Open reduction and endobutton fixation of displaced fractures of the lateral end of the clavicle in younger patients

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Displaced fractures of the lateral end of the clavicle in young patients have a high incidence of nonunion and a poor functional outcome after conservative management. Operative treatment is therefore usually recommended. However, current techniques may be associated with complications which require removal of the fixation device. We have evaluated the functional and radiological outcomes using a novel technique of open reduction and internal fixation. A series of 16 patients under 60 years of age with displaced fractures of the lateral end were treated by open reduction and fixation using a twin coracoclavicular endobutton technique. They were followed up for the first year after their injury.

At one year the mean Constant score was 87.1 and the median Disabilities of the Arm, Shoulder and Hand score was 3.3. All fractures had united, except in one patient who developed an asymptomatic fibrous union. One patient had post-traumatic stiffness of the shoulder, which resolved with physiotherapy. None required re-operation.

This technique produces good functional and radiological outcomes with a low prevalence of complications and routine implant removal is not necessary.

Most fractures of the lateral end of the clavicle are minimally displaced and heal with good functional outcome when treated non-operatively.¹⁻⁵ Fractures with complete displacement are less common, but have a higher risk of subsequent nonunion.^{1,3,6-8} Most displaced fractures occur in elderly patients, many of whom have low functional demands and may have a satisfactory outcome after non-operative treatment.^{4,9,10} A minority of patients are younger, and fare less well with non-operative treatment.⁴ Persistent pain, restriction of movement and loss of strength and endurance of the shoulder may develop if the fracture fails to heal.^{1,11,12} Because reconstruction of an established nonunion may be technically challenging, operation is frequently recommended as a primary treatment.⁷

A wide variety of operative techniques have been described to treat these injuries, the most popular of which are coracoclavicular screws^{13,14} and hook plates,¹⁵⁻¹⁷ and more recently, tailor-made lateral clavicular plates. Although primary operative treatment may reduce the risk of subsequent nonunion it carries its own complications, including hardware failure and infection. In addition, many of these implants are relatively rigid and may restrict acromioclavicular movement, leading to limited movement in the shoulder. Most

authors therefore recommend routine removal of these implants once the fracture has united.^{13,18,19} Coracoclavicular loops and slings of synthetic materials, allograft and autograft are less rigid and have been used in the treatment of acromioclavicular separations.²⁰ In most instances, subsequent removal of the implant is not required. However, the use of these techniques in the treatment of displaced lateral clavicular fractures is less well defined.²¹⁻²⁵

The aim of this study was to assess prospectively the functional and radiological outcomes, and the prevalence of complications, after early operative intervention in patients under 60 years of age with acute displaced fractures of the lateral end of the clavicle. We adopted an operative protocol of open reduction and fixation using a novel twin endobutton implant to maintain reduction until union of the fracture.

Materials and Methods

Between January 2007 and June 2008 we prospectively studied a consecutive series of 16 locally resident patients with a displaced fracture of the lateral aspect of the clavicle. Only medically fit patients aged less than 60 years who were seen within three weeks of the injury were considered. The fracture had to

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be completely displaced, with no residual cortical contact, and located in the portion of the clavicle lateral to a vertical line drawn upwards from the base of the coracoid process.

During the study period, 14 patients aged over 60 were treated for displaced fractures. Their treatment was individualised according to their physiological status, with three more active patients treated operatively and 11 less active ones treated non-operatively. As the treatment of the latter was not protocol driven, they were excluded from the study. During the study period an additional 42 patients of all ages sustained an acute fracture of the lateral aspect of the clavicle which was either incompletely displaced with residual cortical contact (20 patients) or undisplaced (22 patients). They were excluded from the study. Four further patients with displaced fractures were excluded because they were referred more than three weeks after injury. One locally resident patient was treated operatively, but defaulted from any follow-up and became untraceable.

The mean age of the remaining patients was 38.3 years (15 to 56); all were male. The fractures were sustained during sport in 12 patients, following a fall at home in two and a fall from more than two metres in two. There were no open fractures and no patient had pre-operative neurovascular compromise. No patient had a concomitant fracture of the scapula or of the proximal humerus. Two patients had minor head injuries and five had ipsilateral rib fractures.

