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Plate fixation of clavicle fractures: comparison between early and delayed surgery

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Background: The optimal treatment strategy for clavicle fractures remains a topic of debate. We evaluated our step-wise treatment protocol for patients with clavicle fractures to determine our success rate of conservative treatment. In addition, we evaluated the incidence of complications after clavicle plate fixation in patients undergoing acute surgery vs. delayed surgery.

Methods: This was a retrospective analysis in which we registered all patients aged 14 years or older with a clavicle fracture between January 2010 and May 2018 and at least 6 weeks' follow-up. Patients who underwent surgery were included from a prospectively maintained database. Functional outcomes were measured by Disabilities of the Arm, Shoulder and Hand and Constant-Murley scores 6 weeks after surgery.

Results: Conservative treatment was successful in 1627 of 1748 patients (93%). Primary fixation was performed in 73 patients (61%) and delayed fixation in 48 (39%). In 8 patients (6.6%), radiologic widening of the acromioclavicular (AC) joint was present after surgery, suggestive of AC injury. The incidence of complications was significantly higher among patients who underwent delayed fixation vs. those who underwent primary fixation: 15 of 48 patients (31.3%) vs. 9 of 73 patients (12.3%).

Conclusion: Most patients with clavicle fractures have an excellent outcome using conservative management. Acute surgery can be performed in high-demand patients, resulting in high performance scores. Delayed surgery is associated with a higher risk of complications, although the outcome is generally good. Associated AC joint dislocation found on postoperative radiographs does not influence outcomes. Shared decision making is key, and patients should be well aware of the potential risks and benefits of surgery.

Level of evidence: Level III; Retrospective Design; Treatment Study

Keywords: Clavicle fracture; shared decision making; delayed surgery; complications; acromioclavicular joint dislocation; conservative treatment

Fractures of the clavicle are common and account for 2.6% of all fractures seen in the general population.[7] The mechanism of trauma is an axial force caused by a fall on an outstretched hand or direct hit to the shoulder. This is most often seen in young, active persons.[12] Patients can be managed with either conservative treatment or surgery.

This study was approved by the local medical ethics committee of the Meander Medical Center (no. W15.052).

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Despite numerous studies, the optimal treatment strategy remains a topic of debate.[13] A complicating factor is ipsilateral acromioclavicular (AC) joint injury. A recent study showed that 6.8% of patients with a midshaft clavicle fracture has additional AC injury.[6] The exact significance of this remains unclear. Generally, early surgery results in significantly better function after 6 weeks compared with conservative treatment; however, functional outcome scores are identical after 24 weeks.[14] The potential benefits of surgery should be carefully balanced against its costs and complications. Plate fixation of the clavicle seems to be associated with wound infections and hardware failure in around 10% of cases.[16]

These data have mostly come from patients undergoing acute surgery; as such, it would be most interesting to see if there is an increased risk of complications in the case of delayed surgery. Currently, data comparing acute surgery and surgery for nonunion are scarce, and the results are conflicting.[5,8,10]

Our study had 2 main objectives: First, we wanted to evaluate our step-wise treatment protocol for patients with clavicle fractures to determine our success rate of conservative treatment. Second, we evaluated the incidence of complications after clavicle plate fixation in patients undergoing acute surgery vs. delayed surgery, with specific attention regarding patients with postoperative AC joint dislocation.

Materials and methods

Treatment protocol

The Meander Medical Center is a regional level 2 hospital in the Netherlands that treats around 35,000 emergency department patients annually. On the basis of previous research from our group, we have developed a treatment protocol for patients with a clavicle fracture (Fig. 1).[14]

Patients are first seen in the emergency department by the attending physician and receive a full workup including radiographs and a physical examination. In rare cases, such as a potential risk of skin perforation or neurovascular compromise, patients are referred for surgery. Generally, however, initial treatment consists of a "figure-of-8 brace," analgesics, and exercise instructions. After 1 week, patients are seen in the clinic by a specialized trauma surgeon. The option of surgery is discussed, and definitive treatment is chosen after shared decision making. In the case of nonoperative treatment guided by a physiotherapist, the outcome is evaluated 5 weeks later by a physical examination and radiographs. Patients without clinical and radiologic signs of union are offered delayed surgery 6 weeks after injury.

