International Orthopaedics (SICOT) (2003) 27:131–135
DOI 10.1007/s00264-002-0424-7

ORIGINAL ARTICLE

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Operative treatment of mid-shaft clavicular non-union

Accepted: 4 December 2002 / Published online: 28 January 2003

Abstract Between 1974 and 1999, we treated operatively 28 patients with a symptomatic mid-shaft clavicular non-union using AO osteosynthesis, including bone grafting. Nine patients had a wave-plate osteosynthesis and 19 a standard AO/ASIF osteosynthesis. The mean follow-up was 10 (2–25) years. All but one non-union showed full bony consolidation. Pre-operatively, brachialgia was present in 12 patients. Of these patients, six were treated using standard osteosynthesis technique and six by wave-plate osteosynthesis. Post-operatively, patients treated by wave-plate osteosynthesis had no brachialgia and also had a higher Constant score than those patients treated using standard AO/ASIF techniques.

Résumé Entre 1974 et 1999, nous avons opérés 28 malades avec une pseudarthrose symptomatique de la clavicule en utilisant une ostéosynthèse AO avec greffe osseuse. Neuf malades avaient une ostéosynthèse par plaque incurvée et 19 une ostéosynthèse AO/ASIF standard. Le suivi moyen était de 10 (2–25) années. Toute les pseudarthroses, sauf une, ont consolidé. Avant l'opération 12 malades présentaient des brachialgies. De ces malades, six ont été traités par ostéosynthèse standard et six par ostéosynthèse par plaque incurvée. Les malades traités par plaque incurvée n'avaient plus, après l'opération, de brachialgie et avaient un plus haut score de Constant que ceux traités par la technique AO/ASIF standard.

Introduction

Mid-shaft clavicular non-union is a rare and often disabling complication. Etiological factors that predispose to the development of a non-union include open fracture, associated poly-traumatic lesions, re-fracture, gross displacement of the fragments, insufficient initial operative treatment, and an inadequate period of immobilisation [13, 17]. The incidence of a clavicular non-union is reported to be 0.1–0.8% following conservative treatment of a clavicle fracture and 3.7–4.6% following its operative treatment [23]. Indications for operative treatment are pain, instability, limited motion of the shoulder, and brachialgia.

Several operative techniques, including intramedullary, internal, and external fixation have been described for the treatment of these non-unions. AO/ASIF techniques using plate and screws have excellent overall results [4]. However, in 30%, brachialgia presents as a serious problem [1, 7]. Brachialgia is defined as any numbness or paresthesia in the arm, with or without muscle weakness, particularly on the medial aspect of the arm. Symptoms occur predominantly in the ulnar nerve dermatome. Excessive callus and scar tissue formation is an important factor in the occurrence of this complication [14]. Other etiological factors include cervical spine and disc problems, scalenus anticus syndrome, and thoracic outlet syndrome. A previous, unpublished study of our data showed that although bony consolidation was achieved, residual brachialgia did occur.

Wave-plate osteosynthesis involves bending the plate at its mid-portion. An autogenous bone graft can be situated under the plate to share the tensile forces. Due to plate shape at the site of the non-union, the local blood supply is not disturbed. It allows ingrowth of vessels into the cancellous bone onlay graft and reduces the risk of fatigue fracture of the plate [20]. The wave-plate technique may not only reduce unsuitable callus formation, but also contribute to better bone healing and consequently lessen the risk of re-fractures following hardware removal. The wave-plate technique has been previously described for other indications [20, 24, 25]. Its use in clavicular non-unions was introduced by the senior author (RM).

This review reports on indications for, technique used in, and results of, the operative treatment of clavicular non-unions by wave-plate osteosynthesis as compared to the standard AO technique.

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Materials and methods

Between 1974 and 1999, 28 consecutive patients were operated on at our hospital for a mid-shaft clavicular non-union. In nine patients, the wave-plate technique was used and a standard AO/ASIF technique was used in 19. There were 15 women and 13 men. Average age at operative reconstruction was 35 (16–56) years. There were 20 right-sided cases. The clavicle on the dominant side was injured in 17 cases. In 15 cases, fracture was caused by traffic accidents, in eight cases by sports-related accidents, in three cases by a fall, and there were two cases of iatrogenic lesion. There was one open fracture. Initial treatment was operative in two cases and closed in 24. In two cases, the fracture initially went unrecognised and no treatment was given. In eight cases, secondary operative treatments had been performed elsewhere. The time between fracture and our operative treatment was, on average, 4 (1/3–34) years. There were ten atrophic, six oligotrophic, and 12 hypertrophic non-unions. Indications for operative treatment were pain at the non-union site in all but one patient, painful limitation of shoulder movement in 17, loss of power and instability in 11, and brachialgia in 12. Cosmetic difficulties were present in 14 patients. Nineteen patients were unable to work or play sport.

