denise et al. showed no significant difference in shoulder function between treatment groups after five years.[18] Patients had to have a completely displaced midshaft clavicular fracture with no cortical contact between fracture fragments to be eligible for the study.[18] It's noteworthy that this was not a randomized clinical trial; patients were educated on operative and conservative management and chose their treatment group.[18] Of the original 97 patients, 78 (80%) completed the study with a mean follow-up of 5.3 ± 0.6 years.[18] The operative group (n = 38) reported a DASH score of 5.2 ± 9.8 while the nonoperative group (n = 40) reported a score of 2.5 ± 4.9 (p = 0.12).[18] While this data is only based on 78 patients, it coincides with the trend that there is no long-term, statistically significant difference between surgical and conservative treatment of displaced clavicle fractures. Both options provide good functional outcomes.

While none of the studies discussed previously included pediatric patients, Herzog et al. published a retrospective cohort study in 2017 comparing operative and nonoperative treatment of midshaft clavicle fractures in an adolescent population. A total of 20 patients, 10 treated conservatively with an average age at injury of 14.1 years (± 0.9 years) and 10 treated operatively with an average age at injury of 14.6 years (±1.8 years) were included in the study.[20] Herzog et al. reported no statistically significant (p = 0.08) difference in mean DASH scores between operative and conservative treatment groups, 1.7 points and 0.0 points respectively at a median follow up of 2.6 years (range = 1.4-5.2 years).[20] These findings are congruent with other studies involving adult patients. Even though this study had a small sample size (n = 20), it's important to note that DASH scores reported by pediatric patients were lower than adults.

Unsurprisingly, systematic reviews also show there is no clinical, long-term difference between operative and conservative management of displaced, midshaft clavicular fractures on shoulder function. A meta-analysis conducted by Woltz et al. in 2017 included six RCTs and a total of 614 patients (317 were treated surgically and 297 were treated conservatively).[21] The included studies only had follow-ups at twelve months or more.[21] Surgically treated patients had a mean Constant score that was 4.4 points (95% CI 0.9 to 7.9 points, p = 0.01) higher than the group treated conservatively (see figure 9).[21] Additionally, the mean difference in DASH scores favored the surgical group by 5.1 points (95% CI 0.1 to 10.1 points, $p = 0.05$) one year after trauma (see figure 10).[21] While these outcomes are statistically significant, they also included patients with a nonunion who had yet to receive surgery in their calculations.[21] Once the data was analyzed excluding patients with nonunion, the functional difference between the two groups after one year was no longer significant.[21] Therefore, it is difficult to ascertain whether or not these statistics provide an accurate representation of final shoulder function for all patients.

A more recent Cochrane review was published in 2019 and included 14 studies involving 1469 participants.[1] Isolating DASH scores, 8 of the 14 studies included in the review (896 participants) showed no clinically important difference in disability between conservative and surgical treatment at 9 months or more of follow-up (mean difference (MD) -3.87 points, 95% CI -7.75 to 0.01 points, $I^2 = 90\%$).[1] Pooled analysis of Constant scores showed improvement in function favoring surgical intervention, however this was considered clinically unimportant (MD 3.83 points, 95% CI 1.75 to 5.91, $I^2 = 75\%$).[1] Data analysis combining 10 of the 14 studies representing 838 participants revealed a standardized mean difference (SMD) of 0.33 (95% CI -0.02 to 0.67, $I^2 = 83\%$) in favor of surgical intervention at one year or more of follow-up (see figure 11).[1] However, this correlates to a mean improvement of 2.3 points (0.14 points worse to 4.69 points better) on the Constant scale in favor of surgical intervention, which they did not find clinically significant.[1] Furthermore, it’s noteworthy that heterogeneity was substantial for all the statistics above. This indicates that the studies included in the review were highly variable in their respective study designs.

In summary, the literature shows that surgical treatment with ORIF allows for higher shoulder function within 6 weeks of treatment when compared to conservative management. However, this could potentially be attributed to a lower risk of nonunion that comes with operative treatment, and not a result of the treatment itself. Conservative treatment eventually matches surgical treatment in terms of shoulder function between six months to one year after intervention. Therefore, surgical intervention should be offered to patients who value an earlier return to higher shoulder function.

Effects on Pain

Very few studies included pain as an outcome measure. The ones that did report on it utilized either the visual analog scale (VAS) or patient-reported symptoms section on the DASH questionnaire to quantify pain. The VAS is a sliding scale from 0 mm, indicating no pain, to 100 mm, indicating maximum pain.[1] It can also be measured in centimeters; from 0 (no pain) to 10 (maximum pain).[1] The DASH questionnaire has a dimension of questions pertaining to symptoms.[18] Most studies do not break the DASH questionnaire into its component dimensions, however one study included in this review did.

The Cochrane review from 2019 reported no difference in patient-reported pain between operative and conservative management of midshaft clavicular fractures (see figure 12). They pooled analysis from three studies using the VAS and found that there was a small, but clinically insignificant improvement in pain at six weeks in favor of the operative group (MD -4.27 mm, 95% CI -8.18 to -0.37, minimal clinical important difference (MCID) = 14 mm).[1] However, no difference was found at three months (MD -0.08 mm, 95% CI -3.64 to 3.48) or at one year (MD -0.60 mm, 95% CI -3.51 to 2.31).[1]

Even at a mean follow-up of 5.3 ± 0.6 years, van der Ven Denise et al. found no significant difference ($p = 0.30$) in patient-reported symptoms on the DASH questionnaire.[18] The operative group ($n = 38$) had a mean symptom score of 9.4 ± 4.2 while the group treated conservatively (n

= 40) reported a score of 8.5 ± 3.3.[18] Additionally, 14 patients from each group reported sensitive and/or painful fracture site at long-term follow-up, which equates to 37% of the operative group and 35% of the conservative group.[18]

Herzog et al. reported the incidence of chronic pain in a pediatric patient population (n = 20). There wasn't a statistically significant ($p = 1.00$) difference in chronic pain at a median follow-up of 2.6 years (range = 1.4-5.2 years) between pediatric patients treated operatively or conservatively.[20] Only one patient from the conservative group reported chronic pain.[20] No patients from the operative group reported chronic pain.[20] Therefore, conservative and surgical treatment alike yield similar results in terms of pain, even in a pediatric population. Neither one is more effective than the other in reducing the amount of pain felt by patients.

Risk of Nonunion

Randomized clinical trials agree that displaced, midshaft clavicular fractures treated surgically have a lower incidence of nonunion compared to conservative treatment. Robinson et al. showed that 17% (16/92) of conservatively treated patients had a nonunion compared to just 1.2% (1/86) of patients in the operative group in the first year following injury (RR = 0.07, 95% CI 0.01 to 0.5, $p = 0.007$, see figure 13).[16] This correlates to a 93% reduction in risk of nonunion for the surgical group compared to the conservative group ($p = 0.007$).[16] Interestingly, they also reported that age, sex, increasing fracture displacement, and comminution were not significant predictors of nonunion; only smoking and treatment group allocation were found to be significant predictors ($p = 0.0001$ and $p = 0.006$ respectively).[16]

The multicenter RCT conducted by Ahrens et al. reported nonunion rates as a primary outcome. Radiographs were taken of all patients at the six-week and three-month follow-up appointments to assess for clavicular fracture union.[2] Any additional radiographs that were taken after the three-month follow-up but confirmed a nonunion were recorded and analyzed in the data.[2] The proportion of patients with a confirmed nonunion at the three month follow-up was nearly identical between operatively and conservatively treated groups, 28% (n = 38) and 27% (n = 36) respectively.[2] However, there was a statistically significant difference ($p < 0.001$) between groups at nine months. A total of 13 patients (11%) that underwent conservative treatment had a nonunion compared to just 1 patient (0.8%) from the operative group (see figure 14).[2] One major weakness in their methodology was not requiring radiographs for all patients at the nine-month follow-up. There is a possibility that patients with asymptomatic nonunion could have been missed in the data. Nevertheless, the data reported coincides with findings from other studies.

Woltz et al. also reported that a higher percentage of patients in the conservative treatment group developed a nonunion compared to operatively treated patients. In their meta-analysis, they found that only 1.9% (6/317) of patients treated operatively developed a nonunion compared to 16.5% (49/297) of patients treated conservatively (RR = 0.14, 95% CI 0.06 to 0.32, $p < 0.0001$, see figure 15).[21] The follow-up period varied between the included studies, ranging from 4 to 12 months.[21] Lastly, two of the six included studies confirmed nonunion using computed tomography (CT), while the other four used radiographs.[21] The variance of follow-up period and use of imaging indicates a certain degree of heterogeneity between included studies, which should be taken into account.

Another meta-analysis published by Wang et al. in 2015 found risk ratios comparable to what Woltz et al. reported. Pooled data from 13 studies showed that patients treated operatively had an 84% reduction in risk of nonunion compared to patients treated conservatively (RR = 0.16, 95%

CI 0.09 to 0.30, $p < 0.00001$).[22] Only 9 patients out of 507 treated operatively reported a nonunion, compared to 65 patients out of 452 treated conservatively (see figure 16).[22]

Data from the 2019 Cochrane review on rates and risk ratios of nonunion closely matches previously discussed data. The incidence of symptomatic nonunion in the operative group was 1.4% (8/561) and 11.6% (61/527) for the conservative group (RR 0.20, 95% CI 0.10 to 0.40).[1] A risk ratio of 0.20 equates to an 80% reduction in risk of symptomatic nonunion for those treated operatively compared to patients treated conservatively. This data is pooled from ten studies that involved a total of 1088 participants.[1] Furthermore, the Cochrane review also reported pooled data on asymptomatic nonunion from seven studies (see figure 17).[1] Of 411 patients treated conservatively, 43 had asymptomatic nonunion compared to 3 patients out of 434 treated operatively (RR 0.12, 95% CI 0.05 to 0.30).[1] This equates to an 88% reduction in risk of asymptomatic nonunion in patients who opt for operative treatment.

Interestingly, the previously discussed results on risk of nonunion were not replicated in a retrospective cohort study involving a pediatric population ($n = 20$).[20] Neither the conservative nor the operative group reported a single nonunion; all fractures healed successfully regardless of group allocation.[20] Nevertheless, these findings must be confirmed with additional studies, as the low population size limits the strength of the results.

In summary, operative treatment with plate fixation to correct midshaft clavicular fractures in adults results in a decreased risk of nonunion compared with conservative treatment.[1,2,16,21,22] Various studies report a reduction in risk of nonunion ranging from 80% to 93%.[1,16,21,22] A majority of this data comes from meta-analyses and systematic reviews with large numbers of patients, strengthening the efficacy of operative treatment in preventing nonunion.

Normal Function of the Scapula

The scapula and its supporting musculature provide a degree of dynamic stability to the humeral head and shoulder complex.[10] Eighteen muscles originate, insert, or cross both the scapula and glenohumeral joint, each responsible for providing some dynamic stability to the shoulder complex.[10] The supraspinatus, infraspinatus, teres minor, and subscapularis muscles make up the rotator cuff and are the most important muscles for glenohumeral stability. Together they apply a constant axial compressive force that keeps the humeral head in contact with the glenoid.[10]

To optimize the dynamic stability of the rotator cuff muscles, the scapula must keep the humeral head centered over the glenoid during active movement.[10] Cole et al. better explains this using the analogy of a seal balancing a ball on its nose.[10] If the ball, which represents the head of the humerus, begins to fall off the seal's nose, or the glenoid of the scapula, the seal must move to accommodate it to prevent the fall. Therefore, the scapula and glenohumeral joint must work together to provide maximum range of motion of the shoulder. There is an approximate two-to-one ratio between glenohumeral elevation and upward scapular rotation.[14] This means that for every two degrees of glenohumeral elevation, the scapula rotates upward one degree to keep the humeral head centered over the glenoid.[14] For example, if the humerus is elevated to its maximum of 180 degrees, the glenohumeral joint is responsible for 120 degrees while upward rotation of the scapula makes up the additional 60 degrees.[14] Due to the close relationship between the scapula and glenohumeral joint, it's plausible that nonunion or malunion of the scapula could lead to instability or dysfunction of the glenohumeral joint.

