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TRAUMA SURGERY

Volar fixed-angle plate osteosynthesis of unstable distal radius fractures: 12 months results

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Abstract
Background With an incidence of about 2–4 per 1,000 residents per year, the distal radial fracture is the most common fracture in the human skeleton. The introduction of fixed-angle plate systems for extension fractures at the radius was evaluated in a prospective study performed at our hospital after selection and acquisition of a new system. The focus of our interest was whether a secondary loss of reduction can be avoided by this plating system.
Methods We reviewed 80 patients treated for unstable distal radius fractures using a volar fixed-angle plate. Postoperative management included immediate finger motion, early functional use of the hand, a wrist splint used for 4 weeks and physiotherapy. Standard radiographic and clinical fracture parameters after 12 months (range 12–14 months) were measured and final functional results where assessed.
Results Bone healing had occurred in all patients at the time of follow-up after 1 year. On X-rays taken at the time of follow-up 60 patients (75%) had no radial shortening, 20 patients (25%) had a mean radial shortening of only 1.8 mm (range 1–3 mm) compared to the contralateral side. The radial tilt was on average 22° (range 14°–36°); the volar tilt was on average 6° (range 0°–18°). Comparing the first postoperative X-rays with those taken at final evaluation showed no measureable loss of reduction in the volar or radial tilt. Castaing's score, which includes the radiographic results, yielded a perfect outcome in 30 cases, a good outcome in 49 cases and an adequate outcome in one case. The range of motion was on average reduced by 21% during extension/flexion, by 11% during radial/ulnardeviation and by 7% in pronation and supination compared to the contralateral side. Grip strength was 65% that of the contralateral side. The mean DASH score was 25 points.
Conclusion Fixed-angle plate osteosynthesis at the distal radius signifies a significant improvement in the treatment of distal radial fractures in terms of restoration of the shape and function of the wrist. The technically simple palmar access, with a low rate of complications, allows exact anatomical reduction of the fracture. The multidirectional fixed-angle system we used provides solid support for the joint surface even in osteoporotic bone and allows simple subchondral placement of screws with sustained retention of the outcome of reduction. Secondary correction loss can be avoided by this procedure. Early mobilisation can be achieved and is recommended.

Keywords Radius fracture · Fixed-angle plate osteosynthesis

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Introduction

With an incidence of about 2–4 per 1,000 residents per year, the distal radial fracture is the most common fracture in the human skeleton [1–3]. Due to demographic changes in industrialized countries, signifying a growing population of the aged and a markedly increased life expectancy, the incidence of this fracture is expected to increase by a further 50% until the year 2030 [4].

Whereas 20 years ago it was primarily elderly patients around the age of 60 who were affected by distal fractures

of the radius, over the last 20 years a second peak of incidence has emerged among those aged from 20 to 40 [5–7]. The cause is usually the application of substantial force in the course of an industrial or sporting accident, high speed accidents, such as when inline skating [3, 8], or falls from a substantial height [9–11].

The treatment of distal radial fractures has been the domain of conservative therapy for several decades. In the meantime these injuries are treated in accordance with general principles for the treatment of fractures in joints or close to joints. The goals of treatment are restoration of anatomical axial conditions, joint stability, and congruency of the joint surfaces [12–15].

The introduction of fixed-angle plate systems for extension fractures at the radius was evaluated in a prospective study performed at our hospital after selection and acquisition of a new system. The focus of our interest was whether a secondary loss of reduction can be avoided by this plating system.

Fig. 1 Aptus-fixed-angle, multidirectional plate system from Medartis

Patients and methods

At our hospital, 211 dorsal dislocated distal radial fractures were diagnosed between 1 April 2005 and 30 September 2005. During our 6 month prospective study period, 85 patients were treated with a palmar, fixed-angle plate.

The APTUS plate (Medartis AG, Austrasse 24, CH-4051 Basel/Switzerland) we used is a stepless, multidirectional fixed-angle system made of titanium. It offers the possibility to introduce the screws into the plate at a freely selectable angle of ±15° in all directions. The angle of the screw is selected as deemed appropriate by the surgeon and is not pre-given by the implant.

