Fixation of mid-third clavicular fractures with Knowles pins

78 patients followed for 2–7 years

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ABSTRACT – From January 1993 to December 1997, we treated 78 (75 fresh, 1 delayed union and 2 nonunion) fractures of the mid-third clavicle with open reduction and internal fixation using 3.8 mm Knowles pins. All patients used an arm sling for 2–6 weeks after surgery, and were told to avoid vigorous exercise or work with heavy loads for the next 6 weeks. 73 fractures healed within 6 months. 3 complications occurred relating to the surgical procedures. The final rate of bone union was 77/78, although 3 patients showed a delay in bone union and 1 fracture was revised because of a loosened Knowles pin.

After a mean follow-up of 49 (24–86) months, the average shoulder function, as evaluated by a modified Constant-Murley score, was 97% versus the contralateral shoulder. We suggest that if surgery is indicated, open reduction and internal fixation using a Knowles pin is an effective method for managing mid-third clavicular fractures.

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Internal fixation of fractures of the clavicle is usually not recommended because of the risk of nonunion, infection, pin migration and plate fracture. Neer (1960) and Rowe (1968) reported a nonunion rate of 4–5% after open reduction. The indications for open reduction and internal fixation of midshaft clavicular fractures in the literature are: a) a persistent wide separation of bone fragments with interposition of soft tissue; b) impending or manifest open fracture; c) patients with multiple injuries or coma; d) symptomatic bone nonunion; e) neurovascular involvement; and f) initial shortening at the fractured bone exceeding 20 mm (Neviaser et al. 1975, Khan and Lucas 1978, Zenni et al. 1981, Manske and Szabo 1985, Wang et al. 1990, Bradbury et al. 1996, Davids et al. 1996, Hill et al. 1997, Enneking et al. 1999).

We analyzed our results with osteosynthesis of clavicular fractures using Knowles pins.

Patients and methods

From January 1993 to December 1997, we treated 96 patients and 97 mid-third clavicular fractures with open reduction and internal fixation. 10 patients were lost to follow-up, and 8 were subjected to a plate fixation. This study concerned the remaining 78 patients (48 men) who were treated with internal fixation using a Knowles pin (Table 1). The mechanisms of injury included 40 falls on shoulder, 7 direct blows on the shoulder, 8 falls onto an outstretched hand and 23 miscellaneous accidents. In 75 patients, the time between injury and surgery was within 10 days. 3 patients were treated 3, 6, and 8 months after injury due to symptomatic delayed healing or non-union.

The indications for surgery included 46 persistent separations of the fracture with a gap more than half the diameter of the clavicle, 14 had impending open fractures after failure of repeated closed reduction, 11 multiple injuries, 1 painful delayed union, 2 painful nonunions, 1 open fracture, 1 open fracture with a subclavian artery laceration and 2 patients with brachial plexus injuries.

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Table 1. 78 patients treated with open reduction and internal fixation using a Knowles pin