Our surgical department also serves as a tertiary referral center for athletes with clavicle fractures. These physically high-demanding patients generally undergo surgery within 1 week.

Patients

All patients aged 14 years or older who underwent surgery for a clavicle fracture between January 2010 and May 2018 and had at least 6 weeks' follow-up were included. These patients are registered in a prospectively maintained database with the approval of the local ethical committee. Variables included demographic factors, information from clinic visits, and details regarding surgery and recovery. Functional outcomes were measured by Disabilities of the Arm, Shoulder and Hand (DASH) and Constant-Murley scores 6 weeks after surgery. Detailed information about these questionnaires can be found elsewhere.[2,3]

Surgery

Patients underwent surgery in the beach-chair position performed by 1 surgeon. Incision of the skin and subcutaneous tissue was performed parallel to the skin folds. After the fragments were exposed, the anatomy of the clavicle was restored with respect to

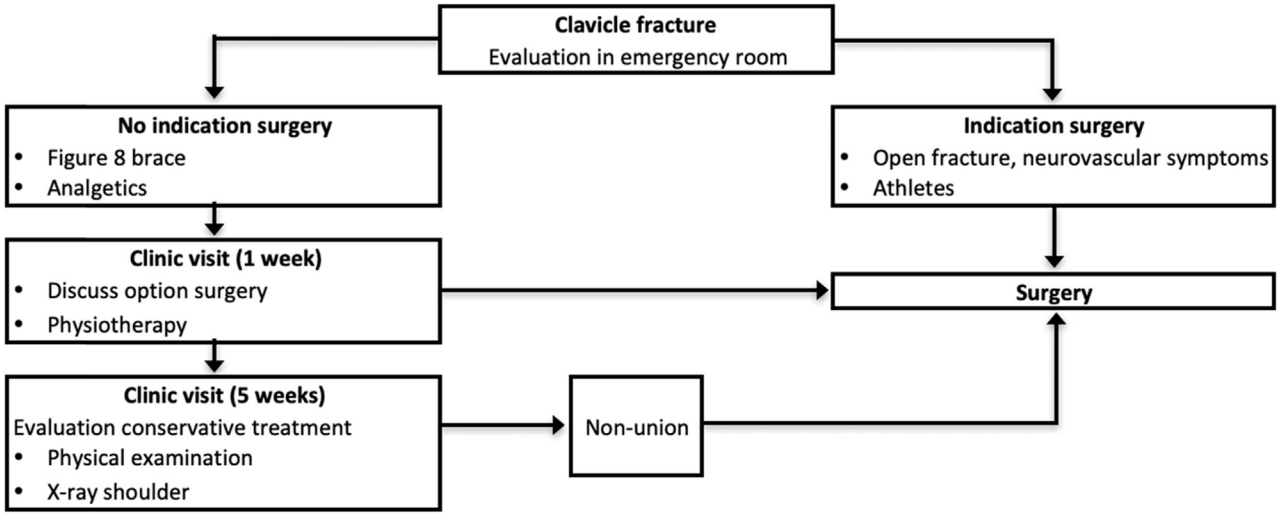

Figure 1 Flowchart of treatment protocol for clavicle fracture.

length, axis, and rotation. In all patients, a variable-angle locking-compression plate (DePuy Synthes, Warsaw, IN, USA) was placed anteriorly. Only autologous bone was used. The length of the plate varied between 7 and 12 holes and was dependent on the type of fracture seen. Plates were bent to fit the patients' unique anatomy. Further details of the surgical procedure were published previously.[15]

Statistical analysis

Standard descriptive statistics (mean, range, and frequency) were used to analyze patient and disease characteristics. The Fisher exact test was used to compare the incidence of smoking and complications. The Student t test was used to compare continuous variables between the 2 surgical groups, consisting of age, DASH score, and Constant-Murley score. $P < .05$ was considered statistically significant. All data analysis was performed using SPSS software (version 21.0; IBM, Armonk, NY, USA).

