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Midshaft fractures of the clavicle with a shortening of more than 2 cm predispose to nonunion

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Abstract Up to 15% of all fractures involve the clavicle. Nonunion of the clavicle is a rare complication after conservative treatment. It mainly presents as pain at the fracture site and a limited range of motion of the shoulder. The purpose of this study is to define a certain type of fracture of the clavicle that is predisposed to malunion and therefore should be treated surgically after failure of conservative treatment. Thirty-nine patients with delayed or malunion of the clavicle were analyzed. There were 13 women and 26 men. The average age of the male patients was 36.4 years (range 20–59 years) and of the female patients, 43.6 years (range 18–55 years). The mean follow-up period was 2.3 years (range 6 months to 4.2 years). All of them were treated surgically. There were 33 Allman I fractures and 6 Allman II fractures. Of the Allman I fractures, 30 (91%) were shortened by at least 2 cm. Allman I fractures were treated using a reconstruction plate or a dynamic compression plate in combination with bone grafting. The time of operation after fracture ranged from 6 weeks to 8.5 years (average 9.8 months). Pain at the fracture site was the leading symptom in all patients. At 6 months after the operation, 38 patients were free of pain with an unlimited range of motion of the shoulder. One patient (2.6%) complained of a slight weakness on the operated site. One fracture failed to unite (2.6%) and had to be replated. There were no refractures, infections, vessel or nerve lesions. To conclude, in Allman I fractures with a shortening of more than 2 cm, we recommend operative treatment in symptomatic patients if there are no signs of callus formation after 6 weeks.

Keywords Nonunion · Clavicle · Osteosynthesis

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Introduction

Fractures of the clavicle are common traumatic lesions and occur in 4%–15% of all fractures [1, 2]. Surgical treatment is seldom necessary, and there are good clinical and radiological results in more than 90% after conservative treatment with a figure-of-eight-bandage [3, 4, 5]. Delayed or nonunion is found in only 1%–2% of the patients [6]. Although uncommon, it can result in pain and restriction of function [7]. While the indications for primary surgery are widely accepetd, there is confusion in the literature about the secondary osteosynthesis of fractures of the clavicle [1, 3]. It is not clear what the appropriate point of time is at which conservative treatment should be stopped in favour of surgical treatment.

In this report, we review the cases of 39 patients with a delayed or non-union of the clavicle after conservative treatment. The goal of this study is to define a certain type of fracture that possibly predisposes to delayed or malunion and as a result should be operated on after failure of conservative treatment.

Patients and methods

From January 1, 1993 to December 31, 1998, 60 patients with a fracture of the clavicle were treated surgically at the surgical unit of the Berufsgenossenschaftliche Kliniken Bergmannsheil in Bochum, Germany. Of these patients, 39 (65%) were operated on after failure of conservative treatment due to delayed or nonunion. Twenty-nine of them (74.3%) were referred to our hospital by family doctors and/or other hospitals for further treatment.

In 25 of the patients (64.1%), we used a LCDC plate for internal fixation, and in 8 patients (20.5%) a reconstruction plate. Autogenous bone grafting or an autogenous iliac crest bone was used in 29 patients (74.3%). In 3 cases (7.7%) the lateral clavicle was resected, in 2 cases (5.1%) we used a wire loop, and in 1 case (2.5%), a dislocated part of the lateral clavicle was refixed.

Thirteen of the patients were women (33.3%), and 26 were men (66.7%). The average age of the male patients was 36.4 years (range 20–59 years) and of the female patients 43.6 years (range 18–55 years) (Fig. 1). The mean follow-up period was 2.2 years (ranging from 6 months to 4.2 years). The intervals for clinical and radiological follow-up examinations were 4 weeks, 3, 6, 12 and

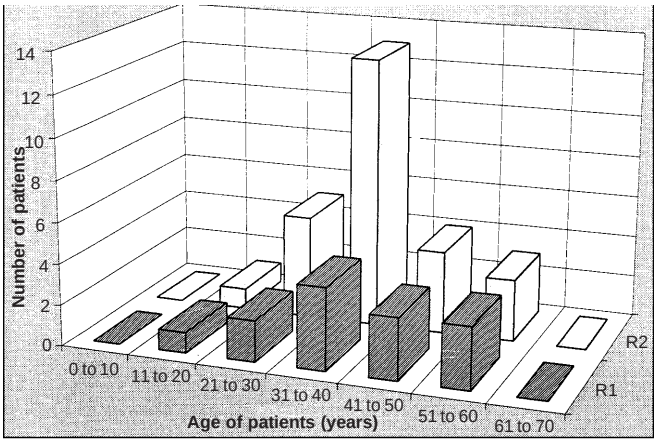

Fig. 1 Age and sex distribution of patients with a delayed or nonunion of the clavicle (R_1 = female, R_2 = male)

