Original article

Outcomes from surgical treatment of middle-third clavicle fractures non-union in adults: A series of 21 cases

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ABSTRACT

Introduction: The aim of our study was to evaluate the results of surgical treatment of clavicle non-union after failure of conservative treatment. Our hypothesis was that stable fixation with bone graft derived from local bone stock (fracture site) or the iliac crest was essential to achieve bone union.

Material and methods: Twenty-one patients with a symptomatic middle-third clavicle non-union after failure of initial conservative treatment were included in the study. Delay between the initial fracture and surgery for non-union was 27 months (6–144). In five cases, the non-union was hypertrophic and bone graft was obtained locally from the callus. In 16 patients, the non-union was atrophic. Bone was harvested from the iliac crest as cortical-cancellous graft (7 patients) and cancellous graft (8 patients). One patient refused bone grafting. A 3.5-mm plate with non-locking screws was placed anterior in 12 and superior in 9 patients.

Results: At 41 months average follow-up (minimum of 12 months), 20 patients were available for review. Bone healing was obtained initially in 15 cases. Six complications required a revision procedure: 3 for infection and 3 for mechanical failure. At last follow-up, 19 patients were satisfied with the surgery. Average Constant score was 84 ± 26 points (7–100), and Quick DASH score 17 ± 22 points (0–91). Radiographic bone healing was obtained in 19 of the cases.

Conclusion: Treatment of middle-third clavicle non-union after initial failure of conservative treatment with stable fixation and bone graft is a reliable, well-suited and effective treatment. Our hypothesis was verified. Preoperative evaluation of appearance of the non-union X-rays can be used to determine the type of bone graft needed, but the final decision is often taken during surgery.

Level of evidence: Level IV.

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1. Introduction

Clavicle fractures comprise 2.6 to 5.0% of all fractures in adults, with an annual incidence of 36.5 per 100,000. The vast majority (70–80%) occur in the middle-third [1–4]. These fractures typically occur in young, male subjects as a result of high-energy trauma during a sports or motor vehicle accident [4,5]. In adults, middle-third clavicle fractures are generally treated conservatively, but the current trend is to provide internal fixation when the fracture is significantly displaced [6,7]. With conservative treatment, the non-union risk varies between 0.1% and 24% depending on the study [5,8,9]. When osteogenesis fails, the standard treatment is direct plate fixation, with or without bone grafting [10–16]. Only one French study has explored this poor outcome, which brings into question the appropriateness of conservative treatment [17].

The main goal of this study was to evaluate plate fixation and autograft for the treatment of non-unions of middle-third clavicle fractures that had failed primary non-surgical treatment. The hypothesis was that stable fixation with bone grafting (either from bone at the fracture site or the iliac crest) would lead to bone union.

2. Material and methods

2.1. Patient population

This was a retrospective study without a comparator group. Between 1996 and 2012, 35 patients were seen for non-union of the clavicle in our hospital. Inclusion criteria consisted of all patients presenting with non-union of the middle-third of the clavicle after the initial fracture had been treated conservatively, no previous treatment of the non-union and symptomatic at the time of inclusion. Fourteen patients were excluded because the clavicle fracture was not in the middle third (five fractures in lateral quarter, one in the medial third and one secondary to a tumour) or because their fracture had initially been treated surgically (three patients).
or their non-union had already been treated (four patients). As a consequence, there were 21 patients included in this continuous, single-centre cohort (Table 1).

There were 11 women and 10 men, with an average age of 37 years (range 18–62) at the time of the fracture and of 47 years (range 29–67) at the time the non-union was addressed. Nine patients performed manual labour. Eleven of the 21 patients were active smokers. In 10 cases, the non-union was on the dominant side. The injury mechanism was high-energy trauma, with nine patients having been involved in a motor vehicle accident, 10 in sports or recreational accidents and two having suffered from a fall while at home. Fourteen patients had no other injury, while three were polytrauma patients and four had multiple fractures. Based on the Edinburgh classification system for recent fractures [12], two were non-displaced (type 2A1), two were not displaced but were angled (type 2A2), 11 were displaced with or without a single intermediate fragment (type 2B1) and 6 were comminuted (type 2B2); seven patients had a significant initial fracture displacement. Of the 21 patients, 14 had initially been treated conservatively in the emergency room at our hospital and 7 had been treated at another hospital by figure-of-eight clavicle immobilization.

