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Original article

Screw-plate fixation for displaced middle-third clavicular fractures with three or more fragments: A report of 172 cases

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ABSTRACT

Background: Although mid-shaft clavicular fractures are generally thought to be non-serious injuries that nearly always heal with non-operative treatment, recent studies found non-union rates of 3%–7% in simple fractures and 20%–33% in complex fractures. The primary objective of this study was to report the functional and anatomical outcomes after screw-plate fixation of displaced mid-shaft clavicular fractures with three or more fragments.
Hypothesis: Screw-plate fixation in this indication is an excellent treatment option that minimises the risk of complications.
Methods: A search of our database from 6 January 2012 to 27 December 2016 identified 410 cases of clavicular fracture, of which 250 were managed surgically, including 172 meeting our inclusion criteria and having complete data. These 172 patients were managed using a curved pelvic reconstruction plate with 3.5-mm non-locking screws positioned over the antero-superior aspect of the clavicle. All 172 patients were re-evaluated at least 1 year after surgery by an independent assessor, who determined the UCLA score.
Results: We studied 172 patients, 154 (89.5%) males and 18 females with a mean age of 34.5 ± 14.5 years (range, 13–69 years). In 84.5% of cases, the fracture was a sports injury, and the most common sports were skiing (26%), cycling (21%), and mountain biking (18.5%). Of the 172 fractures, all but 1 healed, within a mean of 87 days (range, 45–120 days). After removal of the fixation material, 8 (4.5%) patients experienced a recurrent fracture, within a mean of 90 days (range, 2–210 days); 4 of these recurrent fractures were caused by high-energy traumas occurring 6 months after implant removal. The UCLA score determined at re-evaluation indicated that the outcome was excellent in 164 (95.5%), good in 5 (3%), and fair in 3 patients.
Conclusion: Internal fixation using a curved pelvic reconstruction plate fixed with 3.5-mm screws provides excellent functional and anatomical outcomes in patients who have displaced mid-shaft clavicular fractures with three or more fragments.
Level of evidence: IV, retrospective cohort study.

1. Introduction

Mid-shaft clavicular fractures are common [1] and generally perceived as non-serious injuries that nearly always heal with non-operative treatment alone [2]. Recent studies, however, found non-union rates of 3%–7% in simple cases and 20%–33% in complex cases [3–6]. In addition, some forms of mal-union can result in functional impairments [7,8]. Surgical treatment has therefore been increasingly used over the past few years [9]. Although non-operative treatment remains appropriate in patients with little or no displacement, an international consensus seems to be emerging in favour of surgery for fractures characterised by severe displacement or by multiple fragments with tilting and verticalization of the intermediate fragments, such as occurs in Robinson types 2B1 and 2B2 [10].

Screw-plate fixation remains the surgical method of choice [4,11–13], despite the risk of an unsightly scar and of the complications inherent in open fixation.

The primary objective of this study was to report the functional and anatomical outcomes after screw-plate fixation of displaced mid-shaft clavicular fractures with three or more fragments. The

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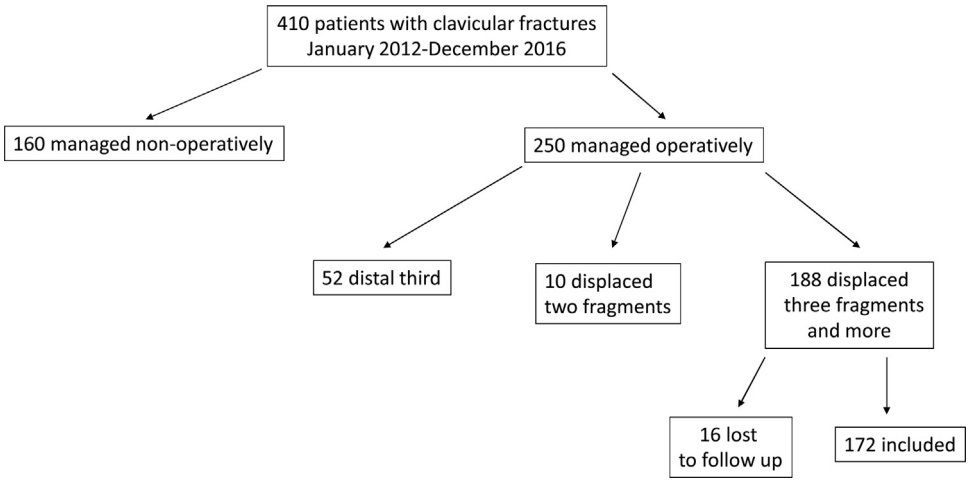

Fig. 1. Flow chart.

secondary objective was to describe the complications associated with this internal fixation method. The working hypothesis was that screw-plate fixation in this indication would prove an excellent treatment option capable of minimising the risk of complications.

2. Methods

A retrospective, observational, cross-sectional, single-centre cohort study was performed with the approval of our institutional review board and in compliance with the Declaration of Helsinki. All patients gave their informed consent to study participation.

