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ORIGINAL PAPER

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Osteosynthesis of distal radial fractures with a volar locking screw plate system

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Abstract We developed a locking screw plate system for the stabilisation of distal radial fractures, which can be inserted through a standard volar approach and in which the locking mechanism allows early post-operative mobilisation. Forty-nine patients with 50 fractures underwent surgical treatment; 66% were type C fractures. The mean follow-up was 26 months. According to the scores of Gartland and Werley and Green and O'Brien, 92% and 68% respectively had an excellent or good outcome; 46% were radiologically identical to the uninjured side and in 42% the reduction remained unchanged after 2 years. The most frequent complication was rupture of the flexor pollicis longus tendon, which occurred in six cases (12%) at a mean of 10 months after operation.

Résumé Nous avons développé un système verrouillable de plaque vissée pour la stabilisation des fractures radiales distales pouvant être inséré à travers une approche palmaire standard et dont le blocage autorise la mobilisation postopératoire précoce. Quarante neuf malades avec 50 fractures ont été opérés; 66% avaient une fracture de type C. Le suivi moyen était 26 mois. D'après les scores de Gartland et Werley et de Green et O'Brien, 92% et 68% avaient, respectivement, un excellent ou bon résultat; 46% étaient radiologiquement identique au côté indemne et dans 42% des cas la réduction est restée inchangée après deux années. La complication la plus fréquente était rupture du tendon long fléchisseur du pouce qui s'est produit dans six cas (12%) à une moyenne de 10 mois après l'opération.

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Introduction

The therapeutic dilemma of distal extension fractures of the radius is that, in most cases, reduction is easy to achieve but difficult to maintain by closed means. Tscherne [36] showed that between 20% and 30% heal with an unsatisfactory anatomical and functional result, and others have reported a high incidence of malunion, radial shortening, and articular incongruity with a poor functional outcome [3, 4, 8, 21, 23, 24, 29, 33, 35, 38]. Surgical methods, which include arthroscopy, plate osteosynthesis with bone graft, and external fixation, are technically demanding, may require long periods of post-operative immobilisation and also have high complication rates.

At the Department of Trauma Surgery, Neunkirchen General Hospital, a locking screw plate system was developed in 1997 for the treatment of these fractures and subsequently has been used routinely. The aim of this system is to achieve satisfactory osteosynthesis through a standard volar approach and allow early functional post-operative mobilisation.

Patients and methods

The locking screw plate was developed in association with Mathys (Mathys® Österreich Medizintechnik GesmbH, A-5020 Salzburg, Austria). The principal of the locking mechanism is the same as that with the Synthes cervical spine locking plate, which was designed by Morscher et al. (Fig. 1).

Between April 1997 and September 1999, 70 patients with 71 extension fractures of the distal aspect of the radius were treated surgically with this plate, and 49 patients with 50 fractures were available for follow-up at a mean of 26 (24–30) months post-operatively.

The distribution of the fractures according to the AO classification system is shown in Fig. 2. There were 40 women and nine men, and 34 fractures of the left radius and 16 of the right. Mean age at the time of injury was 62 (32–89) years. Mean age of the women was 65.5 years and of the men 46.5 years. The operation was performed at a mean of 5 (0–7) days after the injury. Indications for operative treatment included radial shortening of ≥5 mm, as this is a predictive factor for further shortening when treated

