

Clavicular nonunion

31/32 healed after plate fixation and bone grafting

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We report the long-term results in 32 patients with established nonunion of the clavicle; 15 treated with AO Dynamic Compression Plate and autologous cancellous bone graft and 17 treated with an AO reconstruction plate and autologous cancellous bone graft. The patients were followed up for a mean of 8 (4–21) years from injury and 7 (4–12) from non-union operation, both by clinical review and radiographs.

31/32 nonunions united successfully. One fracture which initially failed to unite was replated and subsequently united. 6 compression plates and 7 reconstruction plates were removed for discomfort or cosmesis. None broke.

Both plates give equally good results, but we feel that the reconstruction plate is easier to contour to the complex form of the clavicle.

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The factors predisposing to nonunion of the clavicle include high energy trauma, degree of displacement, lateral third fractures, soft tissue interposition and refracture (Watson-Jones 1955, Frymoyer 1993). The many surgical techniques that have been used to treat clavicular nonunion have met with only moderate success, leaving three quarters of the patients with pain and one third with persistent shoulder dysfunction (Sakellarides 1961, Wilkins and Johnston 1983).

Patients and methods

We operated on 32 patients from the fracture service at the Queen's Medical Centre, Nottingham, for clavicular nonunion over a 7-year period. There were 10 men and 5 women in the group fixed with a 3.5 mm AO dynamic compression plate (D) and 13 men and 4 women in the group treated with a 3.5 mm AO reconstruction plate (R). 4 (D) and 7 (R) patients had heavy manual jobs, whilst 5 patients in each group had a sedentary occupation. The mean age was 33 (17–60) years. Most fractures were from high-velocity trauma; both groups had similar proportions of such patients and 13 patients had associated injuries (Figure 1). 25 of the fractures were in the middle third of the bone. The dominant side was injured in 20 patients (9 (D) and 11 (R)). The mean displacement of the bone ends was 10 mm (D) and 18 mm (R). Primary treatment (except for 2 patients with multiple injuries) was a sling for between 2 and 6 weeks. The diagnosis of nonunion was made at a mean of 4.8 months (D) and

4.3 months (3–18) in the group treated with reconstruction plates.

There were 10 atrophic (Figure 2) and 5 hypertrophic nonunions in the D-treated group. There were 11 atrophic and 5 hypertrophic nonunions in the reconstruction plate group and 1 true pseudarthrosis. Mean fracture displacement in patients treated with the reconstruction plate was more than twice the displacement in the D-treated group.

The operations were performed by a variety of surgeons, all experienced in AO techniques. Consultants operated on 17 patients, split equally between groups. The procedures were carried out at a mean of 12 (4–36) months from injury. The plates were contoured and sited on the anterior or the anterosuperior aspect of the clavicle. Stability was enhanced with an interfragmentary lag screw in 10 (D) and 11 (R) patients and by compression, using the plate in 9 (D) and 7 (R). Autologous cancellous bone graft was taken from the iliac crest. 1 patient in the D and 2 in the R group underwent no bone-grafting procedure. 1 patient, who had an atrophic nonunion, with a wide gap between the bone ends was immobilized in a shoulder spica for 3 months. The remaining patients simply rested in a sling and were mobilized as comfort allowed. None received physiotherapy and all had discarded the sling completely between 3 and 6 weeks after operation. After operation, the average inpatient stay was 3 days.

All patients were followed up at 18 months from operation, to assess union and then later at a mean of 6 (2–10) years from operation, to assess the long-term outcome. At 18 months all patients answered a ques-

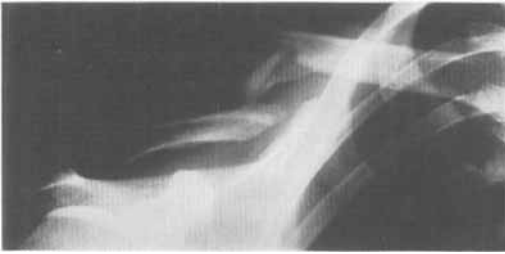


Figure 1. Fracture due to high-velocity trauma.