Standard AO/ASIF operative technique

The patient is positioned on the operating table in the semi-recumbent, so-called "beach-chair" position, with a folded towel under the affected shoulder. The entire extremity is prepared and draped so that the arm is freely movable. The donor site for the bone graft is also prepared and draped. A lower para-clavicular approach or a pre-existent incision is used. The pseudarthrotic tissue is freed using an osteotome; the sclerotic bone ends are freshened with a rongeur until bleeding bone is exposed. The medullary canal is opened on both sides using a power burr. In the case of a hypertrophic non-union, excessive callus tissue is first decorticated and then trimmed to suit the plate. If necessary, a cancellous bone graft is used, and, if the clavicle is shortened, an intercalary bone graft is used. A 3.5 dynamic compression plate (DCP) or, exceptionally, a 3.5-reconstruction plate, is used for fixation [27]. Plate size should allow placement of three screws on either side of the non-union.

Wave-plate osteosynthesis technique

The same operative technique is employed, but the 3.5 DCP plate is bent at its mid-portion. The plate is positioned so that its mid-portion is bent away from the clavicle. The intercalary and cancellous bone graft is placed underneath the mid-portion of the plate. One screw can be positioned through the plate into the intercalary graft.

Passive and active mobilisation exercises of the shoulder are started directly post-operatively. In 22 cases, hardware removal was performed at an average of 21 (6–48) months.

Post-operative results were documented at 4 months, 1 year, and 2 years using the facility of the AO Documentation Centre in Switzerland. Mean follow-up was 10 (2–25) years. Regular post-operative outpatient examination was done in all cases. Two patients had died by the time of the most recent follow-up. In 20 cases, Constant scores [8] were determined only at the most recent follow-up. A hand-held dynamometer was used to assess the shoulder's isometric power [3]. A visual analogue scale (VAS) score evaluation was used for rating subjective result: 0 (no pain) up to 10 (severe pain) was performed on each patient.

Table 1 Post-operative Results: Consolidation, Brachialgia and Constant score. *Age* age at follow-up; *Avg.* average age-related score; *Brachialgia (Pre/post)* presence of brachialgia pre- and post-operatively; *NA* not available

Case	Gender	Age	Side	Operative technique	Outcome non-union	Brachialgia (pre/post)	Constant score		
							Right	Left	Avg.
1	F	38	R	Standard	Healed	+/+	N.A.		
2	M	58	R	Standard	Healed	–/–	N.A.		
3	M	48	R	Wave-plate	Healed	–/–	N.A.		
4	F	28	R	Wave-plate	Healed	–/–	N.A.		
5	F	40	R	Standard	Healed	+/–	N.A.		
6	F	41	L	Standard	Healed	–/–	N.A.		
7	M	47	R	Standard	Healed	–/–	N.A.		
8	M	41	R	Wave-plate	Healed	+/–	100	100	92
9	F	41	R	Wave-plate	Healed	+/–	90	94	80
10	F	49	R	Wave-plate	Healed	+/–	93	93	80
11	F	41	R	Wave-plate	Defect	+/–	89	95	80
12	F	49	R	Standard	Healed	+/+	75	90	80
13	M	58	L	Standard	Healed	–/+	88	77	83
14	M	58	R	Standard	Healed	–/+	47	97	83
15	M	40	L	Standard	Healed	–/–	100	100	93
16	F	29	L	Wave-plate	Healed	–/–	94	86	97
17	F	31	R	Standard	Healed	+/+	74	89	90
18	F	57	L	Standard	Healed	+/–	85	84	70
19	M	45	R	Standard	Healed	–/–	51	98	92
20	F	45	R	Standard	Healed	–/–	90	90	80
21	M	55	L	Standard	Healed	+/+	97	95	83
22	F	63	R	Standard	Healed	–/+	88	86	70
23	F	54	L	Standard	Healed	–/–	90	88	70
24	F	33	L	Standard	Healed	–/–	93	78	90
25	M	61	R	Standard	Healed	–/–	N.A.		
26	M	49	R	Standard	Healed	–/+	92	95	92
27	M	51	R	Wave-plate	Healed	+/–	95	95	92
28	M	26	R	Wave-plate	Healed	+/–	100	100	98