Achieving internal fixation which allows exercise in complex, unstable fractures of the radius requires unstable zones to be bridged using the functional principle of the external/internal fixator. It is therefore essential that the screws introduced to the distal fragments are securely locked in the plate. In the Aptus system, the screws are locked in the plate using a 3-point wedge locking system, which results in a friction-locked connection due to radial tensioning of the screw head in the plate. The height of the profile of the anatomically pre-shaped plate is 1.6 mm and the diameter of the screws is 2.5 mm (Figs. 1, 2).

The inclusion criteria in our study protocol were: age between 16 and 100, no relevant previous damage to the affected side, a dorsal dislocated distal radius fracture (Colles) with a dorsal comminuted fracture zone in combination with a dorsal tilting of more than 10° and radial shortening of more than 3 mm on the initial X-ray. All other patients were treated conservatively with casts.

After carrying out clinical examination and radiological clarification (and CT examination in the case of intra-articular

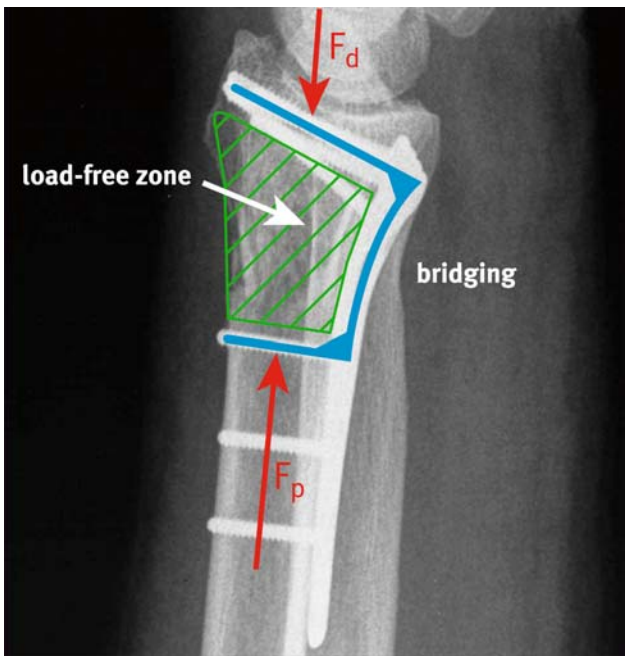

Fig. 2 Bridging produces a load-free area to give added stability to the fracture zone

fractures), where fixed-angle palmar plate internal fixation is indicated the operation in this series is within 12 h after the accident performed. The procedure is usually performed in regional anesthesia with a tourniquet applied to the proximal arm.

All patients receive a single dose of parenteral antibiotics, e.g. a second generation cephalosporin.

At the beginning of the operation two 1.6-mm thick drill wires are bent forward in the manner of a golf club. One is inserted in the ulnar aspect and one in the radial aspect within the fracture gap. Thus, reduction is performed under the guidance of an image intensifier and, simultaneously, the surgeon achieves temporary stabilization of the outcome of reduction.

The palmar access is created along the radial side of the Flexor carpi radialis (FCR) tendon. After splitting the forearm fascia, the FCR tendon, the median nerve and the flexor tendons are held aside towards the ulna and the pronator quadratus muscle is exposed and incised longitudinally.

The plate is fixed in the gliding hole at the bone and its correct position is checked under the guidance of an image intensifier. For intra-articular fractures one usually requires at least three subchondral fixed-angle screws in the distal aspect in order to reliably prevent the joint surface from sinking down in proximal direction. By angling the screws proximally, the multidirectional plate used in our clinic allows secure extra-articular insertion and central support of the joint surfaces in the distal row.

Dorsal subchondral support is ensured by distal inclination of the screws in the second row.

After closure of the Musculus pronator quadratus with absorbable interrupted sutures and placement of a wound drainage, a continuous skin suture is made and a swab with an adhesive dressing is applied. The dressing is reinforced in the wrist with two tongue depressors of wood placed in the dorsal aspect and two placed in the palmar aspect.

Our concept of follow-up treatment is usually functional. From the first postoperative day on, the fingers are actively mobilized every day. The purpose is to achieve complete fist closure and complete extension of the fingers. After removal of the drain on the first or second postoperative day, a removable synthetic thermoplastic forearm splint, including the wrist is placed (Fig. 3). The splint is prepared individually for the patient by the team of therapists specializing in hand and upper extremity.