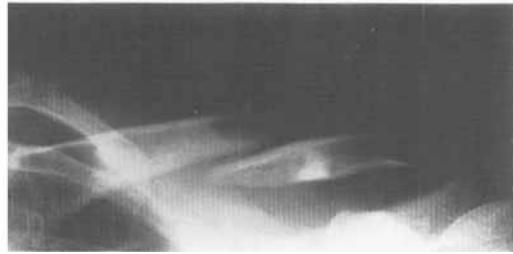


Figure 2. Atrophic nonunion.

tionnaire scoring pain on a 4-point scale. They graded the pain on a scale of 0–3: 0 no pain; 1 mild pain, never restricts activity; 2 moderate pain, restricts activity; 3 severe pain, continuous restriction. Their preoperative score was compared to the score 18 months from operation. They also answered questions relating to the scar and activities of daily living. All were clinically reviewed to assess scar problems, return to work/sport, implant prominence and range of motion. All had adequate follow-up radiographs as part of their continuing clinical management and these were used to assess union rather than expose the patients to further radiation.

Late review was also performed on 26/32 patients using the Constant Shoulder Score (Constant and Murley 1987). This is a simple, well recognized 100-point score, designed to give a reliable indication of shoulder function. It assesses pain (15), activities of daily living (20), range of motion (40) and power (25). 1 patient was given telephone interviews and a functional questionnaire based on the Constant Score, together with information from the last clinic review in the hospital notes. 5 were lost to follow-up.

Results

Early

Pain. When the diagnosis of nonunion was made, all patients had pain at the fracture site. On the 4-point scale, the average score in the 2 groups was 2.4 (D) and 2.1 (R) between moderate and severe with restriction of activity. At follow-up, 15/17 (R) and 13/15 (D) patients had no pain. 1 patient had less pain than preoperatively and 3 described no change.

Work. 13 patients (D) and (9) patients (R) were unable to work prior to operation. 4 patients (R) and 1 (D) failed to return to work postoperatively; (1 became pregnant, 2 were steel erectors and 2 had multiple injuries). The average time before returning to work was 6.4 (2–13) weeks (R) and 6.6 (1–16) weeks (D) following the surgery.

Scar. 3 patients (R) and 4 (D) had mild discomfort

from their scar, if knocked, none reported it to be a problem. One patient complained of the cosmetic result on direct questioning.

Metalwork. 6 Ds and 5 Rs were removed for aching discomfort—worse in cold weather. One reconstruction plate was removed for cosmesis. 1 patient (R) and 2 (D) have persisting mild discomfort, if using a bag with a shoulder strap, but have elected to retain their plates. No plates broke but two Ds cut out and were removed, one requiring replating.

Union. 15/17 nonunions united both clinically and radiologically when treated with a R plate, 14/15 united using a D.

One very displaced (2.3 cm), transverse, atrophic nonunion failed to unite, but became hypertrophic when treated with a reconstruction plate. This was replated, using a D 3 years after the first operation, and subsequently united. During the first operation interfragmentary compression was not used, though a bone graft was. Both compression via the plate and further bone grafts were used at revision.

1 patient treated with a reconstruction plate developed a delayed infection which necessitated debridement and therefore loss of bone graft. The plate held firm, was not removed and further bone grafting was performed 2 months later. The clavicle united.

2 Ds were removed after the screws cut out of the clavicle. One of them did not unite and was replated before subsequent union; the other went on to union.

Complications. Apart from the 3 initial nonunions, 1 patient developed a superficial stitch abscess, which settled on removal of the stitch. There were no major complications.

Late follow-up

Constant shoulder score evaluation was carried out on 16/17 (R) and 10/15 (D) patients (Table 1). The overall constant score was 87 (D) and 82 (R). Most of the deficit was either in the pain or the power categories. Both the activities of daily living and the range of motion categories were almost normal. Overall, the long-term outcome was excellent.

Table 1. Constant score after treatment of clavicular nonunion

	Pain	ADL	Range of motion	Power	Total
D	13.7	19.3	33	21	87
control	15	20	40	23	98
R	12	18	30	22	82
control	15	20	40	24	98

D nonunion treated with dynamic compression plate,
R nonunion treated with reconstruction plate,
control opposite shoulder, ADL activities of daily living

Discussion

The operative techniques employed in some of the earlier series, such as cerclage wiring and intramedullary fixation, gave disappointing outcomes and led many surgeons in the past to treat nonunions conservatively. Johnson and Collins (1966) reviewed 47 patients treated nonoperatively for nonunion over a 22-year period and described the end result as "excellent" in 23. No mention is made of the time taken for the symptoms to settle and in 21 patients the outcome was unknown.