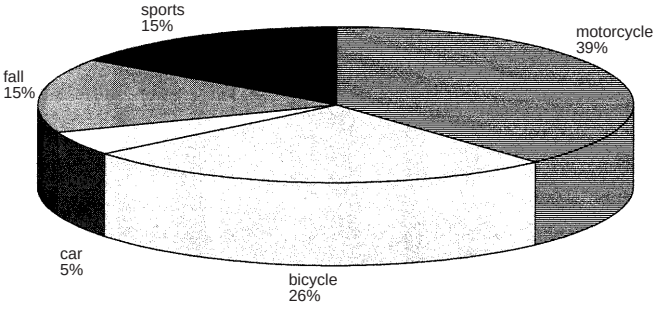

Fig. 2 Primary trauma of 39 patients with a delayed or nonunion of the fracture

24 months after the operation. The time to operation after fracture ranged from 6 weeks to 6.5 years, with a mean of 9.8 months. In 24 patients (61.5%), the right clavicle was injured and in 15 (38.5%), the left. In all patients direct trauma was the cause of the injury (Fig. 2).

After the initial trauma, 33 patients (84.6%) were treated conservatively with a figure-of-eight-bandage for a period of at least 4 weeks. Six multiple trauma patients were treated without a figure-of-eight-bandage.

Results

According to the Allman classification, fractures of the clavicle were divided into three groups [8]: group I, fractures of the middle third of the clavicle; group II, fractures of the lateral third; group III, fractures of the medial third. There were 6 (15.4%) Allman II fractures and 33 Allman type I fractures (84.6%). Thirty of the Allman I fractures (91%) were shortened by at least 2 cm. We did not find any Allman III fractures. Atrophic nonunion was noted in 64.1% (25 patients), 35.9% (14 patients) had a hypertrophic nonunion.

The patient's preoperative situation was graded using parts of the Hospital for Special Surgery Score from Altchek et al. as well as the scores from Imatani and Deluga [9, 10, 11] (Table 1). These scores are regulary used for impingement syndrome of the shoulder or lesions of the acromioclavicular joint. Since there is no special score to compare the results before and after operation for fracture of the clavicle, we modified these scores to check our indications for operation and the success of our treatment.

Pain at the site of malunion was the leading symptom in all patients. Thirty-eight patients (97.4%) had moderate to severe pain during sports, 37 (94.9%) while sleeping on the affected side, and all patients during non-sport overhead reaching. One patient (2.6%) noticed a moderate limited range of motion (ROM), whereas 32 patients (82%) did not have any limitation in ROM. Four patients (10.2%) felt a weakening of the affected shoulder that was severe enough to alter work or sport related activities significantly.

At 6 months after the operation, all patients were free of pain at rest (Table 2). The subjective muscle strength test performed during abduction and adduction revealed one residual weakness at the site of operation (2.6%). With the exception of 1 patient,all enjoyed full ROM. At the time of the follow-up examination, all patients had returned to work. No patient had to change his job due to problems with the clavicle. In 37 patients (95%), sleep was no longer interrupted by lying on the side with the fracture.

One patient (2.6%) whose fracture had failed to unite had to be replated. No patient had a refracture of the clavicle after surgical treatment or metal removal. Metal was removed 1 year after operation. Furthermore, no vessel lesions, nerve lesions or cases of infection occurred. None of the patients had an unsatisfactory cosmetic result.In all, 95% of patients were satisfied with the operation, and 97.4% reported a significant improvement in comparison with the preoperative status.

Table 1 Preoperative condition of 39 patients with a delayed or nonunion of the clavicle

	None	Slight	Moderate	Severe
Pain				
During sports	Ø	1	25	13
Non-sports overhead reaching	Ø	Ø	10	29
Activities of daily living	Ø	3	20	16
Sitting at rest	26	13	Ø	Ø
Sleeping	Ø	2	12	25
Impairment of ROM[a]	32	6	1	Ø
Weakness (in comparison to uninjured side)	Ø	10	25	4

[a] No impairment, free range of motion (ROM) in all planes; slight, restriction of less than 20°; moderate, loss of 20°–60°; severe, loss of more than 60°

Table 2 Follow-up examination 6 months after operation (n = 39)

	None	Slight	Moderate	Severe
Pain				
During sports	35	3	1	Ø
Non-sports overhead reaching	36	3	Ø	Ø
Activities of daily living	34	4	1	Ø
Sitting at rest	39	Ø	Ø	Ø
Sleeping	37	2	Ø	Ø
ROM	38	1	Ø	Ø
Weakness (in comparison to uninjured side)	38	1	Ø	Ø

Discussion

Up to 15% of all fractures involve the clavicle [12, 13]. The gold standard is conservative treatment using a figure-of-eight-bandage for a period of 4 weeks [3, 14]. The indication for primary surgery without conservative treatment includes open fractures, a disturbed integrity of the overlying skin, neurovascular injury, and Neer type II fractures [4, 14, 15]. Factors predisposed to nonunion include open fractures, refractures, associated multiple injuries, significant displacement, and inadequate immobilization [6, 16, 17, 18].