Only in exceptional cases, when the intraarticular fractures are very unstable and accompanying ligament injuries, the wrist is immobilized postoperatively in a circular plaster cast.

Fig. 3 Thermoplastic forearm splint

The synthetic splint is prescribed for a total period of 4 weeks. After the patient is discharged from the hospital he/she is referred to the hand group at the physiotherapy department of the hospital and visits the department twice every week. During physiotherapy the thermoplastic splint is removed. Control X-rays are obtained 1 week postoperatively and after removal of the splint.

Of 85 patients treated, 80 could be followed up after a mean period of 12 months (range 12–14 months). Five patients were not contactable because they had moved out of the area. The patients' mean age at the time of surgery was 58.4 years (range 23–88 years) and the group consisted of 50 women and 30 men. The left arm was affected in 51 instances and the right arm in 29 cases. The fractures were divided into categories according to the classification of the work group for osteosynthesis (AO). In our patients we diagnosed 10 A2 fractures, 26 A3 fractures, 10 B2 fractures and 34 C fractures. The C fractures consisted of 11 C1, 13 C2 and 10 C3 fractures. Clinical and radiographic data were collected to assess the outcome of the treatment. Antero-posterior and lateral X-rays of the injured side and the contralateral side were obtained. To assess the radiographic results, the X-rays taken at the time of injury, postoperative X-rays, and those taken at the time of follow-up were assessed on a PACS system. After assessing the congruency of the joint surface, the radial tilt, the volar tilt and the radial shortening were determined. Secondary correction loss was determined by the difference between the values registered after surgical treatment and those obtained at the time of follow-up. The clinical follow-up included a standardized examination of the injured side and the contralateral side. The range of motion of the wrists in the sagittal and the frontal plane was determined, and forearm rotation on the right side was compared with that on the left side according to the neutral-zero method. Furthermore, finger extension, fist closure and grip strength in kilograms on the left side were compared with those on the right side using a hydraulic hand dynamometer (Jamar, Sammons Preston Rolyan, Canada.

755 Queensway East, Unit 27 Mississauga, ON L4Y 4C5). The external aspect of the wrist, tenderness to pressure on the distal radius, and the consistency of the surgical scar were investigated. Finally, the patient's perception of pain at rest and at loading was tested on a visual analog pain scale (VAS) and the doctor's subjective and objective assessment of the overall outcome according to the school grading system was registered (1 = very good, 5 = insufficient). To evaluate the functional results we used the DASH score [16], which considers function and symptoms in the upper extremities from the patient's viewpoint. The score ranges from 0 to 100 points (0 indicates no

Table 1 Patients and fractures

Number	80 patients, 50 females and 30 males
Age	58.4 years (23–88)
Fracture classification (AO)	10 A2
	26 A3
	10 B2
	11 C1
	13 C2
	10 C3
Follow-up	7 months (6–9)

limitation, 100 indicates maximum limitation) and reflects the outcome of the treatment. The radiographic results (radial/volar tilt, radial shortening, arthrotic changes) were objectified using Castaing's score which also includes subjective (grip strength, limitation in manual activity) and functional (extension/flexion, ulnar/radialduction, supination/pronation) results, [17] (Table 1).

Radiographic results

Bone healing had occurred in all patients at the time of follow-up. On X-rays taken at the time of follow-up 60 patients (75%) had no radial shortening, 20 patients (25%) had a mean radial shortening occurred during follow-up of only 1.8 mm (range 1–3 mm) compared to the contralateral side. In these, settling of the distal fragment occurred until the subchondral support screws came in direct contact with the subchondral plate and stability was achieved.

The radial tilt was on average 22° (range 14°–36°); the volar tilt was on average 6° (range 0°–18°). Comparing the first postoperative X-rays with those taken at final evaluation showed no measureable loss of reduction in the volar or radial tilt.

Twenty-eight of 35 patients who suffered an avulsion fracture of the ulnar styloid in addition to the radial fracture, developed pseudarthrosis in the ulnar styloid after healing. Surgical stabilization of the ulnar styloid was not performed in any case.