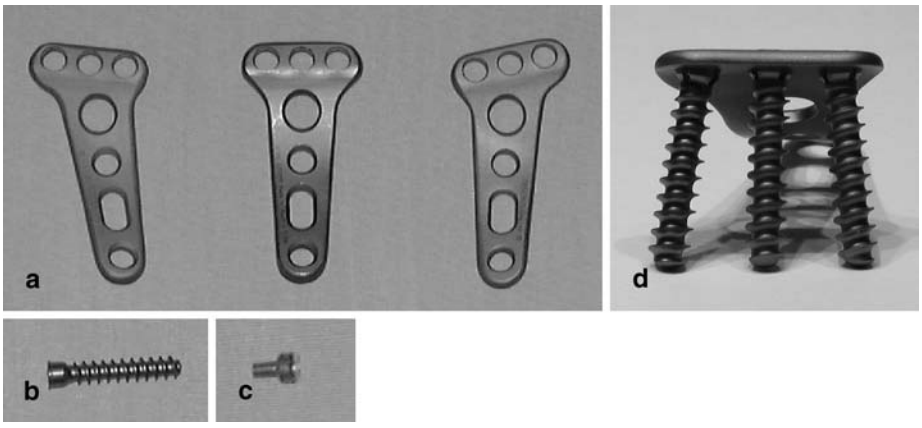

Fig. 1 The locking screw plate system for osteosynthesis of distal radial extension fractures. **a** Plates are available as left, right and straight. **b** The 4 mm cancellous screws with cross-split heads are positioned in the T-bar of the plate. **c** Angular stability is achieved by insertion of the small screws, which spread the cross-split heads, locking them to the plate. **d** The radial screw diverges 10° and the ulnar screw 5°. Proximal screws are common 3,5 mm AO non-locking cortical screws

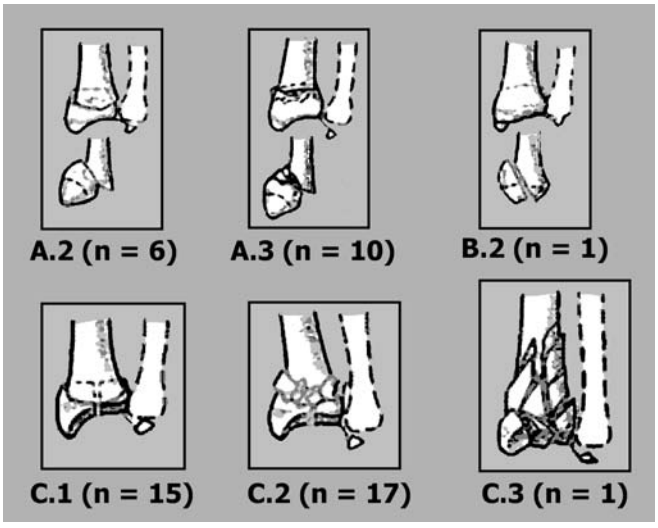

Fig. 2 Fracture distribution according to the AO classification system

conservatively [13]. Further indications included age, activity and the requirements of the individual patient.

At the 2-year follow-up we recorded the range of movement of the wrist and forearm rotation, circumference of the wrist, finger mobility, and grip strength when compared to the uninjured side. Subjective parameters such as the frequency, nature and intensity of pain or paraesthesia, the cosmetic aspects of the skin incision and the ability to cope with activities of daily life were also assessed.

AP and lateral radiographic findings at follow-up were compared with the pre-operative findings and with the uninjured wrist. The radiographic parameters measured were the palmar slope of the radius, the radial inclination, the radial length (radio-ulnar index), articular incongruity, radial displacement of the distal fragment, the presence of scapho-lunate disassociation, and degenerative changes as classified by Knirk and Jupiter [26].

Two functional scoring systems were used: a modified system of Green and O'Brien [9, 17] and the modified demerit system of Gartland and Werley [14, 34]. Statistical analysis was performed with the Mann-Whitney *U*-test and the chi-square test. The significance limit was $P<0.05$.

Surgical technique

The operation is performed under general or brachial plexus anaesthesia. The standard volar approach over the flexor carpi radialis tendon extending distally to the transverse skin crease of the wrist is used. The median nerve is not exposed unless it is clinically compressed pre-operatively. Deep blunt surgical dissection allows exposure and sharp dissection of the pronator quadratus muscle. The volar aspect of the distal radius and the fracture are identified. After preliminary reduction with ligamentotaxis, the distal locking screws are inserted under radiographic control (Fig. 3a). In order to maintain the intra-operative reduction, it is important that the distal screws are placed as close as possible to the joint line. The proximal end of the plate can then be used to reduce the fracture and restore radial length, radial inclination and radial displacement. After placing the proximal screws, the anatomical palmar slope of the radius corresponds to the contour of the plate (Fig. 3b). It is important to have a radiograph of the uninjured side in order to achieve an anatomical reduction, as length and inclination of the radius may be quite variable [30].