An average of 27 months (range 6–144) elapsed between the fracture incident and surgery for the non-union. Every patient was symptomatic: 18 had pain, 7 complained of muscle weakness and 4 of being self-conscious about the appearance of their clavicle. Thoracic outlet syndrome was present in two patients. Six patients could feel motion at the non-union site. Two patients had reduced shoulder range of motion. On standard A-P X-rays of the clavicle, five of the non-unions were hypertrophic and 16 were atrophic (no osteogenesis). The non-union site was at least 1 cm shorter in five cases and had an intermediate fragment in five cases. Nine patients had a gap of at least 1 cm between fragments and two patients had overlap between the bone ends. Patients who were smokers were informed of the increased risk of complications and failure of bone union if they continued to smoke. None of the smokers stopped smoking before the surgery.

### 2.2. Surgical technique

Two different surgeons treated these patients. The surgery was performed under general anaesthesia, with second-generation cephalosporin given as antibiotic prophylaxis. Patients were installed in a semi-seated position with a head rest. A superior longitudinal surgical approach over the clavicle was performed. The skin incision was shifted forward to avoid direct contact with the fixation hardware. Any fibrous tissue was removed from the fracture site and the fractured bone surfaces refreshed with repermeabilization of the medullary canal. In the five patients with hypertrophic non-union, the fracture callus was broken up to provide bone for grafting purposes. Autologous bone was harvested from the iliac crest if the amount of bone excised locally was not sufficient or had no signs of osteogenesis. Either cortical-cancellous grafts (7 patients) or cancellous bone chips (8 patients) were collected in these cases. One patient with an atrophic non-union refused iliac crest harvesting, thus was treated without bone grafting. Fracture fixation was performed with a “carved-out” reconstruction plate with 3.5 mm diameter non-locking screws; the plate was placed anterior in 12 cases and superior in 9 cases. Suction drainage was implanted at the end of the procedure and then removed on the second day after surgery when the wound was dressed. Immobilization was carried out with an arm sling for 2 to 8 weeks (average of 6 weeks).

### 2.3. Clinical and radiological assessments

Patients were reviewed at the clinic to look for the presence of residual symptoms and evaluate the Constant and QuickDASH scores, return to work and/or recreational activities and overall satisfaction score. A-P X-rays of the clavicle were taken to determine if union had occurred. Union was defined as continuity present in two bone cortices.

### 2.4. Statistical analysis

Univariate analysis was performed using Statistics® (version 5.6.6, MericqSoft, Toulouse, France) software. A Mann-Whitney test was used to compare the preoperative and postoperative data. The Chi² test was used to compare categorical data. The significance level was set at 5% when different variables were compared.

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**Table 1**

<table>
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<tr>
<th>Patient No.</th>
<th>Sex</th>
<th>Age when non-union treated (years)</th>
<th>Smoker</th>
<th>Edinburgh classification</th>
<th>Non-union type</th>
<th>Time injury-surgery (months)</th>
<th>Graft type</th>
<th>Plate position</th>
<th>Complications</th>
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</tr>
<tr>
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<td>Y</td>
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<td>A</td>
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<td>F</td>
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<td>Y</td>
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<td>A</td>
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<td>Cancel.</td>
<td>Sup</td>
<td>Infection</td>
</tr>
<tr>
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<td>Cortic.</td>
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<td>Sup</td>
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<td>Cortic.</td>
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<tr>
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<tr>
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<td>32</td>
<td>N</td>
<td>2B2</td>
<td>A</td>
<td>6</td>
<td>Local</td>
<td>Ant</td>
<td>Infection</td>
</tr>
</tbody>
</table>