Changes in Glenohumeral Joint Mechanics Following Scapular Fracture

Changes in osseous anatomy secondary to fracture could promote fatigue and dysfunction of the musculature of the shoulder girdle.[10] If the dynamic stabilizers of the scapula can't move effectively to keep the humeral head centered over the glenoid, dislocation is a definite possibility. Furthermore, if the scapula loses range of motion, it's plausible that the glenohumeral joint will also lose range of motion, especially in ranges that are above 90 degrees of flexion or abduction due to their two-to-one relationship. Complicating matters, scapular fractures rarely exist in isolation due to the high-energy trauma required to cause injury.[9,10,11]

Comorbid Injuries Occurring with Scapular Fractures

Cole et al. noted the prevalence of comorbid diagnoses that occur with scapular fractures. Data from over 9,400 patients with scapular fractures was obtained and analyzed. The most prevalent concomitant injury was rib fractures, which occurred in 52.9% of those patients.[10] Lung injuries were a close second, occurring in 47.1% of patients with a scapular fracture.[10] Head injuries were also present in 39.1% of patients.[10] Spine and clavicular fractures were the least concomitant injuries, present in 29.1% and 25.2% of cases respectively.[10]

Dimitroulias et al. also reported specific comorbidities for their cohort (n = 32) presenting with displaced scapular body fractures.[23] Rib fractures were the most common associated injury, occurring in 17 of the 32 patients (53%).[23] Specific lung injuries recorded were pneumothorax, pulmonary contusion, and hemothorax, which occurred in 41%, 31%, and 25% of patients respectively.[23] A total of 12 patients (38%) presenting with a displaced scapular body fracture also had a closed head injury.[23] Clavicular fractures were present in 8 patients (25%) and cervical fractures were found in 6 patients (19%).[23] These findings coincide with those reported by Cole et al. The frequency and severity of these comorbidities can complicate the treatment and outcome of these patients.

Classification of Scapular Fractures

Like fractures involving the clavicle, scapular fractures are classified based on location. They are commonly grouped into either intra- or extra- articular fractures. Intra-articular fractures involve or cross the glenoid fossa of the scapula, thus impacting the glenohumeral joint directly. Extra-articular fractures do not involve the glenoid fossa, rather they involve the body, neck, or processes of the scapula. These are far more common than intra-articular fractures, representing 80-90% of scapular fractures.[10,12] Therefore, this review will focus on extraarticular fractures exclusively.

The AO/OTA also has an alphanumeric system to classify scapular fractures like the one used to classify clavicle fractures (see figures 18-20). The number 14 is assigned to identify the scapula.[15] Next, either A, B, or F is listed after the number 14 to indicate fractures of the process, body, or glenoid fossa respectively.[15] Extraarticular fractures are either 14A or 14B, while 14F fractures are intraarticular. Then, depending on which letter was selected, modifiers 1, 2, or 3 are listed to indicate precise location or degree of comminution.[15] For example, a two fragment, transverse scapular body fracture without comminution would be recorded as 14B1 using the AO/OTA system.

Conservative Treatment for Scapular Fractures

Conservative treatment with a simple sling and physical therapy has historically been the mainstay for scapular fracture management.[9,10,23] There was only one study found that specifically reported on outcomes following conservative treatment for scapular fractures. A prospective cohort study published in 2011 investigated shoulder function in 32 patients following nonoperative treatment of scapular body fractures that were displaced at least 1 cm.[23]

Sixteen patients had a noncomminuted scapular body fracture (AO/OTA 14A3.1), thirteen had a comminuted scapular body fracture (14A3.2), and three had both scapular body and glenoid fractures (14C3).[23] Nonoperative treatment consisted of two weeks of immobilization in a sling followed by active and passive range of motion exercises with a physical therapist.[23] Strength exercises were initiated eight weeks from the date of injury.[23] At a mean follow-up of 15 months (range of 6-33 months), all fractures had healed uneventfully with acceptable shoulder function as reported on the DASH questionnaire.[23] This study used mean change in DASH scores (last DASH – preinjury DASH) to determine improvement of shoulder function following treatment.[23] To determine the preinjury DASH scores, patients were asked to fill out the questionnaire with respect to their preinjury shoulder function at initial presentation. This result was subtracted from their DASH score at final follow-up, yielding the change in DASH scores. Dimitroulias et al. used a 15-point difference as the threshold to differentiate between patients who have improved and those who have not. The mean change in DASH scores in 32 patients was 10.2 points, indicating that all patients improved following conservative treatment.[23]

Unfortunately, this study was not without its own shortcomings. Their definition of substantial displacement was 10 mm less than the current relative indications for surgical intervention, which will be discussed shortly. This means that, by current standards, most of these patients would have been treated conservatively regardless. Additionally, the study did not report on pain, strength, or range of motion. Finally, the lack of current RCTs supporting the efficacy of conservative treatment allows operative treatment to challenge the status quo.

Operative Treatment for Scapular Fractures

Indications for Surgical Intervention and Surgical Techniques

Currently, only 9.8% of scapula fractures are treated operatively.[11] However, operative treatment of scapular fractures is currently being investigated as a viable alternative to conservative management. To date, absolute indications for surgical management have not been established due to conflicting evidence.[10] Furthermore, the relative indications that do exist are different for intraarticular and extraarticular fractures.

Cole et al. noted that indications for ORIF of intraarticular scapular fractures include: more than 4 mm of articular step-off or involving more than 20% of the glenoid, instability of the glenohumeral joint secondary to glenoid fracture, and anterior rim or posterior glenoid rim fractures involving 25% or 33% of the articular glenoid surface respectively.[10] Since these are only relative indications, clinicians must consider patient-specific factors like age, activity level, job requirements, etc. when deciding on the best treatment plan.[10]

Relative indications for operative management of extraarticular scapular fractures are: angular deformity between the fracture fragments more than 45 degrees on a scapular Y view radiograph, medial/lateral displacement at least 15 mm plus an angular deformity at least 35 degrees, medial/lateral displacement at least 20 mm, Glenopolar angle less than 22 degrees measured on a true Grashey AP shoulder radiograph, displaced double lesions of the superior shoulder suspensory complex (SSSC) where both the clavicle and scapula fractures are displaced at least 10 mm, or coexistence of a complete AC joint dislocation and scapula fracture with displacement at least 10 mm.[10,11] To clarify, the glenopolar angle is the angle between the line connecting upper and lower poles of the glenoid and the line that connects the upper pole of the glenoid to the most inferior point of the scapular body (see figure 21).[10,11] The SSSC is a ring of structures comprised of the glenoid, coracoid and acromial processes, coracoclavicular ligament, distal clavicle, and acromioclavicular (AC) joint.[11] Again, due to the lack of RCTs comparing conservative and operative treatments, absolute indications for surgical management do not exist.

Once the decision to undergo surgery has been made, there are a few different surgical techniques being used to repair scapular fractures. The classic Judet approach was the first procedure described to treat extraarticular scapular fractures.[11] This procedure utilizes a posterior approach that requires the infraspinatus to be reflected laterally to expose the scapular neck and infraglenoid fossa.[11] The important function of the infraspinatus as a dynamic stabilizer of the glenohumeral joint spurred the discovery of new techniques that spared the muscle. A modified Judet approach that spares the infraspinatus was documented in 2004.[11] It involves using blunt dissection to separate the infraspinatus and teres minor, allowing for exposure of the lateral scapular border and posterior glenoid neck without resection of the infraspinatus.[11] In theory, this approach would preserve more shoulder function compared to the classic Judet procedure.

Porcellini et al. compared functional outcomes between the classic Judet approach and the newer modified Judet approach (see figure 22). The retrospective study included 20 patients with scapular neck and body fracture, 11 of which were treated with the modified Judet approach while the remaining 9 were treated with the classic Judet approach.[11] A total of 14 patients completed a mean follow-up of 3.11 years (± 1.17 years), 6 from the classic Judet group and 8 from the modified Judet group.[11] There was a statistically significant difference ($p = 0.002$) between classic and modified Judet procedures in average infraspinatus strength, 4.61 kg (± 1.98 kg) versus 8.38 kg (± 1.75 kg) respectively.[11] Furthermore, the modified Judet group had average ranges of motion in the operative shoulder that were 5.9 degrees more in flexion, 5.4 degrees more in abduction, and 10.9 degrees more in external rotation compared to the classic Judet group, although these differences were not statistically significant ($p = 0.74$, $p = 0.77$, $p = 0.29$

respectively).[11] Better average DASH and Constant scores were also seen in patients that received the modified Judet procedure, 6.25 points versus 10.16 points and 82.75 points versus 75.83 points respectively.[11] The difference in DASH and Constant scores was also not statistically significant ($p = 0.6$ and $p = 0.33$ respectively).[11] Given the small sample size ($n = 14$) of the study, these statistics may not carry much weight in applying them to a larger population, so more studies are warranted. Nevertheless, the study documented differences between classic and modified Judet procedures. It is important to note that when some retrospective studies describe operative treatment or report surgical characteristics, they are including both procedures in their analysis. This means that patients that were treated by the classic Judet approach and those that were treated with the modified Judet approach are combined into one set of statistics, even though the approaches are not the same.

Effects on Range of Motion

Cohort studies report acceptable outcomes in range of motion following operative treatment of extraarticular scapular fractures. A prospective study from 2016 that included 49 patients who sustained a scapular body or glenoid neck fracture (AO/OTA 14A3 or 14C1) reported no difference between injured and uninjured arms in terms of range of motion (see figure 23).[12] Average range of motion in the operative shoulder only trailed the contralateral shoulder by 5, 2, and 4 degrees of flexion, abduction, and external rotation respectively.[12] Specifically, the mean range of forward flexion in the operative shoulder was 154 degrees (± 20.3 degrees), compared to 159 degrees (± 14.1 degrees) on the contralateral side.[12] The mean range of abduction in the operative shoulder was 106 degrees (± 18.5 degrees) while the contralateral shoulder had 108 degrees (±17.7 degrees).[12] Lastly, the operative shoulder had a mean range of external rotation of 66 degrees (± 18.8 degrees) compared to 70 degrees (± 18.8 degrees) in the uninjured shoulder.[12]

Tatro et al. published a retrospective review of prospectively collected data from 67 patients with scapula fractures who underwent surgical treatment.[24] Of the 67 patients included, 37 had an extraarticular scapular fracture with at least one of the surgical indications listed previously.[24] At a mean follow-up of 7.8 years (range of 4.9-10.2 years), those 37 patients reported acceptable range of motion in their operative shoulder (see figures 24-26).[24] Mean range of motion in the treated shoulder was 97% and 93% ($p > 0.05$) that of the uninjured shoulder in forward flexion and abduction respectively.[24] Specifically, the operative shoulder had an average range of motion of 145.9 degrees (± 18.1 degrees) in forward flexion and 113.2 degrees (± 17.2 degrees) in abduction.[24] In contrast, the uninjured shoulder had an average range of motion of 150.2 degrees (± 16.1 degrees) in flexion and 121.5 degrees (± 18.5 degrees) in abduction.[24] There was, however, a significant difference ($p = 0.01$) in range of motion between shoulders in external rotation.[24] The treated shoulder had a range of motion that was 84% of the uninjured shoulder.[24] Specific ranges of motion in external rotation for the treated and uninjured shoulder were 57 degrees (± 15.2 degrees) and 68.3 degrees (± 17.2 degrees) respectively.[24]

This difference could be attributed to the type of surgical repair used. Most of the patients in this study (78%, n = 29) were treated using a classic Judet approach.[24] As discussed previously, this approach necessitates damage to the infraspinatus to expose the scapular fracture for repair.[11] The infraspinatus assists with external rotation of the shoulder. Therefore, it makes sense why some external rotation was lost. Regardless, Tatro et al. reported ranges of motion that were grossly intact, providing evidence to support the efficacy of surgical intervention out to 7 years post treatment.

A retrospective study conducted by Cole et al. reported range of motion values for geriatric patients that underwent surgical correction of extraarticular scapular fractures. Six patients with a mean age of 78.3 years (range = 73-90 years) were included in the study.[25] Five of the six patients completed the study with a mean follow-up of 23.2 months (range = 13.5-33.1 months).[25] The mean range of motion for flexion, abduction, and external rotation in the operative shoulder was 100%, 96%, and 88% that of the uninjured shoulder respectively (see figure 27).[25] This equates to a difference in average range of motion of 0 degrees in flexion, 4 degrees in abduction, and 7 degrees in external rotation between the uninjured and operative shoulder.[25] Even though the population of the study was small (n = 5) and different surgical techniques were used between patients, it's noteworthy that range of motion results discussed previously were replicated in a geriatric population.