A	B	C	D	E	F	G	H	I	J	K	L	M
1	M	15	L	77	15	20	40	22	97	97	N	Y
2	M	35	R	75	15	20	36	20	91	95	N	Y
3	F	16	R	86	15	20	40	17	92	92	N	Y
4	M	18	L	79	15	20	40	23	98	98	N	Y
5	M	16	R	86	15	20	40	22	97	97	N	Y
6	M	34	L	78	15	20	40	20	95	95	N	Y
7	M	23	L	76	15	20	40	25	100	100	N	Y
8	F	20	R	70	15	20	34	17	86	92	N	Y
9	M	21	R	71	15	20	40	22	97	97	Y	Y
10	F	56	L	64	15	20	40	15	90	90	Y	Y
11	F	22	L	69	15	20	40	17	92	92	Y	Y
12	F	20	L	67	15	20	40	18	93	93	N	Y
13	F	19	L	73	15	20	40	15	90	90	N	Y
14	F	40	R	73	15	20	40	15	90	90	N	Y
15	F	23	R	67	15	20	40	20	95	95	N	Y
16	M	18	L	64	15	20	40	20	95	95	N	Y
17	F	30	R	54	15	20	40	17	92	92	N	Y
18	F	22	R	63	15	20	40	15	90	90	N	Y
19	M	67	L	53	15	20	36	15	86	95	Y	Y
20	F	46	R	55	15	20	40	17	92	92	N	Y
21	M	62	L	54	15	20	36	15	86	90	N	Y
22	F	50	R	61	15	20	40	15	90	90	N	Y
23	M	28	R	53	15	20	40	22	97	97	Y	Y
24	F	42	L	54	15	20	40	18	93	93	N	Y
25	M	75	R	60	10	20	20	5	55	90	N	N
26	F	19	L	63	15	20	40	18	93	93	N	Y
27	M	52	L	60	15	20	40	20	95	95	N	Y
28	M	46	R	60	15	20	40	20	95	95	N	Y
29	M	68	R	59	15	20	40	15	90	90	Y	Y
30	F	22	L	59	15	20	40	17	92	92	N	Y
31	M	15	L	52	15	20	40	22	97	97	N	Y
32	M	41	L	62	15	20	40	22	97	97	N	Y
33	M	39	L	47	15	20	40	23	98	98	N	Y
34	M	54	L	51	15	20	40	22	97	97	N	Y
35	M	28	L	49	15	20	40	22	97	97	N	Y
36	M	22	L	51	15	20	40	22	97	97	Y	Y
37	F	49	L	40	15	20	40	18	93	93	N	Y
38	M	43	L	46	15	20	40	22	97	97	N	Y
39	M	19	L	40	15	20	40	25	100	100	N	Y
40	F	32	R	47	15	20	40	17	92	92	N	Y
41	F	21	R	48	15	20	40	18	93	93	N	Y
42	F	37	R	48	15	20	40	15	90	90	N	Y
43	F	37	L	43	15	20	40	15	90	90	Y	Y
44	M	21	R	48	15	20	40	23	98	98	N	Y
45	M	22	R	46	15	20	40	22	97	97	N	Y
46	F	47	R	43	15	20	40	18	93	93	N	Y
47	M	21	R	42	15	20	40	25	100	100	Y	Y
48	M	39	L	51	15	20	40	20	95	95	N	Y
49	M	47	L	49	15	20	40	20	95	95	N	Y
50	F	31	L	44	15	20	40	15	90	90	Y	Y
51	M	47	L	45	15	20	40	20	95	95	Y	Y
52	M	44	R	51	15	20	40	20	95	95	N	Y
53	M	38	R	43	15	20	40	22	97	97	N	Y
54	M	30	L	47	15	20	40	22	97	97	N	Y
55	M	26	R	47	15	20	40	23	98	98	Y	Y
56	M	43	L	42	15	20	40	20	95	95	N	Y
57	M	18	L	24	15	20	40	22	97	97	N	Y
58	M	47	L	27	15	20	40	20	95	95	N	Y
59	M	42	R	27	15	20	40	22	97	97	N	Y
60	F	26	R	29	15	20	40	18	93	93	N	Y
61	F	45	R	27	10	18	34	12	74	90	Y	Y
62	M	27	L	31	15	20	40	22	97	97	N	Y
63	M	23	R	31	15	20	40	23	98	98	N	Y
64	M	24	R	28	15	20	40	25	100	100	Y	Y
65	M	20	L	25	15	2	0	0	17	97	N	Y
66	F	68	L	29	15	16	40	12	83	90	Y	Y
67	M	20	R	28	15	20	40	22	97	97	N	Y
68	M	29	R	30	15	20	40	20	95	95	N	Y
69	M	23	L	32	15	20	40	22	97	97	Y	Y
70	M	45	L	31	15	20	34	23	92	98	N	Y
71	M	32	L	33	15	20	40	20	95	95	N	Y
72	F	57	R	33	15	20	40	12	87	90	N	Y
73	F	23	R	36	15	18	40	15	88	90	N	Y
74	F	61	L	25	15	20	40	15	90	90	Y	Y
75	M	44	L	19	15	20	38	20	93	95	N	Y
76	F	50	L	31	10	18	22	15	65	90	Y	Y
77	M	47	L	25	15	20	40	22	97	97	N	Y
78	F	59	L	24	15	16	32	10	73	90	Y	Y

A Case
B Sex
C Age at operation
D Side of involvement
E Follow-up, months
F Pain at follow-up
G ADL (Activity of daily life) at follow-up
H ROM (Range of motion) at follow-up
I Power at follow-up
J Modified Constant score at follow-up
K Contralateral modified Constant score
L Bone graft (yes/no)
M Bone union (yes/no)