Results

Study group

A total of 1748 patients with clavicle fractures were evaluated in our hospital in the study period. Conservative treatment was successful in 1627 of 1748 patients (93%), determined 6 weeks after injury. The remaining 121 patients underwent surgery, consisting of 95 male patients (79%) and 26 female patients (21%). The mean age at surgery was 40 years (range, 14-81 years). Most patients (105 of 121, 86%) underwent surgery for a midshaft fracture; less frequent was surgery for a lateral fracture (14 of 121, 12%) or medial fracture (2 of 121, 2%). Primary fixation was performed in 73 patients (61%) after a median time of 7 days (range, 0-34 days).

Operative patients

Patients who underwent primary fixation were professional athletes (27 of 73, 37%), had physically demanding occupations (24 of 73, 33%), or preferred surgery over nonoperative treatment because of hobbies or personal preferences (22 of 73, 30%). These patients were significantly younger than the patients who underwent delayed fixation (34 years vs. 50 years). Secondary or delayed fixation was performed in 48 patients (39%) after a median time of 162 days (range, 47-5840 days) (Fig. 2).

After a follow-up period of at least 6 weeks postoperatively, all fractures showed union on both radiographic and clinical examinations. DASH and Constant-Murley scores were available in 118 of 121 patients (98%). Both scores were significantly higher in the group with primary fixation. The mean DASH score was 5.4 ± 6.4 vs. 15.1 ± 13.2 ($P < .001$). The mean Constant-Murley score was 96.2 ± 5.9 vs. 84.4 ± 16.6 ($P < .001$).

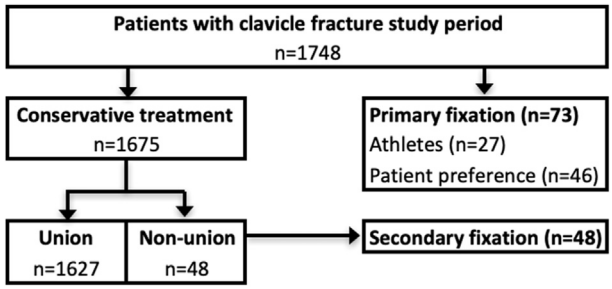

Figure 2 Flowchart of included patients.

In 8 patients (6.6%), radiologic widening of the AC joint was present after surgery, suggestive of AC injury, which was not recognized preoperatively. Two examples of this are shown in Figure 3. This interesting finding was demonstrated both in patients who underwent primary fixation (n = 4) and in patients who underwent delayed fixation (n = 4). All patients had midshaft fractures except for 1 who was treated for a lateral fracture. The AC joint widening was asymptomatic with a full range of motion in 7 of 8 patients. One patient experienced pain laterally in the shoulder that did not resolve with physiotherapy but had a full recovery after the plate was removed. A summary of these findings can be found in Table I.

Complications

Complications after plate fixation were seen in 24 patients (19.8%), of whom 4 had more than 1 complication. The incidence of complications was significantly higher among patients who underwent delayed fixation vs. those who underwent primary fixation: 15 of 48 patients (31.3%) vs. 9 of 73 patients (12.3%) ($P = .02$).

Neurologic symptoms including paresthesia and loss of strength caused by brachial plexus palsy were observed in 7 patients (5.8%). All occurred in patients undergoing delayed surgery. Of these patients, 3 only observed temporary tingling in their fingers, whereas the other 4 were referred to a neurologist because of more severe loss of function. After follow-up, 6 patients had regained full function within 1 year, and the remaining patient is expected to have a full recovery as well.

Frozen shoulder or postoperative pain was seen in 5 patients. All patients were treated with physiotherapy with good results.