Initial treatment protocol and assessment of the anatomical features of the injuries. We obtained standardised pre-operative radiographs of anteroposterior and Velpeau views at the initial presentation. The anatomical features of the fractures were classified using the Craig modification of the Neer classification²⁶ and the Edinburgh classification systems.³ Six fractures were Craig/Neer type IIA (conoid and trapezoid intact and attached to the lateral fragment), three fractures were type IIB (conoid torn, trapezoid intact and attached to lateral fragment), and three were type V (both ligaments attached to a third inferior bony fragment). The remaining four fractures had articular involvement and were type III. A total of 12 fractures were Edinburgh type 3B1 (displaced extra-articular) and four were type 3B2 (intra-articular).

Operative technique. All operations were performed under general anaesthesia in the beach-chair position by the senior author (CMR). Standard antithrombotic and antibiotic prophylaxis was used. The procedure was performed at a mean of six days after injury (2 to 15). The mean duration of surgery was 40 minutes (30 to 75), and the mean blood loss was 80 ml (60 to 120).

The skin incision was infiltrated with 1:200 000 epinephrine solution to reduce cutaneous bleeding. A 6 cm vertical ('bra-strap') incision was made with its base centred on the coracoid process (Fig. 1a). The deltotracheus fascia was incised perpendicular to the incision and released by sharp dissection from the clavicle to expose the fracture. Using a 4.5 mm cannulated drill, bone tunnels were made in the clavicle 15 mm medial to the fracture site and centrally in the coracoid, 20 mm from its tip (Figs 1b and 1c).

The lower tunnel was created under direct vision by splitting the deltoid in the lower aspect of the wound to reduce the risk of eccentric tunnel placement. This tunnel was drilled perpendicular to the flat superomedial surface of the coracoid between 30° and 45° to the coronal plane (Fig. 1c).

The endobutton construct consists of two endobuttons (Smith and Nephew, London, United Kingdom) loaded with a #2 Orthocord (Ethicon, Edinburgh, United Kingdom) suture. The core suture is looped twice through the buttons, creating a six-ply sliding pulley effect. The lower button of the implant is passed through the clavicle and coracoid, and then toggled on the under-surface of the coracoid (Fig. 1d). The fracture is then reduced under direct vision and the suture tensioned. We confirmed accurate reduction and toggling of the lower endobutton below the coracoid fluoroscopically before tying the suture ends over the proximal endobutton (Fig. 1e). The arm was rested in a sling for four weeks after surgery. The patients then started physiotherapy which continued until a full range of shoulder movement was regained.

Outcome assessment. The chief outcome measures in this study were function, the radiological outcome and the prevalence of fracture-related complications within the first year of surgery.

The patients were evaluated at one and six weeks, and at three, six and 12 months after their injury. The Short Form-36 (SF-36) general health questionnaire,^{27,28} the upper limb-specific Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire²⁹ and the shoulder-specific Constant score³⁰ were completed with the help of a research worker (MAA) at six weeks, and at three, six and 12 months after injury. We also recorded whether the patient had returned to work or to normal daily activities. We recorded the range of movement in the shoulder and tested for weakness of the rotator cuff and superior labral dysfunction,³¹⁻³⁴ impingement lesions,³⁵⁻³⁷ and for signs of dysfunction of the acromioclavicular joint.^{34,38}

Displacement of the fracture was assessed at each follow-up, by measuring the vertical displacement of the most superior element of the diaphyseal fragment from the most superior element of the lateral fragment on anteroposterior radiographs, adjusting for magnification artefact. We considered fractures to be united if the patient had no pain or only mild activity-related discomfort in the shoulder, and there were no radiological signs of loss of reduction, implant loosening or breakage, or resorption at the fracture site.

Results

Complications. There were no early post-operative complications. No patient underwent further surgery during the period of review. A 55-year-old patient developed a fibrous union with no signs of bridging callus at the fracture site. This was confirmed using CT scanning six months after injury. There was no radiological evidence of loss of reduction or displacement of either endobutton. He had no shoulder pain or functional disability, and was unwilling to undergo further surgery.