Sex: M = male, F = female; smoker: Y = yes, N = no; Edinburgh classification of recent fractures according to Robinson et al. [10]; non-union type: A = atrophic, H = hypertrophic; graft type: cancel. = iliac crest cancellous bone, cortic. = iliac crest cortical-cancellous bone; local = in situ; plate position: sup = superior, ant = anterior.
3. Results

3.1. Study population

The average hospital stay was 5 days (range 3–7), and 20 of the 21 patients had a follow-up of at least 12 months, with the average follow-up being 41 months.

3.2. Complications and revisions

One patient presented a failure that was successfully operated again at another hospital with new fixation hardware and a vascularized fibular graft. Three cases of complex regional pain syndrome were observed; there was one case of repeat fracture after a new injury event that spontaneously healed without surgery; there was one case of phlebitis in the upper limb after hardware removal. Primary bone union was obtained in 15 cases; six patients had complications requiring surgical revision – surgical site infection in three cases and fixation failure in three cases (Fig. 1).

The first patient with infection (Fig. 2) presented with early wound dehiscence and purulent discharge containing *Propionibacterium acnes*. The first treatment phase consisted of debridement, lavage, plate removal and antibiotic therapy for six weeks to resolve the infection. After a symptom-free period of nine weeks, a new fixation procedure with cancellous bone graft from the iliac crest led to bone union. The second patient with an infection had a fixation failure within one month, was re-operated for new fixation in combination with interposed cortical-cancellous graft. This procedure was complicated one month later by wound dehiscence due to *Staphylococcus aureus*, which resolved with appropriate antibiotics. This patient had not achieved bone union at the follow-up evaluation three years later, but she had no functional impairment and no desire for another surgical procedure. The third patient had early hardware failure after falling one month after the surgery; this required another fixation procedure with an interposed cortical-cancellous bone graft. Microbiology samples were positive for *P. acnes*; the patient achieved bone union with appropriate antibiotic treatment.

Among the three patients requiring surgical revision for mechanical failures, only one did not achieve bone union. One patient with atrophic non-union was surgically treated with a plate and iliac crest autograft and had fixation failure at five months. The revision fixation with additional screws was complications two months later with a repeat fracture of the medial part of the construct at a screw hole. This repeated fixation failure was treated with a second anterior plate, wire cerclage with a stainless steel suture and 45 days of immobilization. This patient sought treatment at another hospital when the healing failed again. A second patient had a repeat fracture after removal of the fixation hardware due to a new injury event. She was initially immobilized for 45 days. Since there were no signs of bone union after 10 months and her symptoms persisted, a new fixation construct was implanted with an iliac crest cortical-cancellous bone graft interposed between the bone ends. The fixation hardware was then removed at the patient’s request. After a follow-up of two years, the patient had achieved bone union and had no functional impairment. The third patient had early secondary displacement of the hardware with screw pull-out; since the initial interposed cortical-cancellous bone was still intact, only the plate was changed and union was achieved. Six patients requested that their fixation hardware be removed. The average hospital stay for this procedure was 3.75 days (range 1–8). In 16 patients, the average time without working due to surgery for clavicle non-union was 4.7 months (range 1–15).

3.3. Clinical results

At the last follow-up for each patient, 19 were satisfied with the surgical procedure performed. Sixteen patients had residual
symptoms, with six of them having weather-related pain that was transient and low in intensity (VAS below 3) and five having problems during forceful movement and with lack of endurance in the upper limb muscles. One patient described his scar as unsightly, hypertrophic and sensitive. Four others had discomfort related to impingement with the subcutaneous fixation hardware. During the return to sport or recreational activities, only 3 patients felt they had limitations relative to their pre-injury status. One patient could not return to work, but this was attributed to multiple factors, not only the non-union. The 20 other patients were able to return to their primary occupation, but one patient still had functional limitations when performing manual labour. Among the 15 patients who needed to have bone harvested from their iliac crest, one had hypoaesthesia in the operated area.