We performed the open reduction and internal fixation with a Knowles pin through a horizontal incision over the anterosuperior aspect of the clavicle. After removal of blood clots, the intramedullary canal was predrilled, reduced, and temporarily fixed with a 3 mm Steinmann pin. The pin length was measured using another pin of the same size and length. The temporary joining pin was removed, and replaced with an appropriate 3.8 mm Knowles pin inserted from the posterolateral to the anteromedial side through the tract of the previously inserted Steinmann pin (Figure 1). Autogenous bone grafts from the iliac crest were placed around the fracture sites of 16 fractures, in which the comminutions exceeded one-third the circumference of the clavicle and of 3 fractures with delayed or nonunion. Decortication was performed on 2 fractures with nounion. All patients received

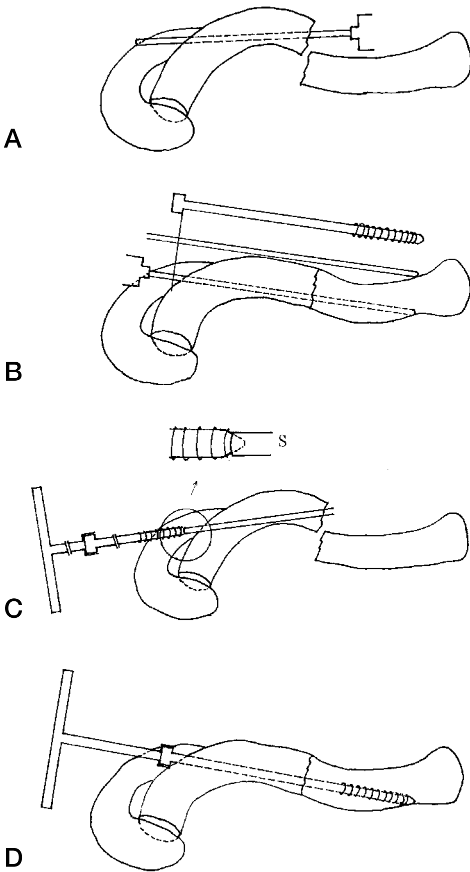


Figure 1. **Surgical technique.**
A. The medullary canal of the distal fractured fragment was predrilled with a 3 mm Steinmann pin.
B. The fracture was temporarily reduced and fixed by a Steinmann pin, and a 3.8 mm Knowles pin of appropriate length was chosen by comparing it with another Steinmann pin of the same size and length.
C. The Knowles pin was inserted through the posterolateral side to the anteromedial side of the clavicle, using a 3 mm suction tip (S) as guide.
D. The fracture was fixed with a Knowles pin.

postoperative arm sling protection for 2–6 weeks after surgery, and were told to avoid vigorous exercise or work with heavy loads using the involved extremities during the following 6 weeks.

After mean 49 (24–86) months, a questionnaire was given to all patients who had undergone physical and radiographic examinations. We used traction weights in one pound increments to measure the isometric strength of the shoulder at 90 degrees to the torso in both combined abduction and forward elevation for the Constant-Murley (1987) shoulder score. This muscle-strength measurement differs from the original method, but it is practical. We called it a modified Constant-Murley score and used it to evaluate the function of both shoulders.

We used ANOVA with correlated measures adjusted for sex, age at operation, and side of involvement for the statistical analysis.

Results

73/78 fractures healed radiographically within 6 months after surgery. 1 patient (case 14) experienced a painful delayed bone union and underwent a second operation with an autogenous bone marrow injection graft at 5 months after operation, and the fracture healed after 3 months. 1 asymptomatic delayed bone union healed 9 months after surgery without any additional operations. Another asymptomatic bone union (case 75) finally healed 15 months after surgery.

1 patient had a hypertrophic bone nonunion verified at follow-up 5 years after surgery. The functional score for this shoulder was 55, and the patient refused further surgery. Thus, the final bone union rate was 77/78.

The mean modified Constant score at follow-up was 92 (17–100), and the mean score for the contralateral shoulder was 94 (90–100) ($p = 0.7$) (Table 2), which was not significantly different.