Effects on Muscular Strength

The literature reports that muscular strength is also grossly maintained following surgical treatment of extraarticular scapular fractures. Schroder et al. compared shoulder strength in flexion, abduction, and external rotation between injured (operative) and uninjured (contralateral) sides (See figure 28).[12] A hand dynamometer was used to objectively measure strength in pounds of force. The results indicated that the operative shoulder only trailed the contralateral shoulder in average strength by 3 pounds in flexion, 2 pounds in abduction, and 4 pounds in external rotation.[12] In terms of percentages, the operative shoulder had strength that was 88% (± 30%), 92% (± 23%), and 85% (± 24%) that of the contralateral shoulder in flexion, abduction, and external rotation respectively.[12] This data comes from 49 patients who were post-surgical repair of a scapular body or glenoid neck fracture (AO/OTA 14A3 or 14C1) with a mean follow-up of 33 months (range of 12 to 138 months).[12]

Data from Tatro et al. (n = 37) showed that mean strength between shoulders was not found to be statistically significant ($p > 0.05$) at long-term follow-up (mean follow-up of 7.8 years, range

4.9-10.2 years, see figures 25 and 26).[24] The strength of the operatively treated shoulder was 89% that of the uninjured shoulder in forward flexion, abduction, and external rotation.[24] Specifically, the operative shoulder's mean strength was 17.8 pounds (± 6.9 pounds) in flexion, 11.9 pounds (± 4.7 pounds) in abduction, and 13.8 pounds (± 4.5 pounds) in external rotation.[24] In contrast, the uninjured shoulder had strength values of 19.9 pounds (± 6.5 pounds) in flexion, 13.4 pounds (± 4.3 pounds) in abduction, and 15.6 pounds (± 4.9 pounds) in external rotation.[24] This equates to a difference in mean strength between shoulders of 2.1 pounds in flexion, 1.5 pounds in abduction, and 1.8 pounds in external rotation.[24] It is interesting to note that external rotation strength was not significantly different between shoulders, even though external rotation range of motion was. Perhaps the other external rotators of the shoulder, namely the teres minor, adapts to the greater demand placed on it.

Cole et al. reported similar mean strength outcomes between operative and uninjured shoulders in a small (n = 5) geriatric cohort (mean age = 78.3 years, see figure 27).[25] Mean forward flexion and abduction strength was identical in both shoulders.[25] There was a minimal difference in mean external rotation strength, with the operative shoulder trailing the uninjured should by only 1 pound of force.[25] These results coincide with the trend in adult patients showing preserved strength following surgical repair of extraarticular scapular fractures.

Effects on Shoulder Function

Since range of motion and muscular strength were found to be relatively intact following surgical intervention of extraarticular scapular fractures, it's no surprise that patient-reported shoulder function was also retained. Schroder et al. reported mean DASH scores of patients (n = 49) at a mean follow-up of 33 months that were comparable to the normative mean; 12.1 points (range of 0-54 points) and 10.1 points respectively.[12] The reported median DASH score was even better, coming in at 4 points.[12] The large range and conversely low mean and median DASH scores imply that there may be outliers in the data set, skewing the reported mean scores and making them appear higher than they are.

Tatro et al. showed that shoulder function was still intact at a mean follow-up of 7.8 years (range of 4.9-10.2 years, see figure 24).[24] Mean DASH scores of 37 surgically treated patients at the final follow-up were comparative to, and even slightly better than, scores from the normal population, 8.9 points (range of 0-55 points) versus 10.1 points respectively.[24] The large range of scores closely matches what Schroder et al. reported, which could indicate outliers in the data. This has the potential to skew mean DASH scores, making them appear higher than they are. Even with this in mind, the mean DASH scores were still comparable to the normative mean, which supports the efficacy of surgical intervention in maintaining shoulder function.

Mean DASH scores were also acceptable in a small geriatric cohort (n = 5) following surgical treatment (see figure 27).[25] At an average follow-up of 23.2 months, the mean DASH score was 12.3 points (range = 0-50.8 points).[25] When one patient who had previously received a total shoulder replacement was excluded from the calculation, the mean DASH score dropped to 2.7 points.[25] Regardless, both mean DASH scores are close to the reported normative mean of 10.1 points and can be considered acceptable functional outcomes.

Operative versus Conservative Treatment of Scapular Fractures

Effect on Function and Range of Motion of the Shoulder

There are very few RCTs that compare operative and conservative treatment of scapular fractures, thus substantially limiting the level of evidence. Most of the studies that cover this topic are retrospective cohort studies looking at outcomes of either operative or conservative treatments independently. However, one retrospective cohort study conducted by Jones et al. performed a matched pair analysis comparing operative and conservative treatment of scapular fractures.[9] A total of 62 patients, 31 in each cohort, were included in this study.[9] All fractures healed and there were no statistically significant ($p \geq 0.05$) differences in pain or range of motion between treatment groups (see figure 29).[9] The group treated operatively had higher mean flexion and abduction ranges of motion compared to their nonoperative counterparts, 152.6 degrees (± 40.1 degrees) versus 144.9 degrees (± 44.6 degrees) and 146.2 degrees (± 41.6 degrees) versus 129.1 degrees (± 47 degrees) respectively.[9] Conversely, the nonoperative group had higher mean external and internal ranges of motion compared to the operative group, 67.0 degrees (± 20 degrees) versus 50.8 degrees (± 26.7 degrees) and 76.3 degrees (± 15 degrees) versus 57.8 degrees (± 29.1 degrees) respectively.[9] Again, these differences were not found statistically significant. It must be noted, however, that the weaknesses of the study diminish the impact of these findings.

First, there was a statistically significant difference in fracture displacement, shortening, and angulation ($p < 0.001$, $p < 0.001$, and $p = 0.004$ respectively) between the two treatment groups (see figure 30).[9] The operative group had a higher mean displacement; 30.8 mm (95% CI 15-45 mm) compared to the conservative group's 19.6 mm (95% CI 5-35 mm).[9] Higher mean shortening was also found in the operative group; 39.0 mm (95% CI 15-55 mm) versus 18.5 mm (95% CI 5-38 mm).[9] Angular displacement was reported higher in the operative group, 27.8 mm (95% CI 0-100 mm) versus 15.3 mm (95% CI 0-45 mm).[9] Secondly, the operative group had more ($p = 0.043$) physical therapy visits than the conservative group; 25 (95% CI 5-45 visits) versus 14 (95% CI 6-22 visits) respectively.[9] Lastly, this data was based on outcomes from only 62 patients.[9] Even with the significant discrepancies in fracture severity and physical therapy visits, it is promising that there was no statistical difference in outcomes between the groups. However, it is difficult to discern if this is due to the surgical intervention or the additional physical therapy visits.

A meta-analysis published in the Scandinavian Journal of Surgery in 2013 compared operative and nonoperative treatment of 463 scapular neck fractures.[26] The analysis included data from 21 retrospective cohort studies and one prospective cohort study.[26] A sum of 234 fractures were treated operatively while 229 were treated nonoperatively.[26] There was no statistically significant difference in restriction of activities of daily living (OR = 1.63, favoring operative group, $p = 0.16$) or Constant score (OR = 1.4, favoring nonoperative group, $p = 0.62$) at any point in time during follow-up.[26] Patients who were treated operatively were 2.71 times ($p < 0.00001$) more likely to be pain free during activities of daily living than their conservatively treated counterparts.[26] However, the group treated conservatively had a higher rate of patients with full range of motion in their injured side when compared to the uninjured side (OR = 0.28, $p < 0.00001$).[26] Lastly, no patients treated operatively experienced a translational dislocation over 1 cm (OR = 27.28, $p = 0.02$) or had a glenopolar angle less than 20 degrees (OR = 17.64, $p = 0.05$).[26] Heterogeneity was substantial between the included studies due to differences between treatment and patient presentation. This can be explained by the high-energy mechanism of injury needed to cause a scapular fracture. As previously discussed, concomitant injuries are frequent resulting in individualized surgical interventions for each patient. Additionally, each study reported on different outcomes and used different methods to analyze them.

Methods

A literature search was conducted using the PubMed database. The search terms used to find articles pertinent to comparing clavicular fracture treatments were “clavicle fracture” AND "operative treatment" AND "nonoperative treatment." Publication dates were restricted to include articles from 1/1/2011 to 7/1/2019 to ensure that only the most recent data was used for this paper. The English language filter was also applied to the search. Using these parameters, the search yielded a total of 71 articles. The reference lists of the articles found were checked for any additional studies that fit the inclusion criteria that the search might have missed. A total of 16 articles were included in this review.

Similarly, the search terms used to find articles relevant to comparing scapular fracture treatments were "scapula fracture" AND "operative treatment" AND "nonoperative treatment." The inclusion criteria were identical to the clavicle fracture search; all articles written in English and published from 1/1/2011 to 7/1/2019. Only 12 articles were found, two of which met inclusion criteria. The search was then widened by splitting the search into two different searches; one utilizing the terms "scapula fracture" AND "operative treatment" and another using "scapula fracture" AND "nonoperative treatment." A total of 66 articles were identified for the first search and 25 for the second. Reference lists for included studies were investigated for any additional studies that fit the inclusion criteria that the search might have missed. A total of 8 articles from both searches were included in this review.

Discussion

Patients with a displaced, midshaft clavicular fracture have two viable treatment options, each with acceptable efficacy. Conservative treatment with either a simple sling or figure 8 bandage followed by physical therapy yields acceptable outcomes.[6] Surgical intervention results in higher shoulder function within 6 weeks of treatment and a lower risk of nonunion compared to conservative treatment.[1,16,17] One year after injury, however, there was no observed difference in shoulder function or pain between the two treatment groups.[1,2,16-18,21]

To translate this in terms of patient care, the preference for or against operative treatment hinges on which outcomes are most important to each individual patient. If a patient is an athlete and desires a faster return of shoulder function, surgical intervention may be the better option for them. Conversely, if a patient is an office worker only concerned with being able to perform their job responsibilities and doesn't wish to go through surgery, conservative treatment might be the better option for them. At one-year post injury, both patients will have similar and acceptable outcomes in shoulder function and pain. The only differences between the two patients are the risks involved with each treatment option. The one who opted for conservative treatment has a higher risk of nonunion, while operative treatment has a higher risk of infection, dehiscence, or hardware irritation.[1,2,16,21,22]

Many of the included studies had shortcomings that merit discussion. First, the reliance on patient-reported, subjective DASH scores to measure shoulder function potentially affects the accuracy of the data. While the DASH score is considered a validated measure of shoulder function, that doesn't mean it is the best way to measure it. One patient's "good" shoulder function could be considered another patient's "poor." Additionally, patients could be more apt to answer subjective questionnaires the way they think the researchers want them to. Ideally, future studies should use more objective measures to evaluate shoulder function and eliminate the problems associated with subjective questionnaires. For example, Constant scores, strength tests measured by a hand dynamometer, and range of motion measured via goniometer could be used to achieve an accurate measurement of shoulder function following treatment.

Additionally, the demographics of the included studies were another shortcoming, limiting the ability to apply the data presented in this review to women, adolescents, or geriatric patients. Men were consistently overrepresented in the literature, frequently comprising 70% or more of patients in individual studies. Furthermore, outcomes in pediatric patients were investigated by Herzog et al. only. That study was comprised of a sample size of just 20 patients, limiting the strength of the findings. None of the studies included in this review reported outcomes following treatment in patients older than 70. Therefore, the data presented in this review and subsequent conclusions made from it may not directly apply to women, geriatric, or pediatric patients until more studies investigate these populations.

More high-quality randomized clinical trials are needed to strengthen the level of evidence. The impact of the current literature is hampered by substantial heterogeneity between studies. I^2 values ranged from 75% to 90% in the 2019 Cochrane review.[1] More RCTs that measure outcomes using the same methods following the same treatment of displaced, midshaft clavicular fracture are required to address this issue. Furthermore, more RCTs are needed to investigate which type of surgical intervention (ORIF with plates, intermedullary pins, or other) results in superior outcomes. Commonly, patients that were operatively treated using ORIF with plates or ORIF with intermedullary pins were grouped together in the data analysis. These are not the same procedure, and therefore, it’s plausible that outcomes differ between the two. Future studies should separate and organize the data based on procedure type, and not lump them all under the term “operative treatment.”