Stanley et al. found out that most of the fractures of the clavicle are a result of a direct trauma, which our results support, as all of our patients suffered a direct trauma [14]. As seen in Fig. 1, 70% of the fractures were related to traffic accidents, 31% to motorcycle accidents. These data are confirmed by Pannicke, who reported an overall increase in the incidence of clavicle fractures which he concluded to be related to increasing traffic intensity [13]. It seems, however, that regional differences exist as Nordqvist and Petersson from Sweden published a retrospective study showing that the majority of 2035 fractures of the clavicle were caused by a fall [19].

Regarding the incidence of fractures of the clavicle, we agree with other authors that in most cases, men sustain the trauma [19]. The mean age of women (43.6 years) was higher than the mean age of men (36.4 years). While the group between 21 and 40 years was made up mostly of men, the distribution was almost equal for patients in the 4th decade (see Fig. 2).

As already described, in most of the studies fractures of the clavicle are sorted according to the Allman classification [8]. According to several authors, 50%–82% of clavicle fractures belong to Allman group I, 10%–18% to group II, and 2%–10% to Group III [1, 19]. Additionally, fractures of the lateral third are classified according to Neer [20]: Type I describes fractures lateral of the coracoclavicular ligament, type II fractures at the site of insertion of the coracoclavicular ligament, and type III intraarticular fractures in the acromioclavicular joint. Nonunion of the clavicle has been reported in up to 30% group II fractures and in 0.1–2.7 group I and III fractures [5, 21, 22, 23]. As a result, delayed or nonunion of the middle of the clavicle is uncommon [6, 19, 20]. Up to now little attention has been paid to what kind of fractures predispose to malunion. Since most of the delayed or nonunions in our study involved the midshaft of the clavicle, we focussed our attention on this specific area. Wilkins and Johnston differentiated the atrophic from the hypertrophic pattern of nonunion [6]. They found patients with an atrophic nonunion had fewer symptoms than those with a hypertrophic nonunion. It was thought that the absence of callus in an atrophic nonunion may diminish the grating and crepitation that could be responsible for the pain. We do not support these results. In our study, there were 12 hypertrophic and 27 atrophic nonunions. All of these patients complained of pain around the fracture site, independent of the kind of nonunion or severity of the initial trauma. The reason that our results differ could be due to the delay, as nonunion occurred before the surgical procedure was performed: The time to operation after the fracture ranged from 6 weeks to 6.5 years, with a mean of 9.8 months in our study in comparison with an average of 5.6 years in Wilkins' study. As a result of our findings, one should differentiate between atrophic and hypertrophic malunions in the preoperative planning: In patients with an atrophic malunion, we performed plate osteosynthesis and autologous bone grafting, while in patients with a hypertrophic malunion, the clavicle was fixed only with plate osteosynthesis. The only exception is to reconstitute the length of the clavicle with a bone graft in a hytertrophic non-union, as already described by Seiler and Jupiter [24]. The bone graft was always taken from the iliac crest. Several groups used the technique of bone grafting without differentiating between atrophic and hypertrophic malunion and also noted good to excellent clinical results: Davids et al. operated on 9 patients with an atrophic and 5 patients with a hypertrophic nonunion using a reconstruction plate in combination with bone grafting [26]. Although Ebraheim et al. conclude that bone grafting should be considered in all cases [7], we think that it is not necessary to produce an additional trauma which could result in additional complications by using a bone graft from the iliac crest. We found out that in operations performed 6 weeks after the trauma, it was possible to reconstruct the length of the clavicle simply by fixation with a plate without using an iliac bone crest. Therefore, the indication for an autologous bone graft or iliac bone crest should be examined case by case.