We had 3 complications related to the surgical procedure. In 2 patients, the threaded tip of the Knowles pin protruded through the anteromedial clavicular cortex and its tip irritated the skin. In one

Table 2. Patients' modified Constant scores after treatment of mid–shaft clavicular fractures

	Pain	ADL	ROM	Power	Total
Fracture	15 (10–15)	20 (2–20)	39 (0–40)	19 (0–25)	92 (17–100)
Contralateral shoulder	15 (15–15)	20 (20–20)	40 (40–40)	19 (15–25)	94 (90–100)

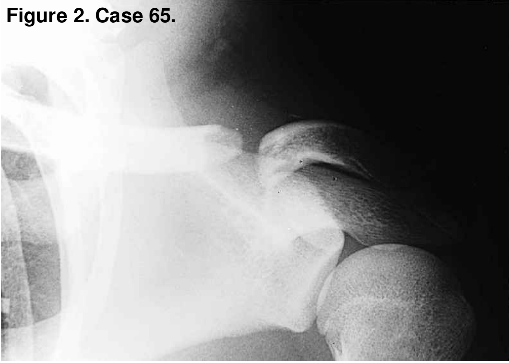
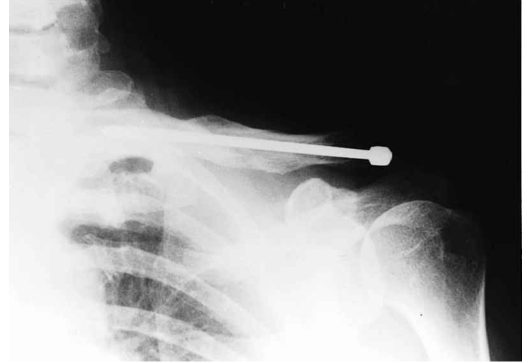


Figure 2. Case 65.

A 20-year-old man sustained a left-sided clavicular fracture with an ipsilateral brachial plexus injury.



The fracture was treated with open reduction and internal fixation with a Knowles pin. Solid bony union was noted 6 months after surgery.

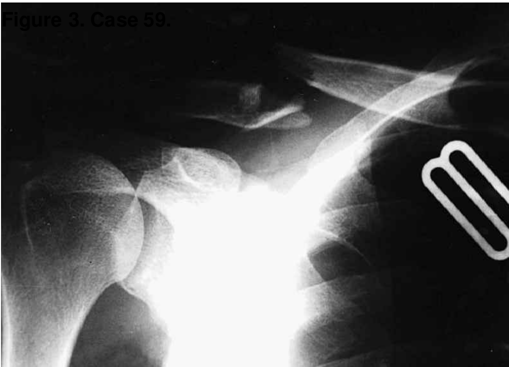
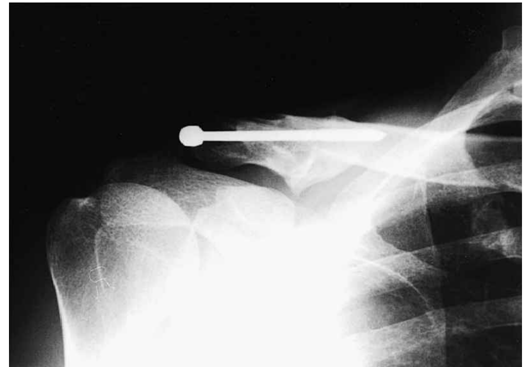


Figure 3. Case 59.

A 42-year-old man sustained a right-sided clavicular fracture and persistent wide separation of fracture was noted after conservative treatment.



The fracture was treated with open reduction and internal fixation with a Knowles pin. Solid bone union occurred 6 months postoperatively.

of these patients, we performed a second operation to cut off the protruding part of the pin. The other patient (case 70) underwent revision and a shorter Knowles pin was inserted. In the third patient (case 29), the Knowles pin failed to fix securely, and a longer pin was used in revision 2 months after the primary operation. The fractures all healed without complications.

Before surgery, 1 patient (case 65) had motor dysfunction of the shoulder (Figure 2) and 1 patient had sensory dysfunction of the forearm and hand due to injuries of the brachial plexus. At follow-up the functional shoulder scores of both these patients were 17 and 92, respectively. 1 patient (case 71) had bilateral clavicular fractures associated with multiple injuries including right-sided tibial open fracture and left-sided 1st rib fracture with traumatic pneumothorax, one side was fixed with a Knowles pin, and the other side was treated with plate fixation. The functional shoulder scores were both 95 at follow-up.