Since there has been a demonstrated benefit of early return of shoulder function following surgical intervention, future studies should also strive to determine absolute indications following clavicular fracture. Identifying which patients could see an additional, clear benefit from undergoing surgical intervention as opposed to conservative treatment deserves to be investigated. Additional RCTs are needed to either cement the proposed relative surgical indications as absolute or discover new indications that can be tested for validity.

It is more difficult to discern whether conservative or operative treatment is superior in the management of extraarticular scapular fractures. There is very limited evidence directly comparing the two. Most of the available literature examines either conservative or operative treatment separately in a retrospective fashion, thus limiting the strength of evidence. Nevertheless, given the current available evidence, it appears that both options result in acceptable and comparable outcomes. Since there is a lack of RCTs, comparisons between retrospective studies may allow for some conclusions to be drawn.

Retrospective cohort studies examining operative treatment of extraarticular scapular fractures report mean shoulder function following treatment that's comparable to the normative mean in healthy, injury-free shoulders.[12,24] Additionally, range of motion and shoulder strength are kept relatively intact following surgical correction.[12,24,25] Strength and range of motion in forward flexion, abduction, and external rotation of the operative shoulder only slightly trailed the uninjured shoulder. These results support that patients can lead normal lives following surgical correction, and that operative management is a viable alternative to the traditional conservative treatment.

Only one study that examined nonoperative treatment of extraarticular scapular fractures met inclusion criteria for this review. They reported acceptable outcomes as evidenced by improved DASH scores following treatment and all fractures healing uneventfully.[23] A questionable flaw in their methodology is the use of preinjury DASH scores, which required the patient to recall their shoulder function prior to injury. It's plausible that patients could provide an inaccurate depiction of their shoulder function based on their recollection of it. Furthermore, most of the fractures included in the study would have been treated conservatively regardless since they were not considered significantly displaced by today's proposed standards. Dimitroulias et al.

considered 1 cm of displacement as significant, which is half of the 2 cm of displacement needed to be considered significant put forth by Cole et al.[10,23] Compound that with a lack of RCTs supporting the efficacy of nonoperative treatment, the applicability of the findings presented by Dimitroulias et al. to fractures displaced more than 20 mm becomes difficult.

Only one matched-pair analysis and one meta-analysis that directly compared operative and conservative treatment of scapular fractures met inclusion criteria for this review. There was no statistically significant difference between groups in shoulder function evidenced by Constant score and patients with restricted activities of daily living.[26] Operatively treated patients were more apt to be pain free during their activities of daily living, while their conservative counterparts reported higher ranges of motion.[26] The findings from Jones et al. conflicted with these outcomes, reporting no difference between groups in pain or range of motion.[9] The weaknesses of that study, namely the significant differences in fracture displacement, fracture angulation, and physical therapy visits between groups, casts doubt on whether the findings can be applied to patients with displaced, extraarticular scapular fractures. Therefore, it is difficult to draw any conclusions recommending one treatment strategy over the other based on these two studies.

Concomitant injuries that commonly occur with scapular fractures are a cause for concern in terms of making conclusions from the outcomes presented in this paper. It’s plausible that these additional injuries could cause pain and even limit shoulder function. For example, the most frequent additional injury reported with a scapula fracture is a rib fracture.[10,23] The scapula articulates closely with the ribs, and as such, it makes sense that a comorbid rib fracture could be the cause of adverse scapular/shoulder function following treatment. Nevertheless, the ability of future studies to analyze scapula fractures in isolation appears improbable because comorbid injuries occur so commonly. However, it would be interesting to see if the results presented in this paper could be replicated in a patient population that had a scapula fracture without a comorbid injury. At the very least, a future retrospective cohort study could compare shoulder function following treatment between patients who suffered concomitant injuries and patients who did not.

The demographics of the patient population in the included studies were another cause for concern. Men were overrepresented again by a large margin and pediatric patients were not included in any study. Additionally, only one study included in this review investigated operative management in a geriatric cohort (n = 5).[25] Even though similar outcomes were found in geriatric patients, a sample size of 5 is far too small to be considered meaningful in terms of strength of evidence. Therefore, it is uncertain if the findings presented in this paper are directly applicable to female, pediatric, or geriatric patients. Future studies should look to replicate the findings presented in this review in these patient populations.

Future studies also need to address the differences in outcomes between surgical approaches. Commonly, studies do not isolate just one procedure in their data and, instead, include them all under the category of "operative treatment." Not all surgical procedures are the same, as evidenced by Porcellini et al. Certain techniques, like the classic Judet, involve the iatrogenic damage of muscles to visualize the fracture for repair while others do not.[11] Further complicating matters is the presence of comorbid injuries that may also require surgical intervention. Therefore, there is no true "standard" or "routine" surgical procedure to repair a fractured scapula. This heterogeneity between procedures could be skewing the data. At a minimum, future studies should isolate either only patients treated via classic Judet or only patients treated via modified Judet procedures in their analysis.

Conclusion

The hypothesis was partially supported by the literature for midshaft clavicular fractures. ORIF of midshaft clavicular fractures results in a decreased risk of nonunion and an earlier increase in shoulder function up to 6 weeks when compared to conservative treatment. However, there is no difference in pain or shoulder function between the two treatments after one-year post-injury. Additional studies are needed to determine if these results can be replicated in pediatric, geriatric, and female patient populations. Since outcomes one year after intervention vary little between ORIF and conservative management, ORIF should not be routinely recommended for all patients. After a discussion of the risks and benefits for each treatment, shared decision making between the patient and their treating clinician should be used to individualize the course of treatment to the patient's preference.

The available literature did not support the hypothesis for scapular fractures. Both ORIF and conservative treatment of extraarticular scapular fractures yield comparable outcomes in shoulder function, range of motion, and strength. However, the lack of randomized clinical trials comparing operative and conservative treatment and the weaknesses of the included studies do not allow for specific conclusions to be made with respect to superiority of treatment. Neither is better than the other and both are considered viable treatment options. More studies, preferably randomized clinical trials, are needed in order to make the distinction of which treatment is superior. Furthermore, additional studies are required to determine absolute indications for surgical intervention, since they currently do not exist. Given that treatment outcomes are similar for both ORIF and conservative interventions, the patient and their treating clinician should use shared decision making when determining the course of treatment, tailoring it to the patient's preference.

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Appendices

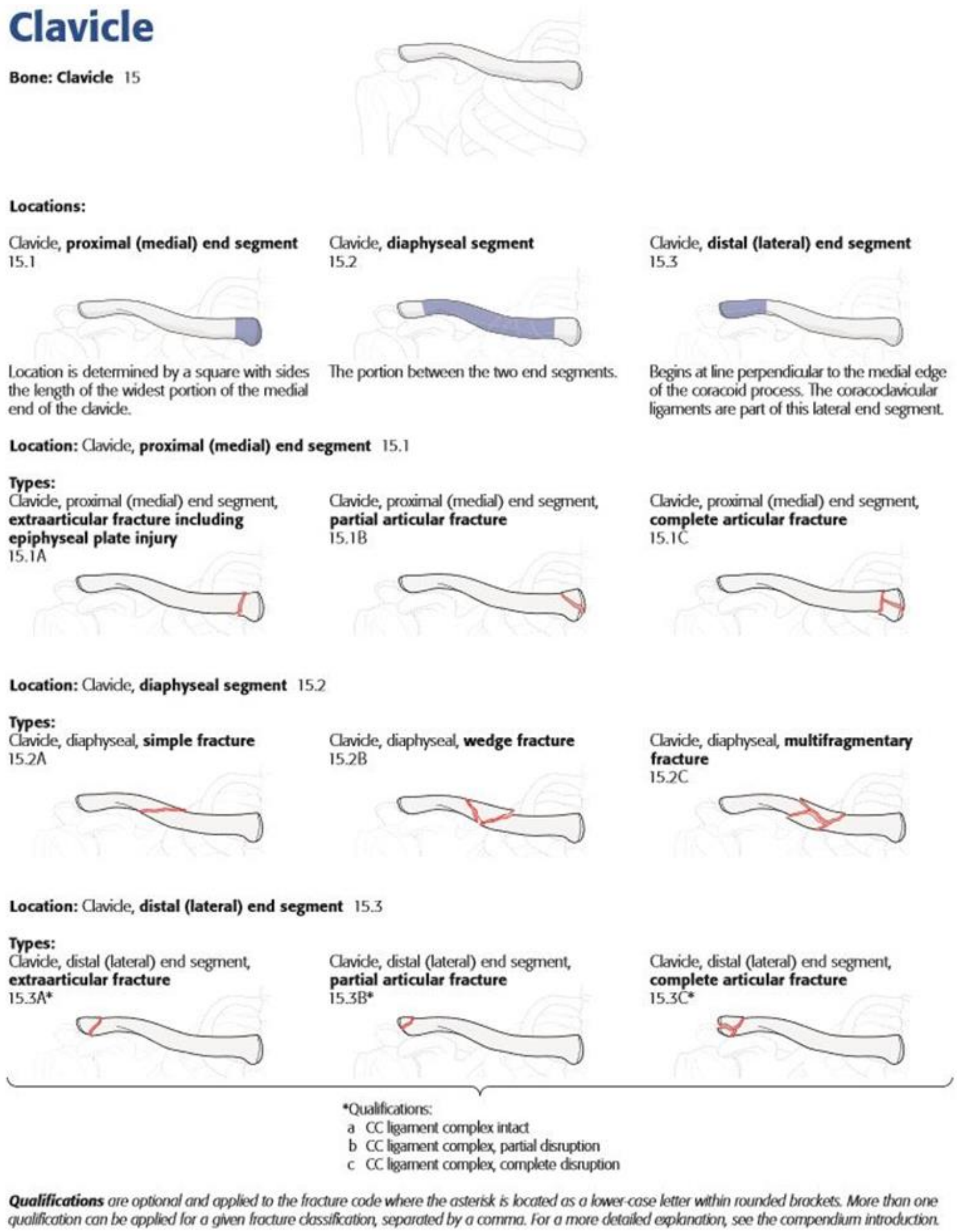

Figure 1. AO/OTA classification of clavicle fractures.[15]

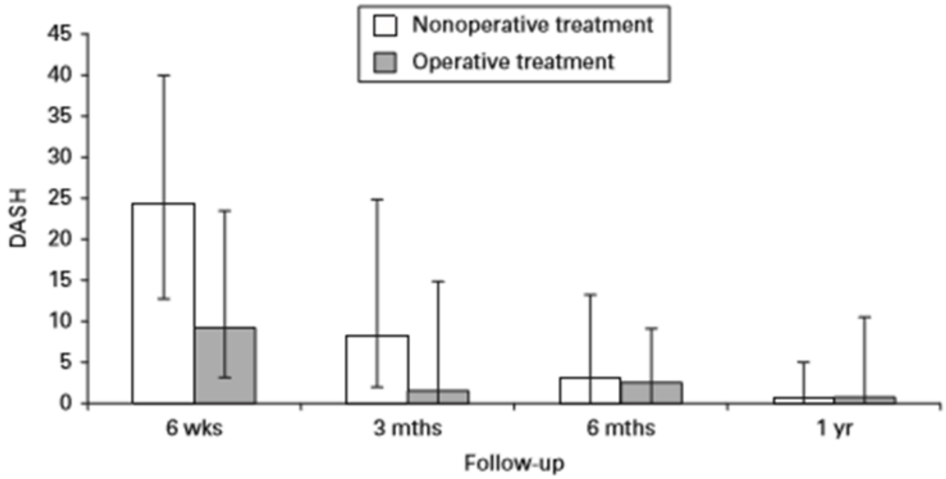

Figure 2. Comparison of median DASH scores during one year of follow-up. Significant differences noted at six weeks' and three months' follow-up (p < 0.001 and p = 0.02 respectively.[17]