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Fig. 1e

The key steps of the operative technique, a) a vertical shoulder strap incision is used (black arrow), with its base on the surface marking of the coracoid (white arrow). The deltotracheus fascia is incised perpendicular to the line of the incision, b) the tunnel in the clavicle is created using a 4.5 mm cannulated drill bit, c) the coracoid tunnel is created under direct vision through a split in the anterior deltoid, using the same drill bit. Note that the superior surface of the coracoid faces 30° to 45° superomedially, and the tunnel should be created perpendicular to this surface, d) the endobutton construct is 'railroaded' through the two tunnels (white arrow). The lower button is then toggled against the undersurface of the coracoid. The fracture is reduced by sequential tensioning on the two free suture ends (black arrows) and e) the suture ends are tied once the fracture is reduced both under direct vision and on fluoroscopic views.

He remains asymptomatic, two years later despite a persistent fibrous union. One 40-year-old patient had shoulder stiffness three weeks after removal of the sling, with loss of 20° of external rotation and 20° of combined abduction, but follow-

ing physiotherapy he had regained a full range of movement by three months.

Functional outcome. Some patients missed one or more follow-up appointments, but a final assessment was

Fig. 2

Graph showing the recovery of functional outcome in the first two years after injury, using the Constant and Disabilities of the Arm, Shoulder and Hand (DASH) scores. A high Constant score denoted better function, with a theoretically 'perfect' score of 100. A lower DASH score denotes better function, with a theoretically 'perfect' score of 0.

obtained at one-year for all 16. The mean DASH and Constant scores showed continued significant improvement within the first six months after injury (Wilcoxon's matched-pairs test, $p = 0.02$; $p = 0.01$ at three months, $p = 0.04$; $p = 0.02$ at six months, Fig. 2), but there was no statistically significant difference between the six-month and one-year measurements. At one year after surgery the mean Constant score was 87.1 points (95% confidence interval (CI) 83.6 to 90.6) and the median DASH score was 3.3 points (95% CI 0 to 6.7). With the numbers available, there was no significant difference ($p = 0.6$) in outcome between dominant and non-dominant injured shoulders.

At one year, 15 patients had no pain in their shoulder; one had mild pain, which was not activity related. The mean combined forward flexion at one year was 172.3° (160° to 180°) and the mean combined abduction was 173° (140° to 180°) and the mean internal rotation was 80° (60° to 100°). No patient had evidence of rotator cuff weakness or impingement, or signs of posterior glenohumeral joint instability on clinical testing at the one-year follow-up. No patients had symptoms or signs referable to the acromioclavicular joint on specific testing.

All 16 patients were in regular employment before their injury. By three months the 13 who had been employed in a sedentary job prior to the injury had all returned to their full work duties and normal daily activities. The remaining three, who were manual workers had all returned to work by six months. The mean time lost from work after the injury was 21 days (7 to 50).

Of the 12 patients who played regular sports (seven contact, five non-contact) prior to their injury, all but two had returned to playing by six months. Of the two patients who had not returned at six months, one returned by one year and the other

Fig. 3a

Fig. 3b

Pre-operative radiograph of a) a displaced fracture of the lateral end of the clavicle in a 31-year-old man who sustained his injury in a fall from a bicycle. At exploration this was confirmed to be a displaced extra-articular fracture with partial disruption of the coracoclavicular ligaments (Neer type IIB, Edinburgh type 3B1) and b) Radiograph taken one year after injury, showing maintenance of reduction and bony consolidation at the fracture site.

had downgraded to non-contact sports. The mean number of physiotherapy sessions during rehabilitation was 3.5 (0 to 35). **Radiological outcome.** The mean initial displacement of the fracture was 20 mm (18 to 25). The mean residual displacement post-operatively was 1 mm (-2 to +4). There were no failures of fixation and no loss of the reduction during the first year after surgery. Apart from the patient with a clearly demonstrable residual gap, all the remaining fractures showed clear evidence of reduction of the fracture gap and remodelling at final follow-up (Fig. 3). There was radiological evidence of mild ectopic bone formation on the under-surface of the clavicle in six patients, but complete synostosis to the coracoid did not occur. There was evidence of mild acromioclavicular joint osteoarthritis on pre-operative radiographs in three cases; none of these patients had symptoms related to this prior to their injury. There was no radiological evidence of progression of the osteoarthritis at one year.

Discussion

The results of this study suggest that open reduction and endobutton fixation for isolated displaced fractures of the lateral end of the clavicle in younger patients is associated

with a high probability of bony union and a low risk of complications. Most patients regained near-normal shoulder function and range of movement during the first six months after the injury, and had returned to their pre-injury occupation and leisure pursuits. To our knowledge, this is the first study to evaluate the results of this technique prospectively in a small but well-defined younger population, with evaluation of function one year after the injury.