With this regime, only one fracture failed to unite. Shortening of the clavicle exceeding 17 mm can result in

Fig. 3 a, b Allman fracture type I with a shortening of 2 cm

Fig. 4 There are no signs of callus formation 6 weeks after conservative treatment

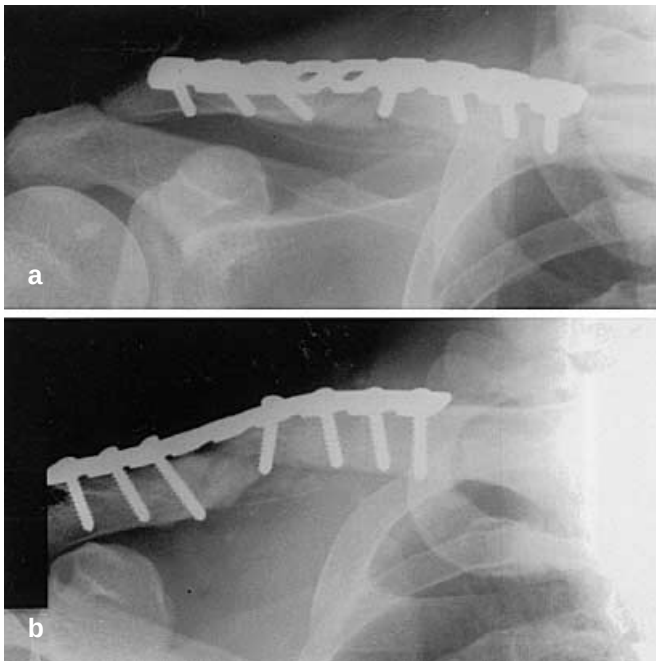

Fig. 5 a, b Surgical treatment with bone grafting and a reconstruction plate

Fig. 6 Fracture healed 3 months after operation

abduction weakness. Eskola et al. explained this by a restriction of the scapula in an adducted position by the shortened clavicle [25]. Thirty of our patients with an Allman type I fracture had a shortening of more than 20 mm, and in 4 of these patients there was a severe weakness in abduction.

Several techniques of internal fixation have been described in the past [2,5, 7, 15, 16, 27, 28]. These include screws, onlay bone grafting, intramedullary stabilization with pins, wire loops, or plates. In 25 of our patients with midshaft fractures, we used a LCDC plate and in 8 patients, a reconstruction plate. We found no difference in operation time, complications, or functional outcome between these two implants. Whenever there was a need for excessive plate contouring, we used a reconstruction plate. We do not have experience with the use of intramedullary pins, but we are not convinced of the rotational stability of these implants, despite encouraging results presented by Boehme et al., with a healing rate of 95% [29].

At 6 moths after the operation, 38 patients had regained a full range of motion. There was 1 patient with a slight weakness in abduction although the clavicular length was completely restored. Only 1 patient had mild pain, while all of the other patients were asymptomatic. As a re-

sult, 94.9% of the patients were satisfied with the operation results. Comparing the pre- and postoperative status, it is apparent that pain and not a limited range of motion is the primary reason that patients agree to an operation. Ebraheim et al. reported 16 patients with clavicular nonunion, for whom persistent pain and not a limited ROM was also the indication for surgery [7].

Currently, there is no common consensus about the appropriate time for an operation when there are signs of a delayed or malunion. Herbsthofer et al. recommend waiting at least 4–5 months, because in follow-up examinations he found a consolidation of the fracture after this period [1]. We think that this regime should be adapted to the specific clinical situation of each patient: In symptomatic patients with a Allman I fracture and a shortening of the clavicle of more than 2 cm, we recommend performing osteosynthesis if there are no signs of callus formation after 6 weeks. This type of fracture predominated in 77% of our patients who were not satisfied with the clinical outcome after conservative treatment. A typical case is shown in Figs. 3, 4, 5, 6. This is an Allman I fracture with a shortening of 2 cm. The distal fragment is pulled distally and medially due to the influence of the weight of the upper extremity and the pectoralis major muscle, while the proximal fragment is elevated due to the force of the sternocleidomastoid muscle. After 6 weeks of conservative treatment, we did not find any signs of fracture healing. Because the 28-year-old man complained of severe pain at the fracture site which significantly limited his daily activities, we decided to operate. Preoperatively, there was just a slight limitation in the ROM. For the first 4 days after operation, he was placed in a Gilchrist bandage. Isometric muscle training was applied from the first postoperative day. The patient received pain-adapted physical therapy with a limitation of 90° abduction for 4 weeks. After this period, we allowed full, pain-adapted physical therapy. After 3 months, the patient was free of pain with an unlimited ROM of the shoulder. There are no signs of delayed union on the X-ray.

The results of our study do not argue against conservative treatment of clavicle fractures. The gold standard is treatment with a figure-of-eight-bandage for a period of 4 weeks. In most cases, this therapy is sufficient to promote healing of the fracture without impairing the ROM of the shoulder. However, in Allman I fractures with a shortening of more than 2 cm, one should inform the patient of the possibility of nonunion. If there are no signs of callus formation after 6 weeks and the patient complains of pain and/or limited ROM, osteosynthesis should be performed. Concerning the implant, we did not find any significant differences between a LCDC plate and a reconstruction plate.

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