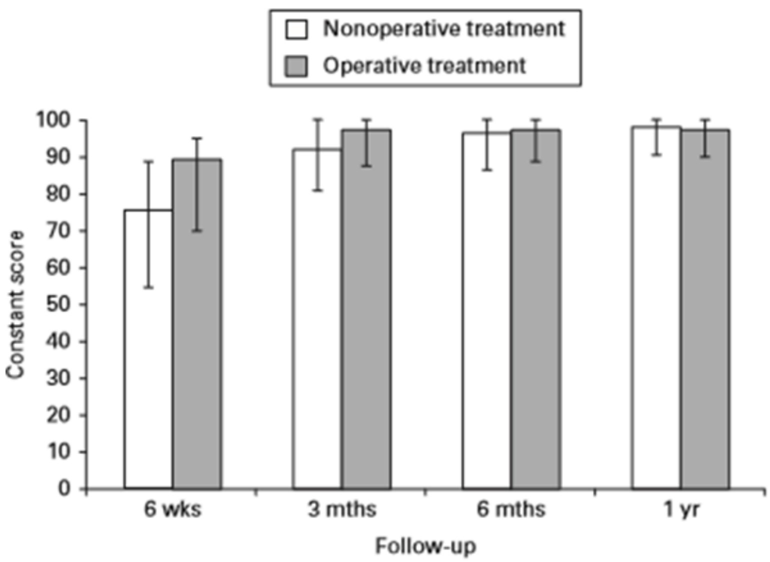

Figure 3. Comparison of median Constant scores during one year of follow-up. Significant differences noted at six weeks' and three months' follow-up (p < 0.001 and p = 0.02 respectively.[17]

TABLE V Results of Analysis of DASH and Constant-Murley Scores

	6 Weeks	3 Months	9 Months
DASH score*			
Median (interquartile range)			
Operative	15.83 (9.17 to 32.61) (n = 112)	5.00 (1.67 to 13.33) (n = 121)	1.67 (0 to 5) (n = 111)
Nonoperative	28.75 (20.00 to 48.33) (n = 106)	8.33 (2.50 to 23.33) (n = 111)	2.5 (0 to 7.5) (n = 93)
Treatment effect (95% CI), p value†			
Unadjusted	−13.33 (−19.60 to −7.07), <0.001 (n = 218)	−3.33 (−6.86 to 0.198), 0.064 (n = 232)	−0.83 (−2.20 to 0.54), 0.231 (n = 204)
Adjusted for clustering by center	−13.33 (−17.97 to −8.69), <0.001 (n = 218)	−3.33 (−6.05 to −0.62), 0.016 (n = 232)	−0.83 (−1.94 to 0.28), 0.141 (n = 204)
Adjusted for center clustering, age, sex, fracture class, & ASA grade	−14.32 (−19.21 to −9.43), <0.001 (n = 213)	−3.55 (−5.65 to −1.45), 0.001 (n = 226)	−0.83 (−1.89 to 0.23), 0.123 (n = 198)
Constant-Murley score*			
Median (interquartile range)			
Operative	76.50 (58.55 to 86.30) (n = 104)	85.20 (76.87 to 91.03) (n = 114)	91.97 (85.32 to 96.50) (n = 88)
Nonoperative	63.97 (53.03 to 73.57) (n = 105)	81.67 (72.77 to 89.93) (n = 107)	89.88 (83.55 to 94.10) (n = 76)
Treatment effect (95% CI), p value†			
Unadjusted	12.37 (6.59 to 18.14), <0.001 (n = 209)	3.43 (−0.37 to 7.24), 0.077 (n = 221)	2.13 (−1.12 to 5.38), 0.197 (n = 164)
Adjusted for clustering by center	12.37 (6.32 to 18.41), <0.001 (n = 209)	3.43 (0.47 to 6.40), 0.023 (n = 221)	2.13 (−0.65 to 4.92), 0.133 (n = 164)
Adjusted for center clustering, age, sex, fracture class, & ASA grade	13.42 (6.99 to 19.84), <0.001 (n = 204)	3.20 (−0.16 to 6.55), 0.062 (n = 216)	1.65 (−1.14 to 4.43), 0.245 (n = 161)

*Interactions between treatment group and follow-up time were significant in models allowing for repeated measurements over time (p = 0.0001 for DASH scores and p = 0.002 for Constant-Murley scores). †Treatment effect estimates are differences in medians estimated using quantile regression.

Figure 4. Analysis of DASH and Constant scores.[2]

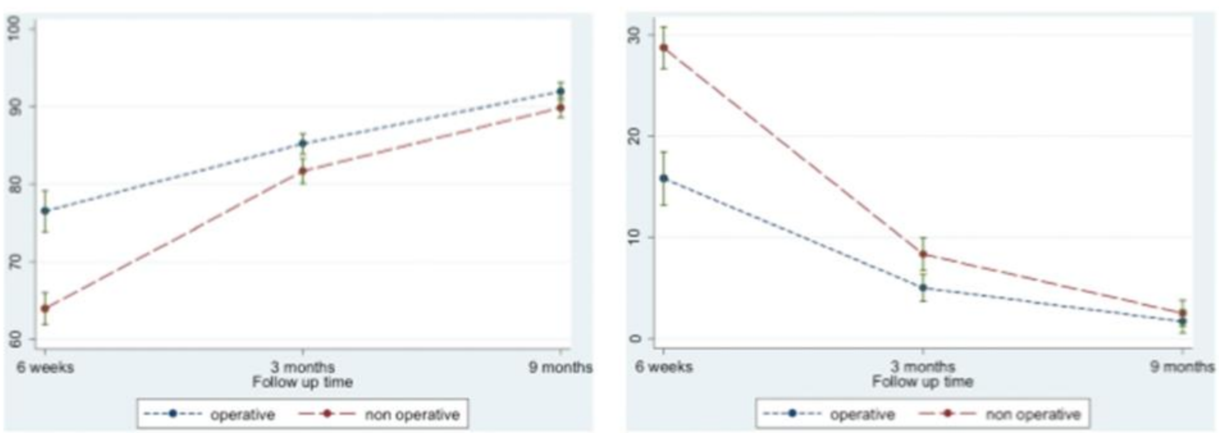

Fig. 2 Fig. 3

Fig. 2 Median Constant-Murley scores, with standard errors, over time by randomized group. **Fig. 3** Median DASH scores, with standard errors, over time by randomized group.

Figure 5. Median Constant scores with standard errors over time by randomized group (left) and median DASH scores with standard errors over time by randomized group (right).[2]

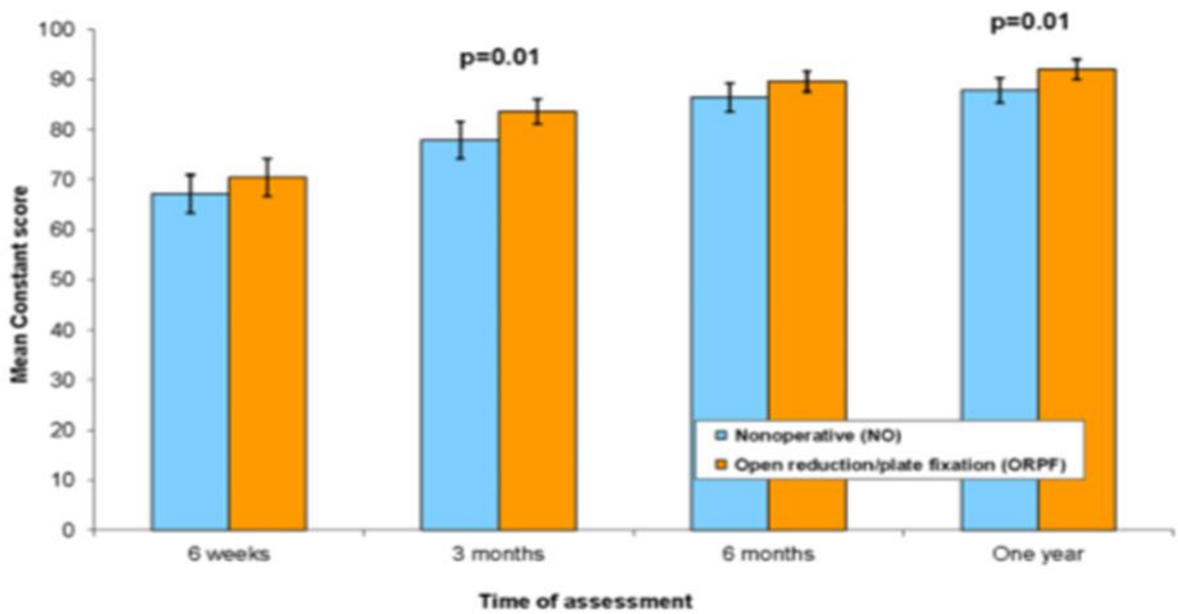

Figure 6. Comparison of mean Constant scores for the two treatment groups during the first year after injury with 95% CI.[16]

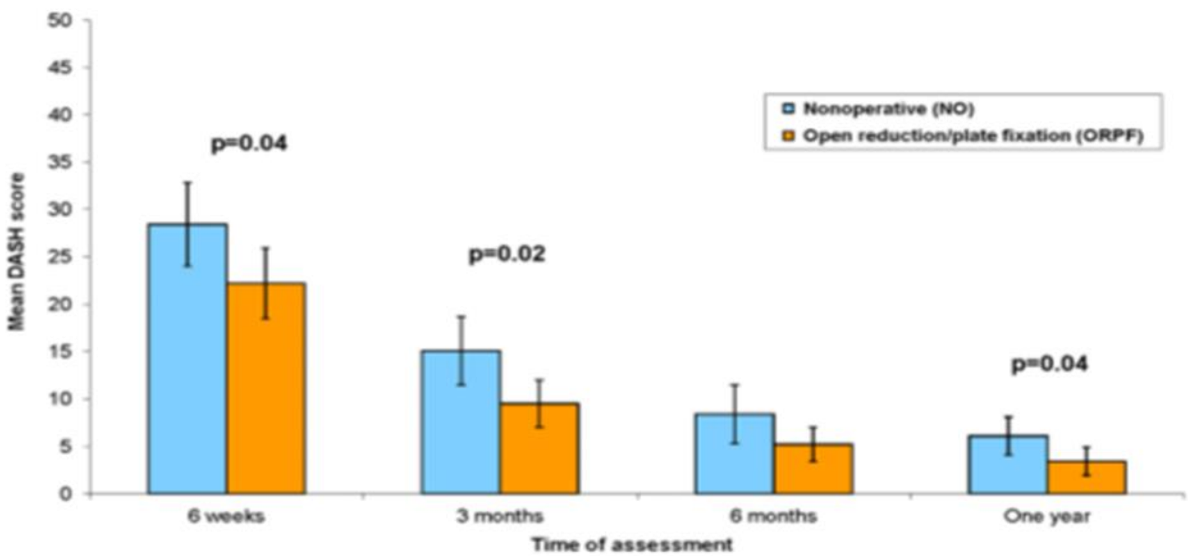

Figure 7. Comparison of mean DASH scores for the two treatment groups during the first year after injury with 95% CI.[16]

TABLE IV Comparison of the Functional Scores, Subjective Outcomes, and Other Assessments Between the Two Treatment Groups

Measurement	Nonoperative Treatment Group	Open Reduction and Plate Fixation Group	P Value*
Validated functional scores at one year†			
Constant score	87.8 (85.2 to 90.3)	92.0 (90.0 to 94.0)	**0.01**
DASH score	6.1 (4.1 to 8.1)	3.4 (1.9 to 4.9)	**0.04**

Figure 8. Comparison of functional scores.[16]

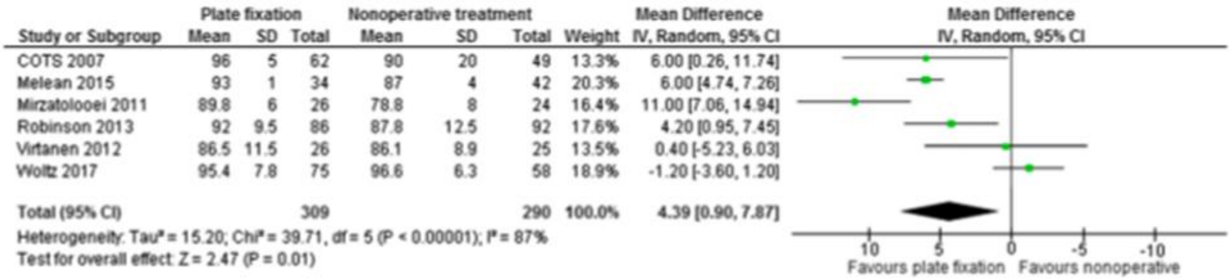

Figure 9. Comparison of Constant scores one year after plate fixation versus nonoperative treatment.[21]