A search of our database identified 410 patients managed for clavicular fractures between 6 January 2012 and 27 December 2016, including 250 patients who were treated surgically. Of these 250 patients, the 52 patients with fractures of the distal third of the clavicle and the 10 patients with severely displaced two-fragment fractures were excluded, leaving 188 patients meeting our inclusion criterion of at least three fragments with tilting and a variable degree of verticalization of the intermediate fragment. Of these 188 patients, 16 (8.5%) were lost to follow-up and the remaining 172 had complete data and were included into the study. Fig. 1 is the patient flowchart.

All patient files were selected and reviewed by an observer who had not been involved in the surgical treatments (GC). This observer and a radiologist reviewed the pre-operative radiographs that had been used to classify the fractures.

A supra-clavicular incision was performed to ensure that the skin on the caudal side of the wound covered the plate, which was thus not directly under the incision. A curved pelvic reconstruction plate fixed using 3.5-mm screws (DePuy Synthes, Saint-Priest, France), without locking screws, was positioned to apply compression to the ventro-cranial (antero-superior) aspect of the clavicle (Fig. 2).

No post-operative immobilisation was used. All movements associated with the activities of daily living were allowed, but the patients were instructed not to lift weights heavier than 1 kg.

For each patient, the following were entered into an Excel spreadsheet: clinical and radiological findings, course of the surgical procedure, and functional and anatomical outcomes.

All patients completed a questionnaire at least 1 year after surgery, during a face-to-face or telephone interview. The data thus collected served to determine the University of California Los Angeles (UCLA) score [14], which was used to categorise the outcome as excellent, good, fair, or poor, with scores below 27/35 considered fair or poor.

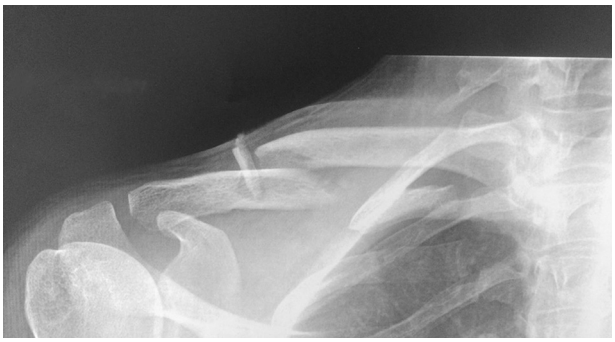

Fig. 2. Right clavicular fracture with three fragments and verticalization of the intermediate fragment threatening to breach the skin.

XLStat software version 2016 (Addinsoft, Long Island City, NY, USA) was used to perform the statistical tests. Quantitative variables were compared using Student's *t* test and qualitative variables using the chi-square test or Fisher's exact test, as appropriate. Values of p smaller than 0.05 were taken to indicate significant differences. The primary outcome measure was the development of non-union.

3. Results

3.1. Patients

The study population comprised 172 patients, 154 (89.5%) males and 18 females with a mean age of 34.5 ± 14.5 years (range, 13–69 years). The left clavicle was fractured in 51.5% and the right clavicle in 48.5% of patients. In keeping with the recruitment at our department, the fracture occurred during sports in 145 (84.5%) patients. More specifically, 26% of the fractures occurred while skiing, 21% while cycling, and 18.5% while mountain biking. In addition, vehicular, work-related, and domestic accidents accounted for 11.0%, 3.5%, and 1.0% of the fractures, respectively. The clavicle was the only fractured bone in 155 (90%) patients. Concomitant fractures of the ribs and of the ipsilateral upper limb were present in 3.5% and 1.5% of patients, respectively.

The number of fragments was three in 56 (32.5%) patients, four in 100 (58%) patients, and more than 4 in 16 (9.5%) patients.

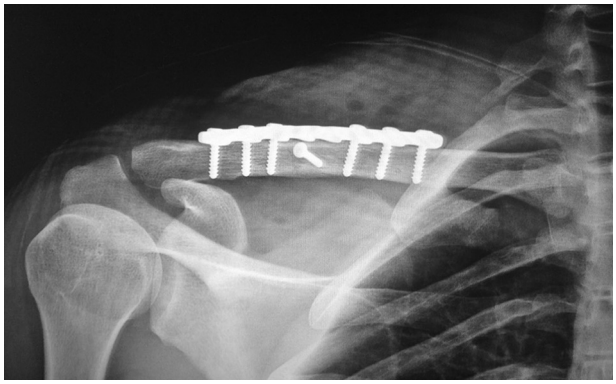

Fig. 3. Internal fixation using a single 2.7-mm compression screw and a curved pelvic reconstruction screw-plate fixed with 3.5-mm screws and positioned on the ventro-cranial (antero-superior) aspect of the clavicle, which is devoid of muscle attachments.

3.2. Fixation material

A 10-hole plate was used in 51.5% and an 8-hole plate in 37.0% of the patients. More rarely, a plate with 12 or 9 holes was used (7% and 4% of the patients, respectively). Preliminary isolated compression screw fixation was performed in 55.5% of patients (Fig. 3) and cerclage with thick resorbable suture in 44% of patients.

3.3. Post-operative course and complications

Mean hospital stay length was 52.5 ± 27 hours (range, 12–96 hours); the median was 48 hours.