Table 2 Post-operative results: Complications

Complication	Standard AO (n=19)	Wave-plate (n=9)
Delay in wound healing	0	2
Clavicle infection, operative drainage	1	2
Iliac crest infection, operative drainage	1	0
Bone defect, clavicle	0	1
Re-fracture	0	1
Brachialgia	4	0

Results

Union of the clavicle occurred after a mean of 4 (3–7) months in 27 patients. In one case, a bony clavicle defect persisted, although symptoms were diminished. All patients experienced an improvement in function and less pain. Brachialgia was present pre-operatively in 12 cases, of which six were treated using standard osteosynthesis technique and six by wave-plate osteosynthesis. Post-operatively. all patients treated by a wave-plate and two treated by standard osteosynthesis improved (Table 1). However, four patients treated by standard osteosynthesis techniques developed brachialgia post-operatively. In six cases, electromyography revealed symptoms of ulnar nerve dysfunction. Of eight patients with post-operative brachialgia, four were treated operatively with resection of the first rib. Four patients were able to cope with their symptoms and refused further treatment.

Two patients operated on with wave-plate technique had a slight delay in wound healing. Wound infection necessitating operative irrigation and drainage occurred in three cases (Table 2); one had a persistent non-union. In one case, a re-fracture occurred after healing of the non-union and hardware removal, preceded by an adequate trauma. Healing was achieved within 3 months of re-osteosynthesis.

Constant score

The overall Constant score was 85 on the affected side compared to 93 on the opposite side (Table 1). Comparing patients treated with wave-plate osteosynthesis and those treated with standard osteosynthesis resulted in an overall score of 93 (96 unaffected side) versus 80 (92 unaffected side). A low Constant score (less than the age-corrected Constant score) was determined in seven patients. In four patients, the low score was caused by brachialgia. The overall VAS score was 1.4 (range 0–5). VAS scores of 3–5 were all due to symptoms of brachialgia.

Radiographs of the clavicles were not all comparable. It is our impression that there is less sub-clavicular callus formation in the wave-plate treatment group. The radiological length of the affected clavicle compared to the unaffected clavicle was determined in 15 cases. The difference was less than 10 mm.

Case report

A forty-nine-year-old male patient sustained a clavicular fracture after a fall from his bicycle. He was treated with a sling. Clavicular non-union developed (Fig. 1). He had neurologically confirmed symptoms of brachialgia, as well as pain and loss of shoulder movement. One year later, wave-plate osteosynthesis was performed (Fig. 2). Two years post-operatively, all symptoms were resolved. The length of the clavicle had been restored and sound bone healing achieved with no excessive callus formation (Fig. 3).

Fig. 1 Radiograph of the clavicle with a mid-shaft non-union showing a bony spike near the brachial plexus

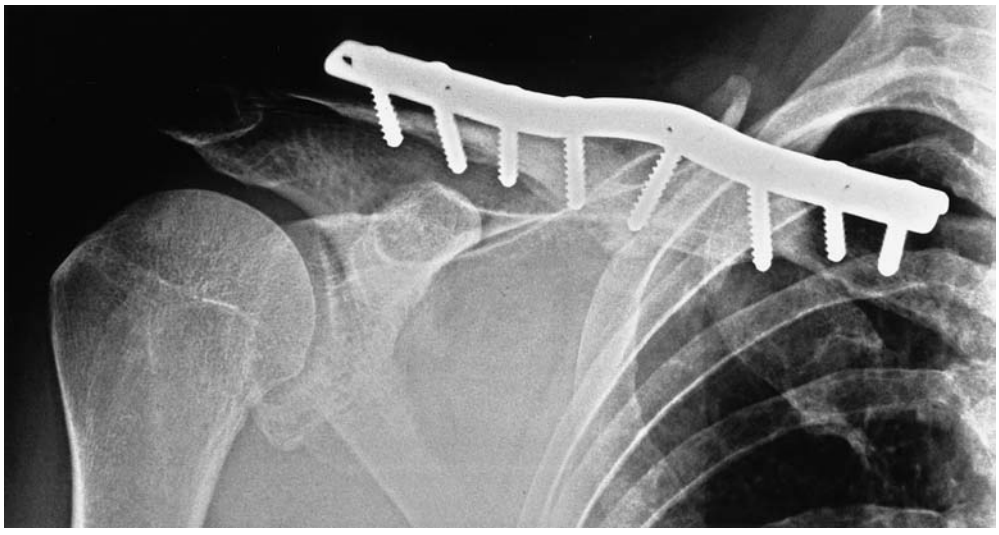

Fig. 2 Radiograph of the clavicle after wave-plate osteosynthesis. The length of the clavicle is restored. There is no abundant callus