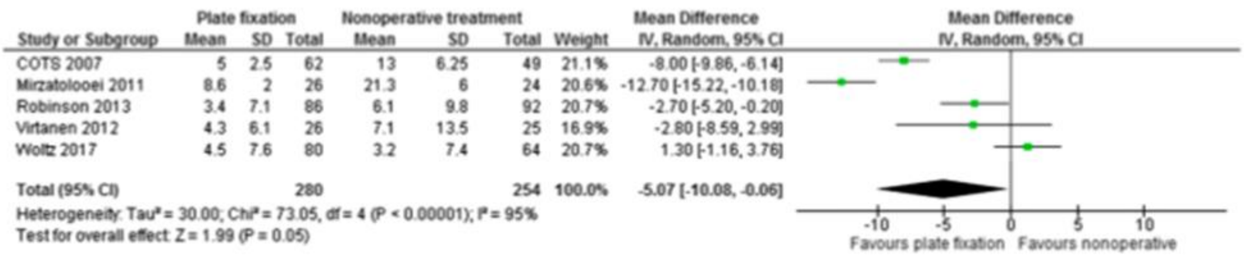

Figure 10. Comparison of DASH scores one year after plate fixation versus nonoperative treatment.[21]

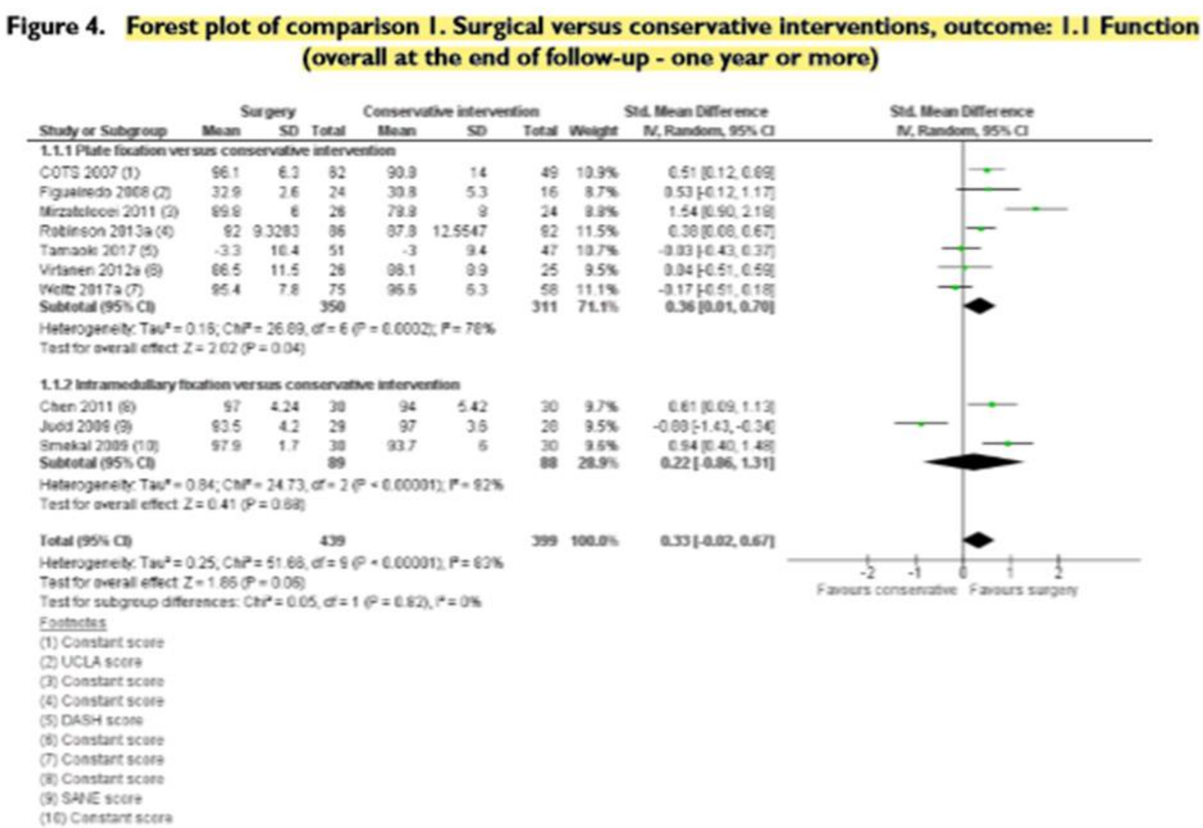

Figure 11. Forest plot comparison of surgical versus conservative interventions on shoulder function.[1]

Analysis 1.7. Comparison 1 Surgical versus conservative interventions, Outcome 7 Pain (measured by VAS: 0 to 100 mm (worst score)).

Review: Surgical versus conservative interventions for treating fractures of the middle third of the clavicle

Comparison: 1 Surgical versus conservative interventions

Outcome: 7 Pain (measured by VAS: 0 to 100 mm (worst score))

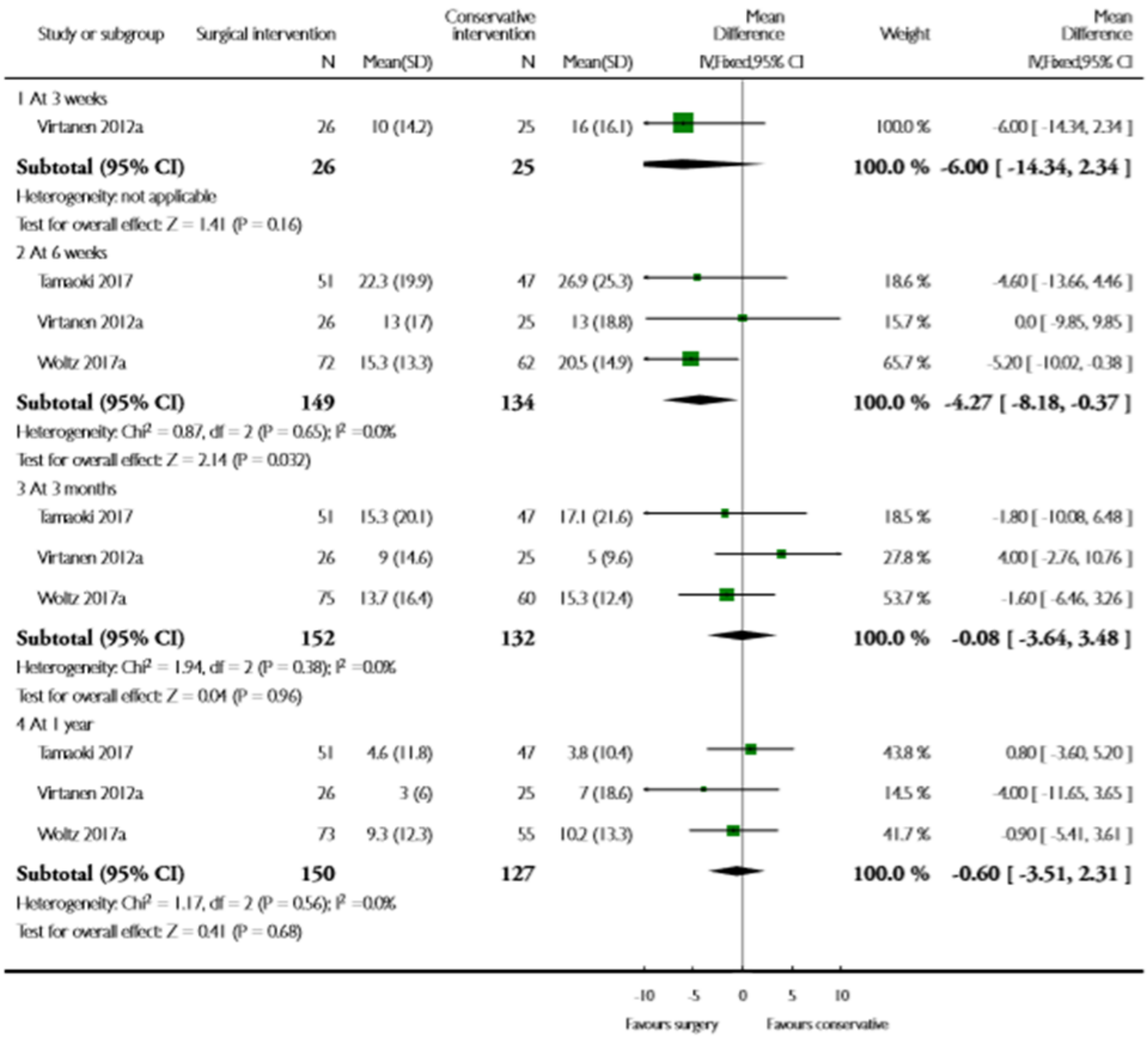

Figure 12. Forest plot comparison of surgical versus conservative interventions on pain.[1]

TABLE II Rates of Nonunion, Mandatory Secondary Operative Procedures, and Secondary Operative Procedures*

	Nonunion				
	Nonoperative Treatment	Open Reduction and Plate Fixation	RR (95% CI)	P Value	NNT
Age					
16 to 30 yr	6/44 (14%)	0/44 (0%)	0	0.03†	7.3
31 to 40 yr	4/20 (20%)	0/19 (0%)	0	0.1	5.0
41 to 60 yr	6/28 (21%)	1/23 (4%)	0.20 (0.03 to 1.6)	0.1	5.9
Sex					
Male	14/82 (17%)	1/76 (1%)	0.08 (0.01 to 0.6)	0.0001	6.4
Female	2/10 (20%)	0/10 (0%)	0	0.5	5.0
Entire group	16/92 (17%)	1/86 (1%)	0.07 (0.01 to 0.5)	0.007†	6.2

*RR = relative risk, CI = confidence interval, and NNT = number needed to treat. †Significant difference in favor of open reduction and plate fixation.

Figure 13. Comparison of rates of nonunion between nonoperative and ORIF plate fixation.[16]

TABLE IV Results of Analysis of Radiographic Evidence of Union at 9 Months (N = 254*)

	Rate or Estimate	95% CI	P Value
Union rate†			
Operative (n = 131)	130 (99.2%)		
Nonoperative (n = 123)	110 (89%)		
Nonunion rate†			
Operative (n = 131)	1 (0.8%)		
Nonoperative (n = 123)	13 (11%)		
Unadjusted analysis‡			<0.001§
Difference in proportions	−0.098	−0.163 to −0.042#	
Odds ratio (of nonunion)	0.065	0.002 to 0.450§	

*The 9-month union information was missing for 23 patients (15%) in the operative group and 24 (16%) in the nonoperative group. Missingness of this outcome was related to dominance and smoking, with more of those with missing data being left-handed (23% versus 11%) and smokers (43% versus 20%). †The data are given as the number of patients with the percentage in parentheses. ‡Adjusted analyses were not performed because of the small numbers of events. §Fisher exact test and exact 95% CIs. #Wallenstein CI calculation[28].