Three patients had infections after surgery. Two could be treated with oral antibiotics, whereas 1 underwent surgery to incise a subcutaneous abscess. None of the plates had to be removed because of infection.

Refractures of the clavicle were seen in 6 patients. Four patients had a second trauma with fracture of the clavicle

Figure 3 (**A, C**) Preoperative radiographs without any signs of acromioclavicular widening. (**B, D**) Postoperative situation with clear widening after fixation of shaft.

medial (n = 3) or lateral (n = 1) to the plate. Two patients underwent surgery with removal of the old plate and fixation of the fracture. Two patients had a refracture without prior trauma after their plates were removed because of irritation of the skin. The plates were removed after 9 and 12 months, with the patients having clinical and radiologic consolidation of the clavicle. Both patients underwent reoperations for plate fixation with good results.

Other complications included plate removal owing to osteolysis of the medial screw (n = 1), a screw in the AC joint (n = 1), lateral release of the plate (n = 1), or broken screws (n = 1). Another patient with broken screws was asymptomatic and did not undergo a second surgical procedure. Two patients had screws that were too long; 1 was symptomatic and underwent surgery for screw replacement. One patient had thrombosis of the subclavian artery, for which an osteotomy was performed in combination with stenting of the artery. An overview of the complications can be found in Table II.

Plate removal

The plate was removed in 21 of 121 patients (17.4%) after a median time of 1 year (range, 0-3 years). Most patients had

Table I Baseline characteristics

Variable	Primary fixation (n = 73)	Fixation nonunion (n = 48)
Male, %	64	31
Mean age, yr	34	50
Smoking, %	6	14
Type of fracture, %		
Medial	—	2
Midshaft	63	42
Lateral	10	4
AC injury (AC joint dislocation), %	4	4
Median time to surgery (range), d	7 (0-34)	162 (47-5840)
Mean DASH score	5.4	15.1
Mean Constant-Murley score	96.2	84.4
Complications, %	9	15

AC, acromioclavicular; *DASH*, Disabilities of the Arm, Shoulder and Hand.

their plate removed because of irritation of the skin (n = 12). The remaining 9 patients had complications such as plate fracture as mentioned before.

Discussion

The objective of our study was to evaluate our treatment protocol for patients with a clavicle fracture and determine the outcome and complications of surgery, in both the acute and delayed phases. Our study showed that 93% of patients could be treated successfully with conservative management after shared decision making.

If surgery was performed, the overall outcome was good, with the highest performance scores after 6 weeks in patients undergoing acute surgery. Complications of surgery were seen in 19.8% of patients and occurred more often if surgery was performed after a delay. Additional AC injury was detected on radiographs in 6.7% of patients postoperatively, all with excellent outcomes after surgery.

Table II Complications

Complication	Primary fixation (n = 73)	Fixation nonunion (n = 48)
Neurologic symptoms	—	7
Frozen shoulder	—	5
Infection	2	1
Refracture of clavicle	6	—
Other*	2	5

* Including hardware failure and vascular injury.

Throughout the years, our hospital has developed a protocol that largely focuses on the conservative treatment of clavicle fractures based on our own research. Following our protocol, we have found that 93% of patients are successfully treated without undergoing surgery. This finding is remarkable because there has been a tendency toward operative fixation of clavicle fractures after the publication of 2 randomized controlled trials showing nonunion rates of 11% and 17%.[1,9]

This can partly be explained by differences in definitions. We do not define a nonunion by radiographs alone. The findings are correlated with the physical examination results. Patients who have excellent shoulder function and do not experience pain are considered healed and do not return to the clinic. Almost half of patients with nonunion in the study of Robinson et al[9] did not undergo surgery because they were asymptomatic or had very minor symptoms that resolved within 1 year.