A major advantage of this technique is that further surgery to remove the implant after the fracture has united is not needed. Despite retaining the implant in all our patients, only one developed minor shoulder stiffness, which resolved after a short period of physiotherapy. Most other techniques to treat these injuries, including coracoclavicular screw fixation and hook-plate devices, have been adapted from those used to treat acromioclavicular dislocation.^{19,20} These techniques provide rigid fixation, which may lead to stiffness of the shoulder if the implant is retained. Most authors therefore recommend removing it.^{13,18,19} However, early removal of the implant may increase the risk of re-displacement of the fracture if there is incomplete union, whereas prolonged retention of the implant may produce intractable shoulder stiffness.¹⁹

Displaced fractures of the lateral end of the clavicle are unstable injuries and are frequently associated with non-union, which may cause functional compromise in younger adults and middle-aged patients. These injuries may be double disruptions of the superior shoulder suspensory complex, when the fracture occurs in association with disruption of the coracoclavicular ligaments.³⁹ For this reason some authors have advocated the use of other coracoclavicular loop and sling techniques using autograft, allografts or prosthetic ligaments to reconstruct these ligaments.¹⁹ However, it is our experience that these ligaments are frequently only partially disrupted (Neer type IIB injury), or intact, with the majority of the ligament complex remaining attached either to the lateral fragment (Neer type IIA injury), or to a third inferior fragment (Neer type V injury). We therefore feel that primary ligamentous reconstruction is unnecessary in most patients. It was our intention that the endobutton construct should function as an 'internal fixation' device to maintain reduction while the fracture united, rather than as a ligamentous augmentation. The fact that secondary instability of the superior shoulder suspensory complex did not occur in our series lends support to this contention.

Newer 'custom-made' endobutton constructs are available, such as the Tightrope system (Arthrex, Sheffield, United Kingdom).^{20,40-43} No detailed clinical evaluation of these implants has so far been described in large series. Their use has been advocated in acute and chronic acromioclavicular separations, Rockwood grade III and above.^{20,40-43} However, it has been our experience that additional ligamentous augmentation is usually required in these patients, as the degree of ligamentous disruption to both the coraco- and acromioclavicular liga-

ments is greater. We therefore cannot advocate the extension of our technique to the treatment of these injuries.

Minimally invasive closed reduction and arthroscopic insertion of a similar endobutton construct has been described.⁴⁴⁻⁴⁶ However, we feel that this procedure is best performed as an open surgical exposure. It has been our experience that obtaining an accurate reduction of two-part fractures may be difficult, owing to the complex pattern of inferior displacement of the shoulder girdle, combined with retraction of the diaphyseal fragment, frequently with 'button-hole' of the deltotracheus fascia. Infolding of periosteum at the fracture site is also frequently encountered and may initially prevent accurate reduction. We have also found that intra-operative fluoroscopic views are often misleading and that an accurate reduction is easier to obtain under direct vision. In addition, the superior coracoid pillar averages only 14.2 mm (11 to 19 in 102 scapulae) in breadth and its flat superior surface is inclined 45° medially in the coronal plane.⁴⁷ Accurate placement of a bone tunnel centrally within the coracoid may be difficult using arthroscopic techniques, even when a jig is employed. Eccentric tunnel placement increases the risk of implant cut-out and failure. We therefore prefer to drill the coracoid tunnel under direct vision, to ensure central placement within the pillar. The size of the incision for the open surgical approach is scarcely larger than the combined sizes of the incisions using an arthroscopic technique and cosmetically there is little to choose between the two.

Although a prospective evaluation of outcome was performed during the first year after injury, no direct comparison with other more established techniques was made. We are therefore uncertain whether the low rates of secondary surgery and complications produce better function than other existing techniques. Although the operative technique is relatively simple, there is a learning curve, and as this study was a single-surgeon series it is unclear whether the satisfactory results would be generalisable. A number of late complications have been described which may be associated with the use of similar techniques, including re-fracture of the clavicle and stress fracture of the coracoid.¹⁹ Furthermore, generic complications, including acromioclavicular osteoarthritis, may take longer to develop. Although these complications have so far not been encountered in our patients, long-term follow-up would be required to assess the true incidence of complications.

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