Figure 14. Analysis of radiographic evidence of union at 9 months (n = 254).[2]

	Plate fixation		Nonoperative treatment			Risk Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	IV, Random, 95% CI
COTS 2007	2	62	7	49	27.8%	0.23 [0.05, 1.04]
Melean 2015	0	34	4	42	7.8%	0.14 [0.01, 2.45]
Mirzatolooei 2011	1	26	1	24	8.8%	0.92 [0.06, 13.95]
Robinson 2013	1	86	16	92	16.2%	0.07 [0.01, 0.49]
Virtanen 2012	0	26	6	25	8.1%	0.07 [0.00, 1.25]
Woltz 2017	2	83	15	65	31.3%	0.10 [0.02, 0.44]
Total (95% CI)		317		297	100.0%	0.14 [0.06, 0.32]
Total events	6		49			

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 3.10$, $df = 5$ ($P = 0.68$); $I^2 = 0\%$
Test for overall effect: $Z = 4.71$ ($P < 0.00001$)

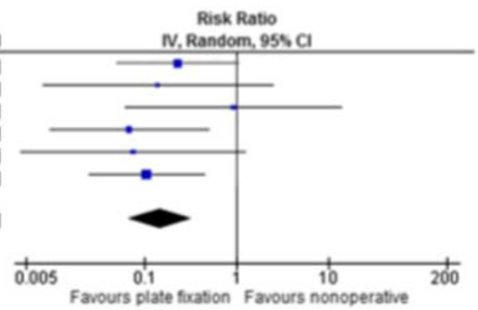

Figure 15. Nonunion after plate fixation versus nonoperative treatment.[21]

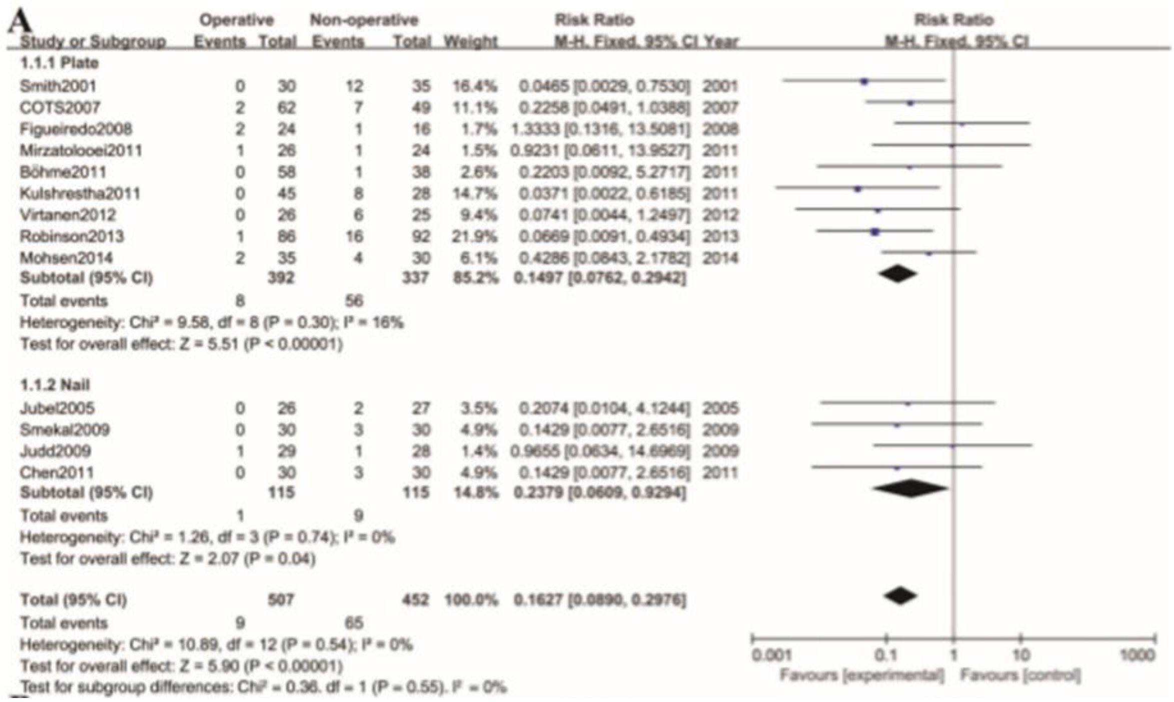

Figure 16. Forest plot comparing nonunion rate between operative (experimental) and nonoperative (control) treatment groups.[22]

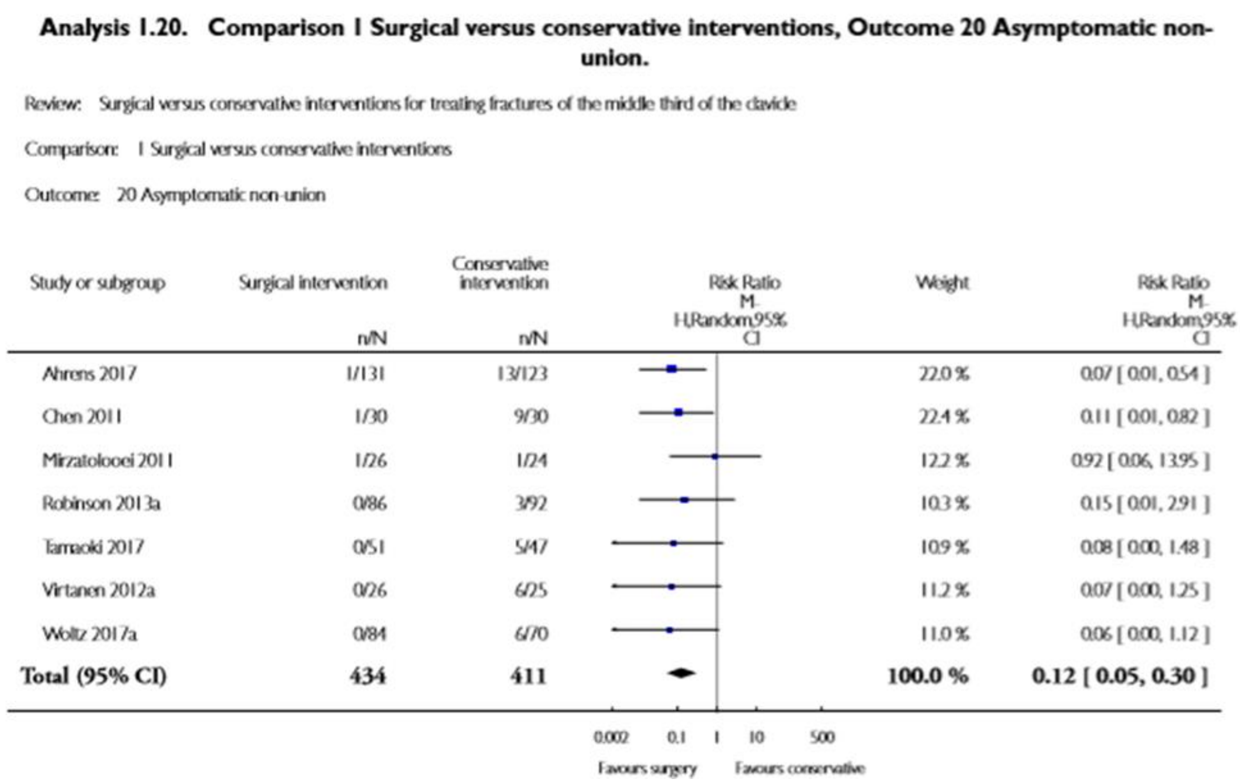

Figure 17. Forest plot comparison of surgical versus conservative treatment on asymptomatic nonunion.[1]

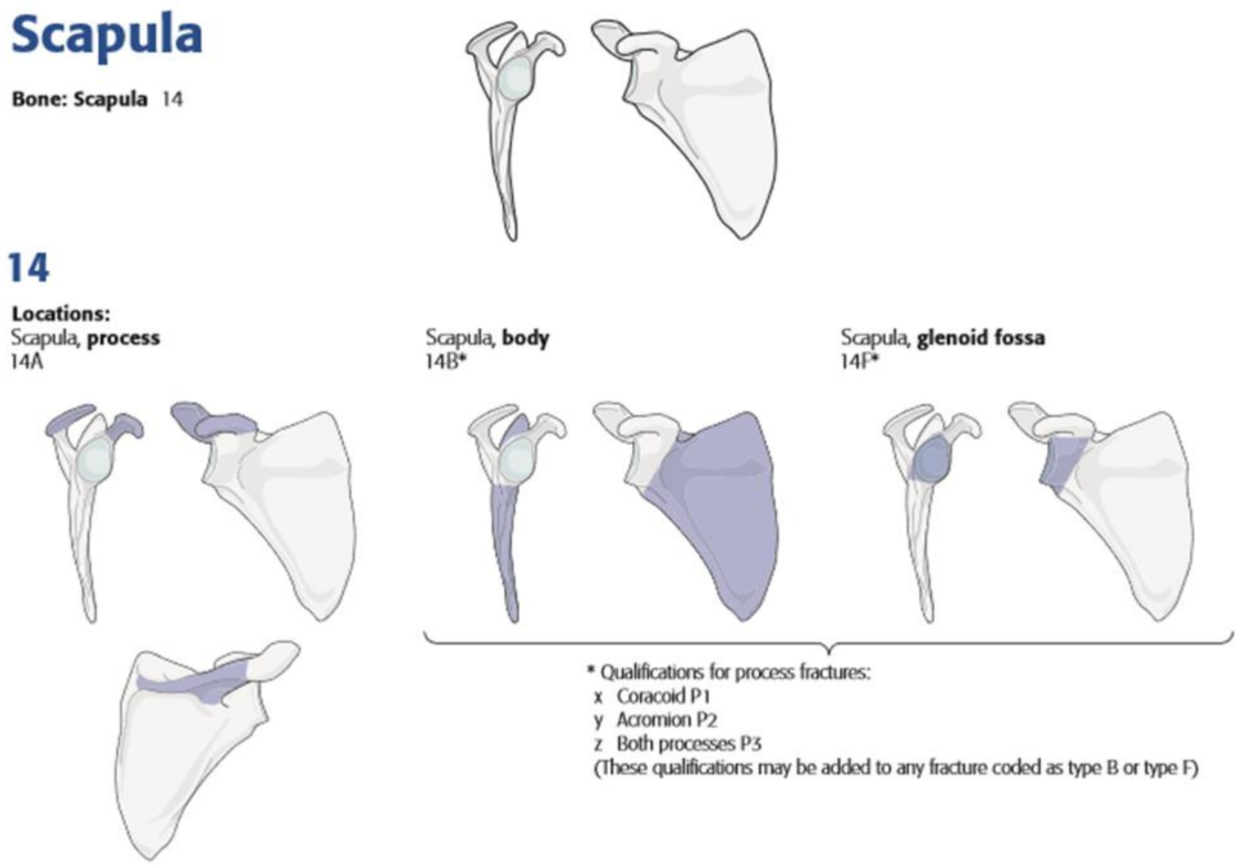

Figure 18. AO/OTA classification of scapula fractures.[15]

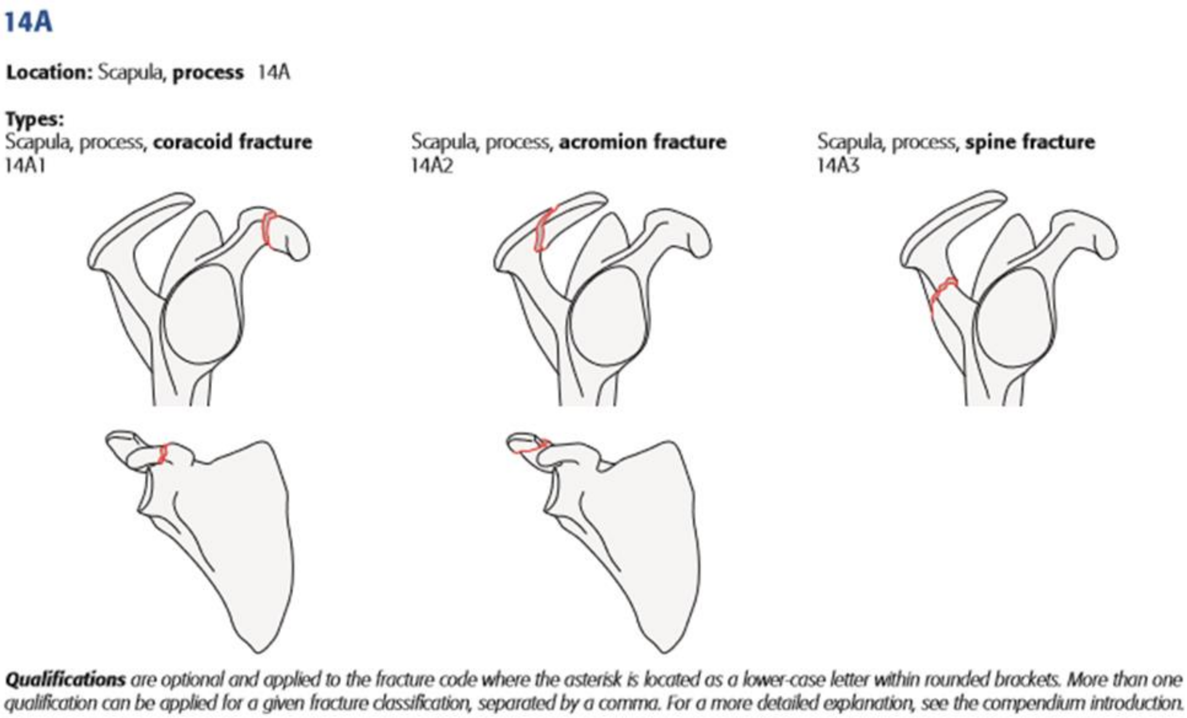

Figure 19. AO/OTA classification of scapular process fractures.[15]