Castaing's score yielded a perfect outcome in 30 cases, a good outcome in 49 cases and an adequate outcome in one case (Figs. 4, 5, 6, 7).

Clinical results

Wrist range of motion (assessed by the physician with a goniometer) averaged 54° of wrist extension (range 35°–75°),

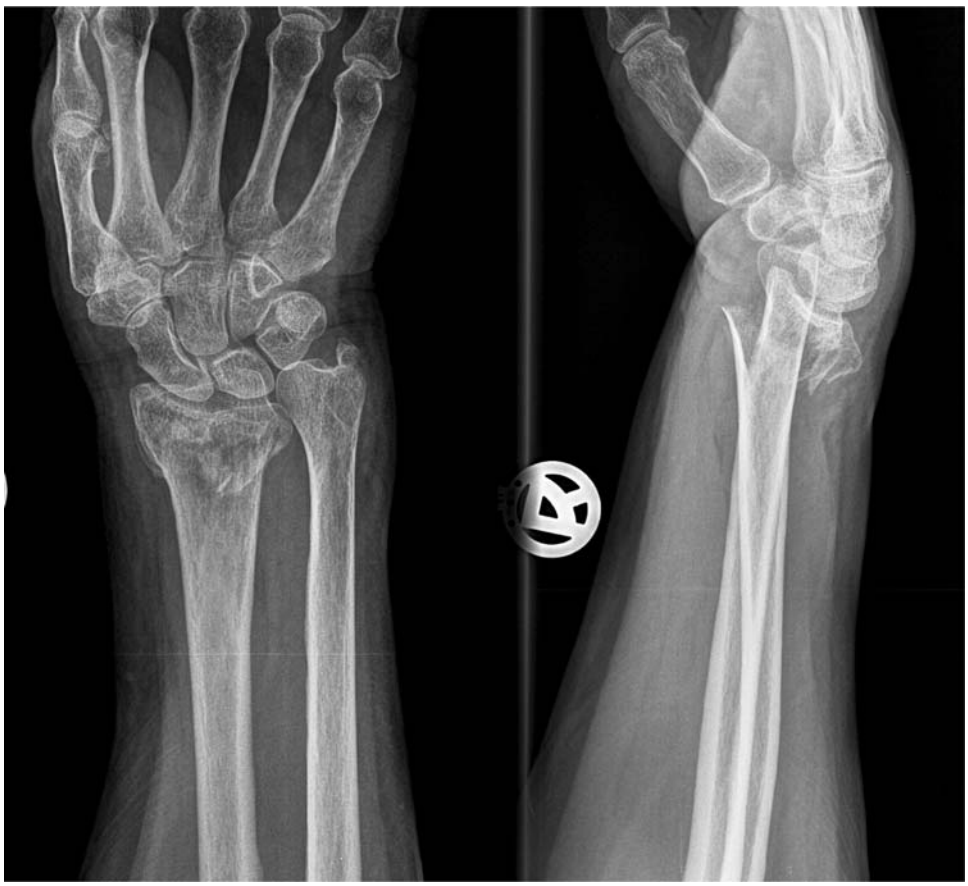

Fig. 4 66 year-old female patient (E.A.) following a fall

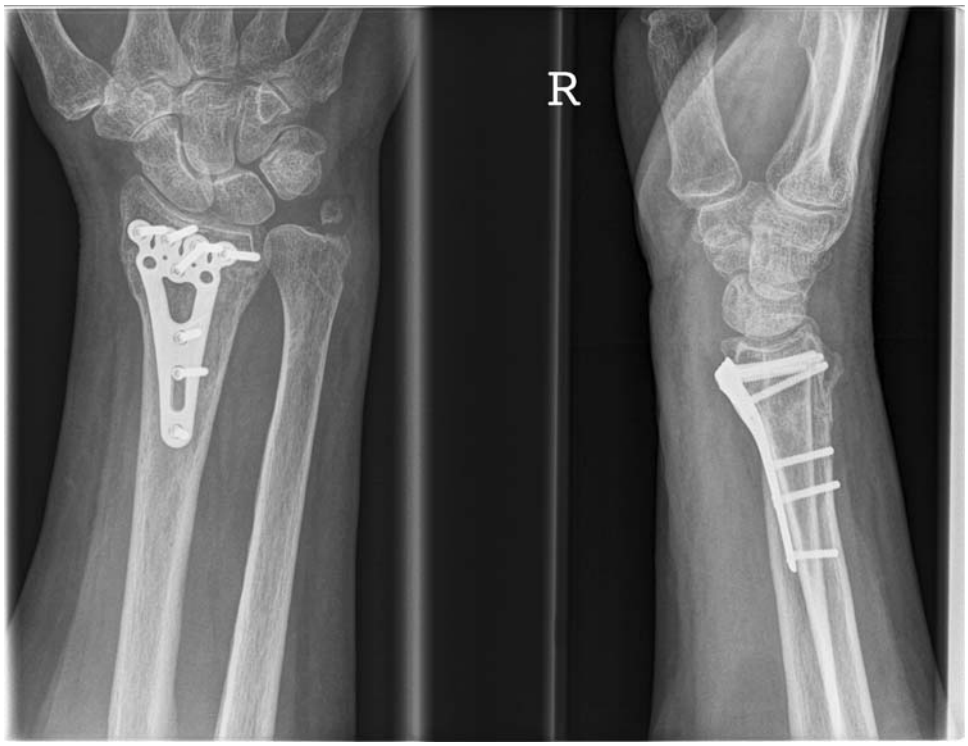

Fig. 5 66 year-old female patient (E.A.) 6 months post-op

Fig. 6 44 year-old patient (M.G.) following a fall whilst mountain biking

52° of wrist flexion (range 32°–81°), 32° of ulnar deviation (range 25°–40°), 26° of radial deviation (range 17°–32°), 86° of pronation (range 81°–90°), and 87° of supination (range 75°–90°).

The range of motion was on average reduced by 21% during extension/flexion, by 11% during radial/ulnardeviation and by 7% in pronation/supination compared to the contralateral side. Grip strength was 65% that of the

Fig. 7 44 year-old patient (M.G.) 6 months post-operative

Table 2 Functional and radiological results

Functional and radiological results (n = 80)	
Extension/flexion (% of that of the contralateral side)	79
Ulnar/radialduction (% of that of the contralateral side)	89
Pronation/supination (% of that of the contralateral side)	93
Grip strength (% of that of the contralateral side)	65
Radial tilt	22° (14–36)
Volar tilt	6° (0–18)
Radial shortening	2.7 mm (1–5) in 20 patients
DASH score	25
Castaing-result score	30 perfect
	49 good
	1 adequate

contralateral side. Here a correction of 15% was taken into account for handedness.