The average Constant after surgery was 84 ± 26 points (range 7–100) and the average QuickDASH score was 17 ± 22 points (range 0–91). The Constant score was 85 (range 7–100) in the 15 patients who had bone union after the first surgery and was 81 (range 60–100) in the patients requiring surgical revision. The QuickDASH score was 16 in the 15 patients who had bone union after the first surgery (range 0–91) and it was 19 (range 0–41) in the patients requiring surgical revision.

3.4. Radiological results

Overall, bone union on X-rays was achieved in 19 patients; the two failures occurred in smokers (Fig. 3).

3.5. Prognostic factors

The potential impact of age, gender, smoking, age of the non-union, non-union type (atrophic or hypertrophic), graft type (from callus, cancellous of cortical-cancellous) and plate position (antero or superior) on the occurrence of complications was evaluated. Only the duration of the non-union was significantly correlated with fixation failure (22.6 ± 21.3 months vs. 90.7 ± 58.8 months; P<0.01). No preoperative or intra-operative factor had a statistically significant effect on the occurrence of an infection.

4. Discussion

Although the number of patients included in this study was relative small, it was still within the range of similar published studies [18–27] (Tables 2 and 3). Our hypothesis was validated by the results of the series. The general principles for treatment of clavicle non-unions are the same as for other fracture sites: bone union is achieved with stable fixation, fracture site reduction and bone grafted from the site itself or the iliac crest [28]. Hypertrophic non-union is typically the result of lack of stability at the fracture site, while atrophic non-union is secondary to instability and non-existent osteogenesis.

Retrospective analysis of this series revealed a higher complication rate than the one reported in other published studies [18–27]. Of the 21 patients, three had infection-related complications. The clinical picture was as expected: early infection after wound healing disturbance. This again highlights the particular features of clavicle injuries, especially their superficial nature and lack of soft tissue protection over the periostium. In two cases, the plate was placed superior and in one case it was placed anterior. Although one could easily assume that an anterior plate has the best muscle protection, this study’s findings do not support this assumption. Two of the three infection complications were secondary to P. acnes, which is a known bacterium in the shoulder region because it is a commensal micro-organism [29–33]. One patient had acute scars in the shoulder region, while the two other patients did not have any specific risk factors. Prophylactic antibiotics with second-generation cephalosporin may not have provided sufficient coverage for this micro-organism and may need to be modified in the future for this type of surgery.

Mechanical fixation failure was found in three cases and required surgical revision in all cases. Fracture fixation was performed in all cases with a “carved out” reconstruction plate with 3.5 mm non-locking screws; three bicortical screws were placed on either side of the non-union site. These failures highlight the limitations of this material. Only the duration of the non-union seemed to be related to the occurrence of this complication. An older non-union is usually atrophic and the deformity is often non-reducible. Extensive cortex removal and extensive tissue release are often needed. This may result in local devascularization and trigger a process leading to fixation failure.

The union rate was 90.5% in this series, with 71% being achieved following the first procedure (15 of 21). This was below the rate found in published studies after failure of non-surgical treatment only (Table 2) or all types of initial treatment (Table 3). There is no agreement in published studies on the type of bone graft to use (local or remote harvesting) or even the requirement for bone substitutes [23,24,27]. No definite conclusions can be made on the relative benefits of various types of bone graft, either based on published studies where union is optimal (Table 2) or based on this study. In two studies, local bone graft material was used alternately with iliac crest graft with nearly 100% success rate [20,24]. But others have questioned the systematic use of bone grafts and only use them with atrophic non-unions [21,24]. Ramoutar et al. [34] reported a 100% union rate in 11 patients treated by decortication and compression plate fixation without bone grafting. Huang et al. [35] treated 51 patients with hypertrophic non-union of the clavicle using LC-DCP plates without bone grafting. Bone union was achieved in all cases after an average follow-up of 20.4 months. Huang et al. [36] directly compared treatment of atrophic non-union of the clavicle using LC-DCP plates with and without bone grafting. No differences were found in the union rate upon follow-up. Bone graft is only needed with atrophic, shortened non-unions, especially if the non-union is old. Some studies have shown that osteo-inductive proteins exist at the non-union site that can contribute to bone growth once the site has been burred to expose bleeding bone and stable fixation has been applied [37]. Use of larger, vascularized bone grafts is limited to patients who have failed one or more surgical courses for the non-union [38–40]. Use of inductive proteins (BMP) has not been effective as an adjuvant for the treatment of clavicle non-union [41]. Use of ultrasound to