Sakellarides (1961) studied 15 cases treated by operation. 3 had Kirschner wire and graft, 2 united; 6 had 2 screws, intramedullary Kirschner wire and graft, all united, 1 had screws and graft and united, 2 had plate and graft, 1 united, 3 patients failed to unite that were treated by graft and suture, graft and kangaroo tendon and graft alone. None of the 5 cases in his series treated nonoperatively united. In all, 18 had pain and 7 had restricted shoulder movement. Wilkins and Johnston (1983) reviewed 33 patients, of whom 20 underwent surgery. 24 of 33 patients experienced pain on movement and the symptoms appeared worse in hypertrophic nonunion. Of the 20 patients treated by a variety of operations, 5 patients underwent resection of the mid-part of the clavicle, 3 were left with pain: 1 had resection of the lateral half of the clavicle, which resulted in myositis ossificans; 4 had an intramedullary pin—2 of them broke; 3 had screw fixation and bone graft—2 failed; 4 underwent osteotomy and bone grafting without fixation—2 failed; and 3 underwent plate fixation and grafting—all united. Boehme et al. (1991) found that only 12 of 20 patients treated for clavicular nonunion by a modified intramedullary Hagie pin had function which could be described as "excellent" and 17 required pin removal after union, due to formation of a tender bursa. This fixation method would also not appear to control rotation, a fault inherent in all single-pin fixations since the clavicle rotates approximately 40 degrees when the scapula is elevated.

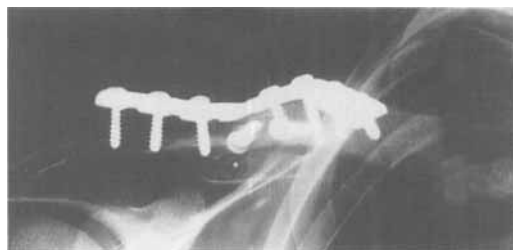


Figure 3. Reconstruction plate contoured to fit angulated nonunion.

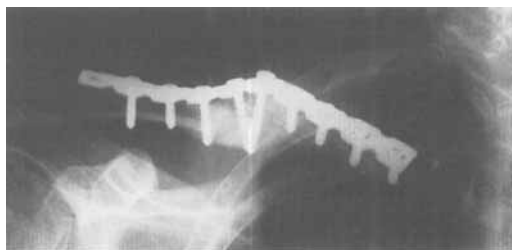


Figure 4. Reconstruction plate acting as a tension band on superior surface of clavicle.



Figure 5. Plate cutting out due to contour difficulty.

Kona et al. (1990) reported that transacromial Kirschner wires were associated with the highest incidence of complications. Neer (1960) noted that wire-loop bone sutures alone could not control angular displacement and intramedullary rods could not control rotation and distraction forces. He therefore recommended that both methods of fixation be combined with a shoulder spica.

Evardsen and Odegard (1977) used onlay bone graft, sandwiching the nonunion between a strip of cortical bone, usually from the tibia, and a 4-hole plate, and reported success in all 6 treated patients. Although apparently successful, this would seem a bulky construction requiring extensive soft-tissue dissection.

Experience with AO techniques and early mobilization has been shown to be effective in a number of small series. Karaharju et al. (1982) used semitubular plates. Although there were no reports of breakage of these plates, we have found that the 3.5 mm recon-

struction plate is easier to contour to the sigmoid shape of the clavicle and has the advantage of being stronger.

Jupiter and Leffert (1987) reported a series of 14 clavicular nonunions which successfully united following plate fixation and grafting; 11 D, 3 semitubula and 2 reconstruction plates, including a number of gunshot wounds, clavicular osteotomies, secondary procedures and patients with vascular and neurological problems. A mean fracture displacement in patients treated with the reconstruction plate was more than twice the displacement in the D-treated group lends further weight to the effectiveness of the reconstruction plate. Many of the nonunions treated with the reconstruction plate had a degree of angulation or displacement that precluded use of a D, since it would have been impossible to contour (Figure 3). Jupiter and Leffert (1987) also argued that the apex of deformity in a clavicular nonunion is directed superiorly. Therefore, a plate applied to the superior surface acts as a tension band (Figure 4). This theoretical advantage, together with the plate's ability to resist rotation, may explain the high rate of success in their and our own series. In addition, 2 D plates cut out in our series and we suspect that this happened due to the difficulty of contouring the plate. We suggest that the use of an AO plate with autologous bone-grafting is a reliable method of treating nonunited fractures or nonunions of the clavicle.

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