Type C fractures are immobilised with a forearm plaster cast for 2 weeks, whereas types A and B fractures are treated functionally without immobilisation. Type C fractures in patients with osteoporosis, or type C3 fractures with pronounced articular involvement and small fragments, are immobilised for 4 weeks (n=4/50). Routinely, the plates are not removed initially.

Results

Twenty patients with 21 fractures were pain free with a full range of movement of the forearm, wrist and fingers, and wrist function, which was identical to the contra-lateral side. These patients were rated "excellent" (Table 1). Eighteen patients reported pain after strenuous manual labour or weather-dependent pain, had a slightly reduced limitation of movement (25% less than the contra-lateral side), or occasional paraesthesia in the region of the scar, or a combination. None experienced limitation of activities of daily life. These patients were rated "good". Four patients had pain after moderately heavy work or limited movement (33% less than the contra-lateral side), or both. These patients were rated "moderate". Seven patients had pain during activities of daily life in forearm, wrist and finger movement, which was at least 50% less that on the contra-lateral side. They also had significant loss of grip strength. Four had rupture of the flexor polli-

Fig. 3 **a** After a preliminary reduction the distal, locking screws are inserted first, which usually makes the plate stand away from the shaft. **b** Using the proximal end of the plate for manipulation can then further reduce the fracture. After fixation of the plate to the radial shaft, the palmar slope is restored due to the shape of the plate. **c** Four months post-operatively the plate was removed; the fracture has healed anatomically

Table 1 Clinical results in relation to fracture type

Excellent (*n*=21)		Moderate (*n*=4)	
A2	*n*=3	A3	*n*=1
A3	*n*=4	C2	*n*=3
C1	*n*=8		
C2	*n*=6		
Good	*n*=18	Poor	*n*=7
A2	*n*=2	A2	*n*=1
A3	*n*=4	A3	*n*=1
C1	*n*=6	B2	*n*=1
C2	*n*=5	C1	*n*=1
C3	*n*=1	C2	*n*=3

cis longus tendon and one had rupture of the extensor pollicis longus tendon. These patients were rated "poor".

Functional outcome according to the score of Gartland and Werley was excellent in 26, good in 20, moderate in three and poor in one. According to the score of Green and O'Brien, the outcome was excellent in 23, good in 11, moderate in 12 and poor in four.

Fifteen fractures healed with an anatomical reduction and were radiologically identical to the uninjured side. In six, anatomical reduction was not achieved at the time of operation with regard to radial length and palmar slope. The position, however, remained unchanged, and thus in 21 fractures the position at follow-up had not changed from that which was achieved at operation.

Eight fractures were "over-corrected" at operation, with radial length 2–3 mm longer than the contra-lateral side. In these patients at follow-up, the radial length was the same as the contra-lateral side due to loss of correction.

In 21 fractures the appearances were not the same as on the post-operative radiographs with regard to radial length and palmar slope. There was some loss of correction of radial shortening with a positive radio-ulnar index, or loss of the radial inclination achieved intra-operatively, or palmar slope, or a combination. Seventeen of these 21 fractures had a maximum loss of correction of 3 mm in the AP view (radial length), or 10° of palmar slope, or radial inclination, or a combination. In all cases, the loss of AP reduction corresponded to the distance between the distal screws and the articular cortex. Compared to fractures in which the screws were placed correctly (as close a possible to the articular margin) and which remained unchanged, this loss of correction with regard to screw position was statistically significant ($P<0.05$). In the remaining four fractures, there was a loss of correction of more than 4 mm due to loss of an-

Table 2 Complications in 49 patients with 50 fractures

Complications	16/50 (32%)
Rupt. tend. flex. poll. long	5 (repair 4×)
Rupt. tend. flex. poll. long and tend. flex. prof. die II.	1
Algodystrophy	3
Adhesion of flexor tendons	1 (tenolysis)
Rupt. tend. ext. poll. long	1
Late carpal tunnel syndrome	1 (nerve release)
Early post-operative infection	1 (revision, plate removal)
Late (4 months) infection	1 (revision, plate removal)
Post-op. screw displacement	1
Loss of angular stability	1

gular stability, with implant failure in two and due to advanced osteoporosis with extensive comminution in two, in which the fractures "sank through" between the screws after correct inter-operative reduction.