The post-operative course was uneventful in 99.5% of patients. A single patient experienced partial wound dehiscence, which healed with local care. No cases of superficial or deep surgical-site infection were recorded.

In 1 patient, construct disassembly 30 days post-operatively required revision surgery for internal fixation. Adhesive capsulitis of the shoulder developed in 2 patients, who recovered with appropriate physical therapy.

In 126 (73%) patients, the plate was removed, either as a pre-planned procedure or due to protrusion under the skin, after the 16th post-operative month. In 8 (4.5%) patients, the fracture recurred at a mean of 90.0 ± 74.5 days (range, 2–210 days) after removal of the fixation material. In 4 of these patients, a high-energy trauma 6 months after plate removal caused the fracture. Of the 8 recurrent fractures, 4 were managed by plate fixation and 4 using non-operative methods. One patient experienced a fracture recurrence on the second day after plate removal, probably as a result of non-union that was not detectable on the radiographs.

3.4. Outcomes

Mean time to fracture healing was estimated at 87.5 ± 20.0 days (range, 45–120 days). Thus, all the fractures healed within a reasonable time frame.

At re-evaluation 1 to 7 years after surgery, the UCLA score indicated an excellent outcome in 164 (95.5%) patients, a good outcome in 5 (3%) patients, and a fair outcome in 3 patients.

The scar was a thin line in 92% of patients, a wider line less than 5 mm in width in 4% of patients, wider than 10 mm in 3% of patients, and keloid in 1% of patients.

4. Discussion

The results of our study confirm our working hypothesis. Internal fixation using a curved pelvic reconstruction plate fixed using 3.5-mm screws produced a 99.4% healing rate if the fracture recurrence on the second day after plate removal is classified as a non-union. The functional outcomes were no less satisfying, with 98.5% of excellent results according to the UCLA score. Our findings are consistent with the 97% to 100% healing rates reported by others [4,5,11,15,16]. However, we included only patients with Robinson 2B1 or 2B2 fractures, which are the types most at risk for non-union, whereas earlier studies included all types of displaced fractures. The greater fracture severity in our population probably explains the rate of recurrent fractures after removal of the material. Although many patients reported a high-energy trauma as the cause of the recurrent fracture, a contribution of clavicular fragility related to more or less extensive necrosis of the intermediate fragments is difficult to rule out. The need to remove reconstruction plates has been described as a drawback compared to pre-contoured locking plates [17]. In our study, the fixation material was usually removed as a pre-planned procedure, as we believe that fixation material at any site, particularly when bulky, is best removed in young patients. At the clavicle, the plate is immediately under the skin and can therefore generate unpleasant sensations even in the absence of functional interference, requiring its removal. In a recent meta-analysis, Nourian et al. [18] reported that plates were better tolerated when positioned on the antero-inferior (ventro-caudal) aspect rather than on the antero-superior aspect of the clavicle. However, we are not in favour of antero-inferior plate positioning, which causes greater disruption of the blood supply to the bony fragments. The antero-superior position, on the subcutaneous aspect of the clavicle, puts the plate in direct contact with the bone without requiring detachment of any muscles.

The appearance of the scar can be a major consideration when making treatment decisions, notably in women. However, among our patients 92% had a thin linear scar that was probably less disfiguring than a bump due to mal-union, clavicular shortening, anterior projection of the tip of the shoulder, and scapular winging.

None of our patients experienced surgical-site infection. The supra-clavicular location of the incision at a distance from the plate may have contributed to this result. In addition, our patients were young, engaged in sports, and free of comorbidities.

Intra-medullary fixation can provide interesting results when performed by experienced surgeons [19]. However, high complication rates of 16% to 50% have been reported [20–22]. The complications included pin migration, material breakage, non-union, and skin complications at the pin sites.

The strengths of our study are the large sample size and highly uniform nature of the population, with only displaced fractures having at least three fragments, surgical treatment using a single plate type, and standardised post-operative management. The main limitations of the study are the retrospective design and absence of a control group. In addition, some patients were lost to follow-up; however, they accounted for only 8.5% of the initial population, which is reasonable given the mean patient age of 34.5 years, causes of the fracture (skiing, cycling, and mountain biking accidents in 26%, 21%, and 18.5% of cases, respectively, with a quarter of the patients being tourists from other parts of the country or from abroad), and the long time since the injury in some cases. The group lost to follow-up did not exhibit any differences compared to the overall study population.

5. Conclusion

Internal fixation using a curved pelvic reconstruction plate fixed using 3.5-mm screws provides excellent anatomical and functional outcomes in patients who have displaced mid-shaft clavicular fractures with three or more fragments. The good quality of the

outcomes and short recovery time suggest that this technique may deserve to be used also in simpler fracture types.

Disclosure of interest

The authors declare that they have no competing interest.

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Contribution

D.S. wrote the manuscript.

G.C. collected the study data and re-evaluated the patients.

B.R.D. revised the manuscript for important intellectual content.

R.P. performed the literature review and established the reference list.

G.L. performed the literature review and established the reference list.

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