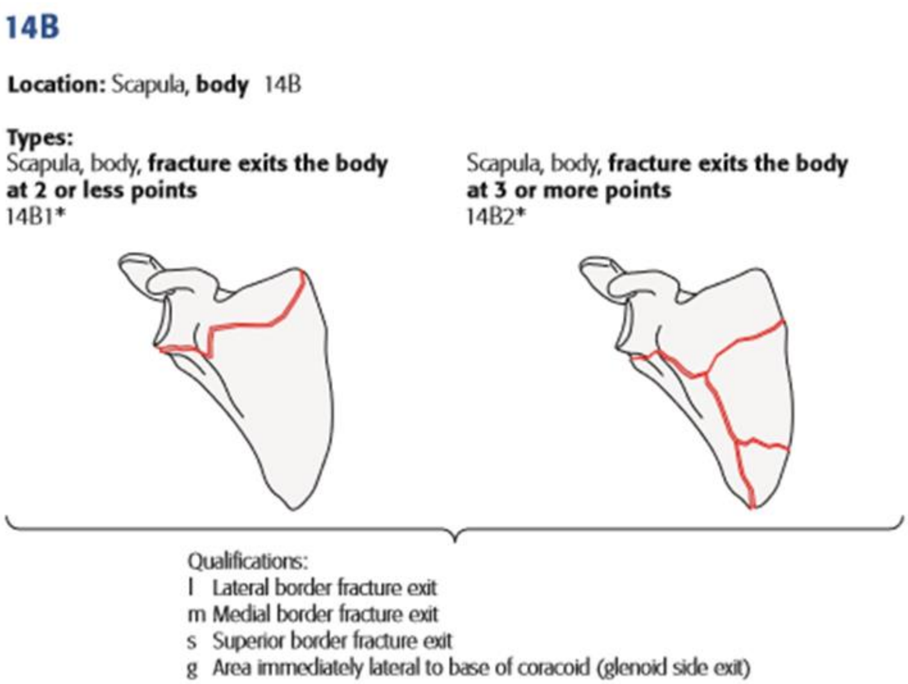

Figure 20. AO/OTA classification of scapular body fractures.[15]

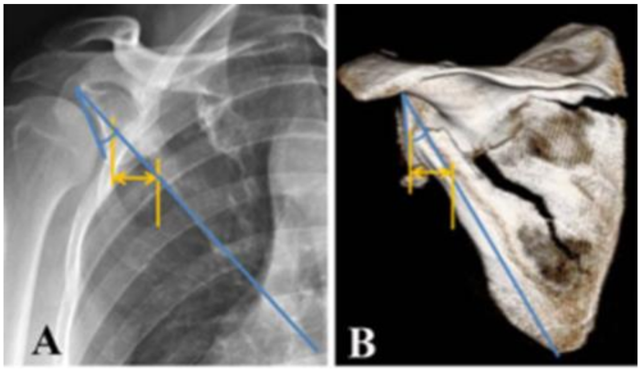

Figure 21. Measurement of the glenopolar angle (blue angle).[10]

	CJ group	MJ group	*p*-value	Total
Infraspinatus hypotrophy	5	1	0.008	6
IST test noninjured arm (kg)	8.76 (±1.5)	9.22 (±1.18)	0.53	9.02 (±1.29)
IST test injured arm (kg)	4.61 (±1.98)	8.38 (±1.75)	0.002	6.77 (±2.63)
ISRT test noninjured arm (kg)	8.98 (±1.51)	9.28 (±1.09)	0.66	9.15 (±1.24)
ISRT test injured arm (kg)	4.95 (±2.1)	8.7 (±1.64)	0.002	7.09 (±2.61)
AH distance (mm)	7.95 (±1.06)	9.48 (±0.65)	0.006	8.82 (±1.13)
Forward flexion injured arm (°)	146.6 (±36.6)	152.5 (±28.1)	0.74	150 (±32.1)
Abduction injured arm (°)	148.3 (±37.1)	153.7 (±30.6)	0.77	151.4 (±32.3)
External rotation injured arm (°)	61.6 (±18.3)	72.5 (±18.3)	0.29	67.85 (±18.5)
Internal rotation injured arm (points)	7 (±3.03)	7.25 (±2.37)	0.86	7.14 (±2.65)
Forward flexion noninjured arm (°)	176.2 (±6.9)	173.3 (±7.4)	0.69	175 (±7.3)
Abduction noninjured arm (°)	176.2 (±6.9)	171.6 (±8.9)	0.46	174.3 (±8.2)
External rotation noninjured arm (°)	81.2 (±6)	80 (±5.7)	0.61	80.7 (±5.9)
Internal rotation noninjured arm (points)	9 (±1.4)	9.3 (±0.94)	0.74	9.14 (±1.24)
Constant Shoulder Score (points)	75.83	82.75	0.33	79.78
DASH Score (points)	10.16	6.25	0.6	7.92

Figure 22. Results from Porcellini et al. CJ = classic Judet; MJ = modified Judet.[11]

	Mean ± Stand. Dev.		
Range of Motion	**Injured *(deg)***	**Contralat. *(deg)***	**Injured/Contralat. *(%)***
Forward flexion	**154 ± 20.3**	**159 ± 14.1**	**96 ± 9**
Abduction	**106 ± 18.5**	**108 ± 17.7**	**99 ± 12**
External rotation	**66 ± 18.8**	**70 ± 18.8**	**97 ± 22**

Figure 23. Comparison of ranges of motion between operative (injured) and uninjured (contralateral) shoulders.[12]

	Extra-Articular (N = 37)	Intra-Articular (N = 29)
Follow-up* *(yr)*	7.8 (4.9-10.2)	7.3 (4.7-10.3)
DASH* (normal population: 10.1)	8.9 (0-55)	9.1 (0-32)
SF-36v2 or SF-12v2* (normal population: 50 ± 10)	49.9 (29-64)	52.6 (38-64)
Pain score* (0 = none, 10 = worst)	2 (0-9)	1.7 (0-5.5)

Figure 24. Patient-reported outcomes at a mean follow-up of 7.8 years.[24]

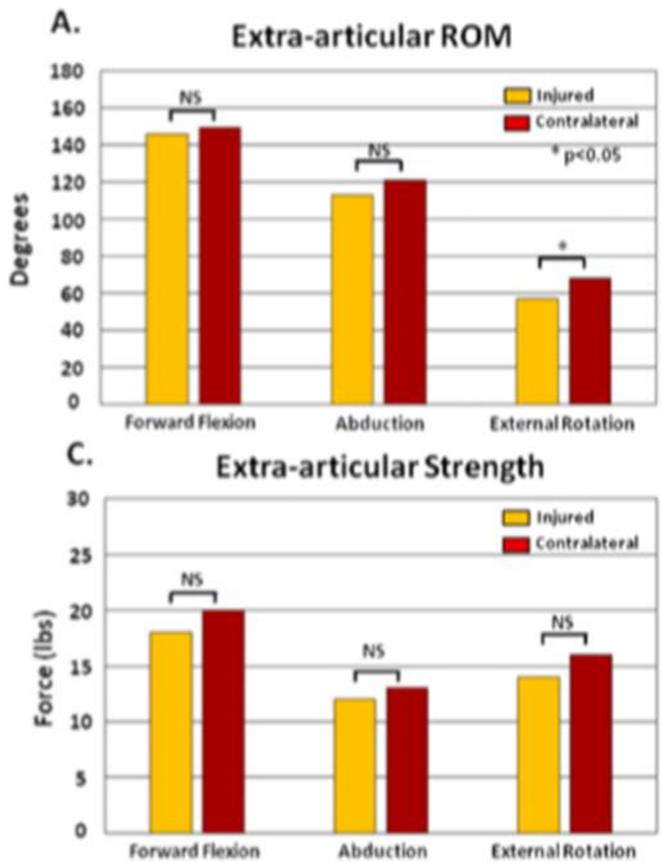

Figure 25. Comparison of mean active ranges of motion and strength between operative (injured) and contralateral shoulders. NS = not significant.[24]

	Extra-Articular (N = 31†)	
	Injured/Uninjured	P Value (Paired Student T Test)
Active range of motion (°)		
Forward flexion		>0.05
Mean	146/150	
95% CI	139-152/143-156	
%	97	
Abduction		>0.05
Mean	113/121	
95% CI	107-119/115-128	
%	93	
External rotation		0.01
Mean	57/68	
95% CI	52-63/62-74	
%	84	
Strength *(lb of force‡)*		
Forward flexion		>0.05
Mean	18/20	
95% CI	15-20/18-22	
%	89	
Abduction		>0.05
Mean	12/13	
95% CI	10-14/12-15	
%	89	
External rotation		>0.05
Mean	14/16	
95% CI	12-15/14-17	
%	89	

Figure 26. Comparison of clinical outcomes between operative (injured) and uninjured shoulders at a mean follow-up of 7.8 years.[24]

				ROM[a] (injured/contralateral)			Strength[b] (injured/contralateral)		
Patient number	Follow-up, months	Return to ADL	DASH	FF	ABD	ER	FF	ABD	ER
1	33.1	Y	0	133/133	98/102	55/55	21/20	18/18	23/20
2	13.5	Y	0.8	162/162	92/92	46/53	20/19	15/12	19/22
3[d]	27.8	Y	50.8	112/136	72/85	42/52	9/7	8/6	14/11
4	23.0	Y	3.3	149/125	100/94	42/59	14/14	12/11	14/18
5	18.9	Y	6.5	140/140	90/95	65/65	12/15	4/7	17/21
6	23.0	Y	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]	n/a[c]
Mean	23.2	6/6	12.3	139/139	90/94	49/56	15/15	11/11	17/18
Percent	100	100		100	96	88	100	100	94

Abbreviations: ADL, activities of daily living; DASH, disabilities of the arm, shoulder, and hand; ROM, range of motion; FF, forward flexion; ABD, abduction; ER, external rotation; n/a, not applicable.
[a]The values are given in degrees as the injured/noninjured shoulder.
[b]The values are given in pounds of force as the injured/noninjured shoulder.
[c]Patient was not able to travel to clinic. A detailed phone interview revealed that the patient is able to perform all ADLs with minimal pain and does not use pain medications chronically.
[d]At final follow-up, patient 3 had a known rotator cuff tear on the uninjured side, limiting the range of motion and strength of the uninjured side.

Figure 27. Outcomes of 6 geriatric patients at final follow-up.[25]

Strength	Mean ± Stand. Dev.		
	Injured *(lb [N])*	Contralat. *(lb [N])*	Injured/Contralat. *(%)*
Forward flexion	20 ± 7.4 (89.0 ± 32.9)	23 ± 7.5 (102.3 ± 33.4)	88 ± 30
Abduction	14 ± 5.1 (62.3 ± 22.7)	16 ± 5.8 (71.2 ± 25.8)	92 ± 23
External rotation	19 ± 6.9 (84.5 ± 30.7)	23 ± 7.2 (102.3 ± 32.0)	85 ± 24

Figure 28. Comparison of strength between operative (injured) and uninjured (contralateral) shoulders.[12]

ROM (degrees)	Nonoperative (n = 31)	Operative (n = 31)	t	p
Forward flexion	144.9 ± 44.6 (70–180)	152.6 ± 40.1 (35–180)	−0.500	0.621
Abduction	129.1 ± 47 (70–180)	146.2 ± 41.6 (65–180)	−0.982	0.334
External rotation	67.0 ± 20 (45–90)	50.8 ± 26.7 (10–90)	1.371	0.182
Internal rotation	76.3 ± 15 (60–90)	57.8 ± 29.1 (15–95)	2.127	0.050

Values are mean ± SD; ranges provided in parentheses.

Figure 29. Mean ranges of motion (in degrees) recorded at last follow-up.[9]

Measurement	Nonoperative (n = 31)	Operative (n = 31)	p
Displacement (mm)	19.6 (5–35)	30.8 (15–45)	< 0.001
Shortening (mm)	18.5 (5–38)	39.0 (15–55)	< 0.001
Angulation (degrees)	15.3 (0–45)	27.8 (0–100)	0.004

Figure 30. Pre-treatment fracture characteristics with ranges shown in parentheses.[9]