Other frequently used arguments in favor of primary fixation are a better functional outcome and a faster return to work compared with patients undergoing conservative treatment.[11] Although we did not specifically investigate this in our study, our results confirm that patients undergoing primary fixation have excellent outcome scores 6 weeks after surgery (mean DASH score, 5.4; mean Constant-Murley score, 96.2). These findings are concordant with a previous prospective trial from our group.[14] It is interesting to note that the functional outcome after 24 weeks was identical to that of patients undergoing conservative treatment in that study. Equal function at long-term follow-up has been confirmed by other prospective research as well.[9]

Our study did find significantly lower performance scores after 6 weeks for patients undergoing delayed plate fixation compared with primary fixation. This is not surprising for several reasons: First, a substantial number of patients in the primary fixation group were (professional) athletes who received intense physiotherapy training. Second, the patients with nonunion only underwent surgery if they had significant shoulder complaints. It is likely that not all of these complaints resolved within the first 6 weeks. Finally, the patients undergoing delayed plate fixation had significant more complications than the patients with primary fixation (31.3% vs. 12.3%). These complications are likely reflected in the functional outcome scores.

This is an important point of discussion. If the rate of complications is higher in the case of delayed surgery, this should be part of the decision-making process. To date, very little is known about complications in patients undergoing delayed surgery.

Our incidence of complications in patients undergoing surgery in the acute phase (12.3%) corresponds to the percentage found in the literature.[16] In contrast, our rate of complications in the group undergoing delayed surgery was almost 3-fold higher. In our study, all neurovascular complications were seen in the delayed surgery group,

potentially reflecting a more difficult operation. The largest study so far used data from a national database and included 1215 patients (209 nonunions) with midshaft clavicle fractures.[5] Patients with nonunion were found to be at a greater than 2-fold increased risk of any post-surgical complication, comparable to our findings. In addition, the operating time was significantly longer and there was a higher need for osteotomy in patients with nonunions. It must be noted that the study's overall rate of complications was remarkably low (<3%), which might be explained by the use of a national registry with limited variables.

A single-center study from the United Kingdom including 20 patients with nonunion found similar results, with more complications compared with acute surgery and a tendency toward more frequent reoperations.[10] By use of logistic regression, however, these findings were not significant, potentially because of the limited number of patients included.

Ultimately, the key will be to identify the unlucky few patients in whom a nonunion will develop, thereby offering surgery to those patients who benefit the most with the lowest risk of complications. Although our study did not investigate this, factors that have been associated with nonunion include fracture displacement and refractures.[4] Further study into risk factors for nonunion is warranted.

Concomitant AC joint injury does not seem to be a risk factor because this rare combination of injuries was found in both patients undergoing acute surgery and patients undergoing delayed surgery. The widening of the AC joint was asymptomatic and incidentally found on postoperative radiographs in 6.6% of patients. All of these patients had an excellent outcome after surgery. The only other study that investigated this found a similar rate of AC dislocation of 6.8% overall.[6] It is interesting to note that those authors found an association with superior plating whereas our patients underwent anterior plating. The type of surgery therefore seems to be unrelated.

Our study has several strengths and limitations. First, to our knowledge, this is the largest single-center study investigating the difference in complications between patients undergoing acute surgery and those undergoing delayed surgery for clavicle fractures. The study was performed in a high-volume center using consecutive patients and used data from a prospectively maintained database. In addition, it is 1 of the few studies investigating the role of AC joint dislocation. The main limitation of the study is that no patient-reported outcome scores are available for the conservatively treated patients. Because we performed a retrospective analysis of the data, the results need to be confirmed by prospective trials.

Conclusion

Most patients with clavicle fractures have an excellent outcome using conservative management. Acute surgery can be performed in athletes and other high-demand patients with a low risk of complications and high performance scores. Delayed surgery seems to be associated with a higher risk of complications, although the outcome is generally good. Associated AC joint widening found on postoperative radiographs does not seem to influence outcomes. Shared decision making is key, and patients should be well aware of the potential risks and benefits of surgery. Future research should focus on identifying those patients who have a high chance of nonunion and would benefit from acute surgery.

Disclaimer

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