Loss of correction occurred in seven out of 16 type A fractures and in 21 out of 33 type C fractures, but there was no statistically significant correlation between loss of correction and severity of fracture.

There were 16 complications in 13 patients (Table 2). The most common was rupture of the flexor pollicis longus tendon, which occurred in six patients at a mean of 10 (3–24) months post-operatively.

Discussion

Most complications of distal radial fracture treatment are the consequence of required immobilisation of the wrist for between 4 and 6 weeks with either a plaster cast or an external fixator [10, 31]. This also applies to operative methods either by volar plating with non-locking screws [11, 12, 16], combined volar and dorsal plating [2, 12] or arthroscopically assisted techniques [10]. Dorsal plating alone has a high complication rate of up to 30%, and plate removal is required due to irritation of the extensor tendons [5, 18, 22, 25, 32].

Volar plating with a locking screw plate system, however, has the advantage of an easy surgical approach, and removal of the plate is not essential [22, 37]. Types A and B fractures can be treated without post-operative immobilisation, and most type C fractures require immobilisation for two weeks only. In order to achieve reproducibly good results, some aspects of the surgical technique are very important. The distal locking screws have to be placed as close to the articular surface as possible. These screws act as a rake, maintaining reduction. To assess the correct positioning of the distal screws, it is necessary to take an inclined lateral radiograph intra-operatively (Fig. 4). There is a tendency to place the distal screws too proximally, which may lead to loss of correction even in type A fractures without articular complication (Fig. 4).We found that the functional outcome was not related to the severity of the fracture (Table 1). Even complicated type C fractures had a good outcome. The correlation between radiological outcome and clinical results indicates that a post-operative loss of reduction (up to 3 mm of radial length or palmar slope of 10° or both) does not affect the outcome. This has been reported previously [7, 22, 27, 38].

Fig. 4 **a** The distal screws are placed too far away from the articular cortex. **b** Seven months post-operatively, loss of reduction with positive ulnar variance and radial shortening of about 3 mm

However, not all fractures can be treated with the locked angle plate. The plate is too short for many type C3 fractures and some C2 fractures with articular comminution, and small fragments with significant associated osteoporosis cannot be treated using the plate alone but require additional bone grafting to maintain reduction.

Rupture of the flexor pollicis longus tendon was a common complication in this series. This occasionally has been reported, usually as isolated cases [1, 6, 15, 19, 20, 28]. We think that these tendon ruptures have a multifactorial pathogenesis. Firstly, the locking mechanism of the screws is not optimal. The cross-split screw heads have sharp edges; in three patients they were not completely flush with the plate and caused abrasion of the tendon. This complication also has been described by Heim and Pfeiffer [19]. Bell et al. [1] and Lugger and Pechlaner [28] described ruptures of the flexor pollicis longus tendon due to irritation of a plate positioned too

distally. This could have been a factor in our cases. Since January 2000, we have routinely removed the plate 4 months post-operatively and have not seen any further tendon ruptures. Last, the ridged coating of the plate may lead to abrasion of the tendon. Lastly, the trauma itself and intra-operative manipulation of the fracture may be a factor. One patient developed, probably due to intra-operative manipulation, marked adhesion of all flexor tendons, requiring adhesiolysis. Inter-operatively it was noted that the plate had no contact with the tendons in any position of the wrist. Castaing [6] has reported rupture of the flexor pollicis tendon after conservative treatment, suggesting initial damage due to the fracture. Rupture of the flexor pollicis longus tendon has a marked negative effect on the functional outcome. Four out of seven patients who had a "poor" outcome had a tendon rupture, with subsequent loss of grip strength and limited range of movement even after tendon repair. Since January 2001, we have used a modified plate with rounder screw heads and a smooth polished surface, which means that the requirement for plate removal needs further evaluation. Uzdil et al. [37] had no tendon ruptures with a volar locking screw plate system and do not recommend implant removal; however, their follow-up was shorter.

We conclude that distal radial extension fractures may be treated using a volar locking screw plate system, which allows early functional mobilisation with good reproducible radiographic and clinical results. Further investigation is required to show whether the plate must be removed to prevent rupture of the flexor pollicis longus tendon.

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