All but 3 fractures were operated on for a fresh fracture. 1 patient (case 78) had had a mid-third clavicular fracture on the left-side treated by a figure-of-eight harness. After 3 months, the patient had a painful impending delayed union and bone resorption, and we performed an open reduction with internal fixation using a Knowles pin and autogenous bone graft. Bone union occurred 9 months after surgery. The modified Constant shoulder score was 73 for the injured shoulder and 90 for the contralateral one. 2 patients (cases 19 and 50) had a symptomatic left-sided mid-third clavicular atrophic nonunion after injury. The time intervals from injury to surgery were 8 and 6 months. Open reduction with internal fixation using a Knowles pin together with decortication and autogenous bone graft were performed in both patients. Suc-

cessful bone union occurred 6 months after surgery in both. At follow-up their functional shoulder scores were 86 and 90, respectively. 1 patient (case 59) had a persistent wide separation of the fracture after closed treatment with a figure-of-eight harness (Figure 3). Open reduction and internal fixation with a Knowles pin was subsequently performed. Successful bone union was noted 6 months after surgery. His modified Constant shoulder scores were 97 in both shoulders.

Discussion

Most authors recommend nonsurgical treatment for clavicular fractures (Neer 1960, Rowe 1968, Eskola et al. 1986, Andersen et al. 1987, Stanley and Norris 1988). Pins and wires (Ngarmukos et al. 1998, Enneking et al. 1999) may migrate (Lyons and Rockwood 1990, Liu et al. 1993, Leppilahti and Jalovaara 1999) and plate fixation has caused several complications, including infection, plate breakage, nonunion and refracture after plate removal (Böstman et al. 1997).

Fixation with a Knowles pin produces interfragmentary compression. The hub of the pin, which, typically, nestles behind the posterior cortex of the clavicle, can barely be felt through the skin, and prevents medial migration of the pin. Lateral migration of the pin can be prevented by firm fixation of the threaded portion of the Knowles pin in the anteromedial cortex of the clavicle. Neviaser et al. (1975), Zenni et al. (1981) and Wang et al. (1990) have reported good results with Knowles pin fixation similar to our findings, but in small numbers of patients.

Neviaser et al. (1975) treated 7 fresh mid-shaft clavicular fractures and 4 nonunions with a Knowles pin; all of them healed successfully. In our series, the rate of bone union 6 months after surgery was 73/78 and 77/78 after more than 2 years of follow-up, including autogenous bone marrow injection in 1 patient and additional surgery for postoperative complications in 3.

The butterfly fragments in comminuted fractures are always large enough to permit augmentation by cerclage wires or sutures in addition to Knowles pin fixation. We preserve the remaining soft tissue attachment to the butterfly fragments and add an autogenous bone graft (small amount of cancellous bone) around the fracture site if the comminution exceeds one-third circumference of the clavicle to reduce the chances of non-union. In our series, 16 comminution cases, 1 delayed union, and 2 nonunion cases received an autogenous bone graft.

In our view, the severity of the comminution in our fractures was greater than in some other reports (Neer 1960, Rowe 1968), which increases the rate of nonunion (Hill et al. 1997, Robison 1998). Insertion of the Knowles pin is atraumatic and does not increase soft tissue injury.

Enneking et al. (1999) used Rush pin fixation together with an autogenous bone graft to treat clavicular nonunions with a good result in 13 of 14. However, Rush pin fixation does not cause interfragmentary compression and may permit backward migration. Bradbury et al. (1996) treated 32 clavicular nonunions with plate fixation and an autogenous bone graft and had good results in 31. Our previous experience of plate fixation (Wang et al. 1990) was associated with many complications and we abandoned this technique. In the present study, 3 delayed unions or non-unions healed with satisfactory results.

We had no complications with pin migration or metal failure when using the Knowles pin. The surgical scar after Knowles pin fixation is smaller than that after plate fixation. After removal of a Knowles pin, there are no screw-holes which weaken the clavicle. The simple removal of the Knowles pin under local anesthesia is a further advantage.

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