Fig. 3 Radiograph of the clavicle after plate removal. The clavicle is healed with a nearly normal configuration

Discussion

In mid-shaft clavicular non-unions treated with AO plate osteosynthesis and bone grafting, excellent results have been reported, with bony consolidation in 89–100% [1, 4, 9, 10,11, 13, 16, 17, 19, 21]. In our series, 27/28 non-unions healed following this technique. All operations were performed by three senior orthopaedic surgeons familiar with the operative technique. The typical deformity, with the lateral fragment depressed and pulled posteriorly and the medial fragment elevated, was counteracted by a cranial plate functioning as a tension band [27]. An antero-inferior placement of the plate has shown good results in small series [11]. A more extensive devascularisation of the clavicle is to be expected however . Short, semi-tubular plates should not be used because of the high risk of failure [22]. The LC-DC plate [19] offers some advantages by causing minimal damage to the underlying bone and gives good stability due to its rigidity.

External fixation constitutes a solution in infected cases. It can produce satisfying results in open fractures and non-infected non-union [26], although wound problems can be expected. The AO plate used as an external fixator [18] provides good stability, and bone healing can be achieved even in infected non-union cases. Intramedullary nailing has been reported to give good results in small series [5, 12]. We have no experience of this technique. In a retrospective study, Wu [28] compared intramedullary nailing and plate osteosynthesis in the treatment of aseptic clavicular non-union. Intramedullary nailing had a slightly lower complication rate and was not considered inferior to plate osteosynthesis.

Some authors mention that brachial plexus lesions [1, 7], subclavian vein compression [15], or even a thoracic outlet syndrome [2], may accompany clavicular non-union. The conditions are associated with hypertrophic mid-shaft clavicular non-unions. Most often, the lower trunk of the brachial plexus is affected, thereby causing ulnar nerve symptoms [14]. These symptoms do not always disappear after operative treatment. In most clinical reports on treatment of clavicular non-union, the problem of brachialgia is underestimated [7]. In our series, pre-operative brachialgia was a serious problem in 12/28 cases. In four cases, brachialgia developed post-

operatively. It was to prevent this complication that wave-plate osteosynthesis was introduced. In nine cases treated by this method, brachialgia either did not develop or did not persist post-operatively.

Wave-plate osteosynthesis has several advantages. Firstly, a form of 'biological plating' is established [24, 25]. It preserves the residual blood supply to the bone and soft tissues. Secondly, a mechanically stronger construction is achieved [25]. Thirdly, bone healing is enhanced beneath the mid-portion of the plate, where controlled callus formation is needed.

In complex un-united femoral shaft fractures, the wave-plate osteosynthesis technique has achieved very good results [24]. In cases of atrophic humeral non-union, wave-plate osteosynthesis in combination with cancellous bone grafting was followed by union in 14/15 patients [25]. Initially, the only disadvantage of wave-plate osteosynthesis in clavicular non-unions was wound healing problems.

Shortening of the clavicle following fracture can cause shoulder girdle dysfunction [6]. In some cases, a corrective osteotomy of a malunited clavicle fracture is necessary to achieve a better shoulder function [6]. In our series, clavicular length was approximately restored after treatment.

Although consolidation of the non-union, decrease in pain, and improvement of shoulder movement are considered the most important factors in patient outcome, the Constant score is considered to be the gold standard in evaluating shoulder girdle problems [16, 21] and is able to discriminate between slight and serious impairment of shoulder function. In this study, the Constant score was determined in 20 cases. Patients treated by wave-plate osteosynthesis had markedly higher scores than patients treated by standard osteosynthesis.

It is our opinion that this study clearly demonstrates the overall excellent results of wave-plate osteosynthesis in the treatment of clavicular non-union. Following wave plate osteosynthesis all established cases of brachialgia improved and new cases did not occur.

Acknowledgements We would like to thank A.B. Stibbe, M.D., orthopaedic surgeon, for his work on the treatment of clavicular non-union, and also the AO Documentation Centre.

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