Fig. 3. Atrophic non-union (A) treated with a 3.5 mm anterior reconstruction plate in combination with cortical-cancellous iliac bone graft (B).
encourage bone union in the clavicle still needs to be validated [42–44].

In the current study, we cannot ignore the fact that two of the failures were in patients with atrophic non-union who were also smokers, even if the effect of these factors was not statistically significant. It was also noted that half of the patients who suffered from non-union after conservative treatment were smokers, which clearly has a greater effect than in the general population. The harmful effect of smoking on bone healing has been well described [45]. A contract should be made between the patient and treatment starts that he/she will not smoke for 4–6 weeks before and after the procedure, so as to optimize the probability of success and reduce the risk of complications.

The tolerance for and compliance to conservative treatment was not evaluated in this study. However, clavicle fractures treated urgently often are comminuted and have significant residual displacement, thus are proof of the relatively poor efficacy of figure-of-eight splints for fracture reduction. This study is innately removed from the debate between conservative treatment and surgical treatment for a fresh fracture, but it provides some arguments to support published studies focusing on this problem. In a multicentre, prospective study of 132 patients with a recent clavicle fracture, union occurred much faster after surgical fixation but there were more complications in these patients; the non-union rate was higher after conservative treatment [46]. Based on this information, the presence of fracture displacement is a near-certain predictor of non-union. A surgical procedure should be considered in these cases, especially if the fracture is comminuted.

5. Conclusion

Treatment of non-union of the middle-third of the clavicle secondary to conservative treatment is based on stable plate fixation and addition of a bone graft. In this study, this type of treatment was reproducible, well-suited and effective as it led to primary union 7 out of 10 times. An osteogenic component is essential, and can be derived either from the hypertrophic fracture callus or from the iliac crest, if no osteogenesis is present at the initial fracture site. The X-rays of the non-union can be used to plan the graft type before surgery, but the final choice must be made intra-operatively and the patient should be warned of the possible need for an iliac crest harvest. We need to be more vigilant with these cases, as the early infection rate was higher and success rate was lower than the ones reported in other published studies. This study does not aim to make a case against conservative treatment of recent clavicle fractures, but it retrospectively highlights its limitations: fracture comminution and insufficient reduction will inevitably lead to non-union.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

8. Zlowodzki M, Zelle BA, Cole PA, Jay K, McKee MD. Treatment of acute midshaft clavicle fractures: systematic review of 2144 fractures: on behalf of

Table 2

Results from published studies of clavicle non-union treatment in fractures that had initially all been treated conservatively.

<table>
<thead>
<tr>
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<th>n</th>
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<th>Graft</th>
<th>Complications</th>
<th>Union</th>
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<td>In situ - 5</td>
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<td>In situ</td>
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<td>100%</td>
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Table 3

Results from published studies of clavicle non-union treatment in fractures that had initially all been treated conservatively or surgically.

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<th>Union</th>
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<td>Iliac -15 Substitute - 1</td>
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<td>Singh et al. [27]</td>
<td>30</td>
<td>Conservative - 27 Surgery - 3</td>
<td>Iliac - 20 Substitute - 10</td>
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