Fist closure and finger extension were markedly reduced in the terminal aspect in one patient. In 64 patients the wrist was normal in appearance. On comparison of the left and the right side, 16 patients showed thickening of the surrounding soft tissue. The scar was non-reactive in all patients. In six patients the scar had spread. Tenderness to pressure on the distal radius was seen in four patients. Fifteen patients (19%) reported pain at rest with a mean VAS score of 2 (range 1–3) while 37 patients (46%) had pain on load-bearing with a mean VAS score of 2.9 (range 1–8). The overall outcome according to the school grading system was assigned a rating of 1.85 by the patients while the doctor performing the follow-up investigation rated the final outcome 1.45. Twenty-nine patients (36%) rated the outcome on average one grade poorer than the doctor did. Eleven patients (14%) experienced the plate as a foreign body. The mean DASH score [16] was 25 points. This value indicates a good outcome considering the range of 0 (no limitation) to 100 (maximal limitation) (Fig. 8; Table 2).

Complications

Two patients developed sympathetic reflex dystrophy (Sudeck's syndrome) postoperatively. After medication and ergotherapy the sympathetic reflex dystrophy had completely resolved at the time of follow-up in both patients.

Fig. 8 Outcome for a 35 year old patient 6 months post-operative

In one patient the plate had to be removed after 4 months because of the patient's mind.

A carpal tunnel syndrome with abnormal EMG was diagnosed in two patients and was treated by surgery in both cases.

Five patients reported occasional sensitivity disorders in the fingers in the region supplied by the median nerve. In no case was a reduction in nerve conduction velocity (NCV) or an obvious carpal tunnel syndrome observed and the EMG was normal.

Three patients reported occasional paresthesia and tingling in the thenar region.

Discussion

Unstable extension fractures of the distal radius require anatomical reconstruction of the articular surface and fixation of the reduced fracture until healing of the bone has taken place. Sequelae as a result of post-traumatic arthrosis, which primarily occurs in the distal radioulnar joint or the radiocarpal joint, must be avoided [18]. Clinical studies in recent years have shown a significant correlation between radiological and functional outcome in distal fractures of the radius [19, 20]. Further, the literature shows a clear trend towards operative treatment of fractures of the radius. Up to now evidence exists, that young patients achieve favourable results following anatomic restoration of the wrist. However, prospective randomised trials are missing to prove this fact in the elderly and low demand patients without load bearing.

Various internal fixation procedures, depending on the type of fracture, have been recommended with widely varying outcomes and conclusions [21–25].

Kirschner wire internal fixation frequently fails to meet requirements for treatment of extensive, unstable fractures of the radius and generally leads to healing with a relative ulnar shift and a consequent incongruence in the distal radioulnar joint and ulnocarpal impingement. Thielke et al. [25] have shown that Kirschner wire internal fixation alone as a treatment for complex fractures of the radius with joint involvement gives results ranging from satisfactory to poor in 50% of cases.

At our clinic, Kirschner wire internal fixation is now only used as an additional procedure where necessary.

Use of an external fixator permits reliable length adjustment, but in intra-articular fractures it generally leads to joint offsets, as ligamentotaxis is insufficient in this case. In addition, at our clinic we have observed a cluster of cases of posttraumatic osteoporosis where an external fixator has been used.

Because neither procedure permits early mobilisation, there is a tendency to long term mobility and functional deficits.

Fixed-angle internal plate fixation offers new possibilities in this area. Permanent fixation of the reduced fracture prevents secondary loss of correction. Achieving a state which permits mobilisation allows early functional follow-up even in the case of complex fractures or with osteoporotic bone. Angular fixation results in stable support of the articular surfaces until bone formation in the defect zones is

complete. The result is that cancellous bone graft is only necessary in exceptional cases with huge defect zones. Numerous studies provide evidence of improved radiological and functional results [2, 26–29].

We consider the major advantage of the system we use to be the ability to perform infinite multidirectional placement of the screws. Comparisons with other fixed-angle systems have demonstrated that unidirectional systems or systems with only limited multidirectionality are associated with significant problems during surgical treatment. After insertion of the plate from a unidirectional system and insertion of the first fixed-angle screw, the remaining two screws must follow the set geometry of the plate if they are introduced at a fixed angle. In the case of multiply fractured articular surfaces, this makes secure fixation of the fragments by the screws difficult and sometimes impossible. The ability to insert screws in multiple directions with an angular range of $\pm 15°$ in all directions allows an intra-articular location to be reliably avoided. The angle of the screw can be selected by the surgeon and is not determined by the implant. Following its anatomical reconstruction, the articular surface is supported by the distal row of screws. Subchondral placement of the second row of screws does not present any difficulties. Our data clearly demonstrated that secondary loss of correction (radial shortening, volar or radial tilting) was avoided.

Indications for implantation of a palmar fixed-angle plate in respect of the AO fracture classification were determined in a similar way in our data and in the literature. Differences emerged, however, with regard to the timing of the operation.

Comparison with the literature shows significant differences in this regard in comparison to other authors. Krimmer et al. [30] performed their surgical intervention after an average of 5.5 days, after an average of 10 days. In our clinic, on patients with a fracture of the radius for which surgery is indicated surgery is performed within the first 12 h after the accident, depending on the options available.

Conclusion

Fixed-angle plate osteosynthesis at the distal radius signifies a significant improvement in the treatment of distal radial fractures in terms of restoration of the shape and function of the wrist. The technically simple palmar access, with a low rate of complications, allows exact anatomical reduction of the fracture. The multidirectional fixed-angle system we used provides solid support for the joint surface even in osteoporotic bone and allows simple subchondral placement of screws with sustained retention of the outcome of reduction. Secondary correction loss can be avoided by this procedure. Early mobilisation can be achieved and is recommended.

Conflict of interest statement None of the authors will receive benefits from a commercial party related directly or indirectly to the subject of this article. There is no commercial connection between the authors and Medartis AG.

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