Is minimally invasive application by intramedullary osteosynthesis in comparison with volar plating real benefit in the treatment of distal radius fractures?

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Abstract

Purpose of the study: Can minimally invasive intramedullary osteosynthesis of distal radius fractures provide better therapeutic results than multidirectional locking plates. Retrospective study of 68 patients operated for distal radius fractures, 18 were treated with intramedullary X-screw (XSCR) fixation and 50 with the multidirectional angle-stable plate system (APTUS). The evaluation at 1-year follow-up included functional status of the wrist and hand, and radiographic findings. In the XSCR group, the functional outcomes of the treated extremity did not achieve values comparable with those of the uninjured side in any of the parameters measured. The radiographic findings did not meet the requirements of successful healing due to failure to restore an anatomical volar tilt in 22.2% cases. In the APTUS group, comparable values of the injured and the uninjured side were achieved in radial deviation, ulnar deviation, pronation, supination and grip strength. The radiographic criteria of successful healing were met by all fractures treated by locking plate osteosynthesis. Implant migration associated with secondary displacement of bone fragments was recorded in 33.3 % of the XSCR patients and only in 4.0 % of the APTUS patients. The overall evaluation show that intramedullary osteosynthesis does not produce better treatment outcomes compared with plate osteosynthesis in indicated types of fractures.

KEY WORDS: distal radius fracture, locking plate osteosynthesis, intramedullary osteosynthesis, complications

INTRODUCTION

Fractures of the distal radius are complex injuries with varied prognosis depending on the type of fracture and method of treatment [1].There is still no clinical evidence suggesting a superior modality for their management [2]. The current therapy most frequently involves open reduction and plate osteosynthesis [3]. Angle-stable fixation provides sufficient stability of the fracture to allow early start of rehabilitation soon after surgery; consequently, the total treatment time is shorter and good functional outcomes are achieved even in unstable grossly comminuted intra-articular fractures [4, 5]. Application of a volar plate with angle-stable fixation has been used successfully in a number of cohort studies but needs to be examined in stringent trials to determine if there is any benefit when compared with other treatment modalities [2]. Intramedullary osteosynthesis is used for fragment fixation less frequently and good radiographic and functional outcomes have been published [6]. However, its range of indications limited to the management of extra-articular and simple intra-articular fractures is a disadvantage of the method [7]. Only a few clinical evaluations are available. Lerch et al. [8] in an isolated study on a small patient group report comparable results for plate and intramedullary osteosyntheses (Targon DR, Aesculap Implant Systems, Center Valley, PA, U.S.A.) and relate the excellent functional scores for nailing to the minimally invasive procedure. Ilyas et al. [9] have reported that using the intramedullary nail (Micronail, Wright Medical Technologies, Arlington, TN, U.S.A.) in the treatment of displaced distal radius fractures can result in good functional outcome, but is associated with a high incidence of complications, i.e., screw penetration into the distal radioulnar joint, 30% and transient superficial radial sensory neuritis, 20 %. No studies evaluating the results of X-screw (Zimmer, Inc., Warsaw, IN, U.S.A.) intramedullary osteosynthesis have been published so far. Since 2006 for surgical stabilization to all types of distal radius fractures multidirectional angle-stable plates

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applied from volar approach are used in our practise. In 2009 we have also started to use X-screw implant allowing intramedullary osteosynthesis. In a retrospective study, we decided to elucidate whether this minimally invasive implant can provide comparably good therapeutic results as multidirectional locking plates.

MATERIALS AND METHODS

Therapeutic approaches at our department

Patients with non-displaced fractures of the distal radius referred to the Trauma Center at the Teaching Hospital in Motol are indicated for conservative treatment. Those with displaced fractures receive urgent treatment at the in-patient and emergency department of the center, involving reduction of the fracture under local anesthesia (10 ml 1 % Mesocaine injected into the fracture site) and immobilization of the extremity with a dorsal and a volar plaster splint. Based on plain postero-anterior and lateral radiographs taken after reduction, the patients are indicated for further treatment. Patients who failed to achieve anatomical reduction that meets the criteria for successful treatment [10] are then indicated for surgical treatment either by intramedullary or plate osteosynthesis.

Patient groups

Between February 2009 and November 2010, a total of 1024 fractures of the distal radius were treated at our department, and of this number were 156 fractures surgically solved. Of the patients treated, 68 came to the final examination and evaluation of outcomes at a follow-up of 12 months although all patients operated on by the first author in the period mentioned above had been invited. All patients were adults with an uninjured contralateral extremity, who underwent surgery within 22 days of injury. The indication criteria for treatment of distal radius fractures by intramedullary X-screw osteosynthesis included an absence of osteopenia on plain X-ray and the patient's preference for a minimally invasive procedure. The remaining patients were treated by open reduction and internal fixation (ORIF) using volar locking plates with variable-angle screw insertion. Indications for surgery were based on antero-posterior and lateral radiographs; when a fracture was more complicated, CT examination was carried out. Fracture types were assessed according to the AO classification system [11]. Patients with pseudoarthrosis, pathological fractures, refractures, open fractures, multiple factures of the ipsilateral extremity and fractures associated with multiple injuries were excluded. The XSCR group of patients with distal radius fractures treated by intramedullary X-screw osteosynthesis (Zimmer, Inc., Warsaw, Indiana, U.S.A.) comprised 18 patients with a mean age of 61.0 years (range, 40 to 75; SD, 9.8) (Figure 1).

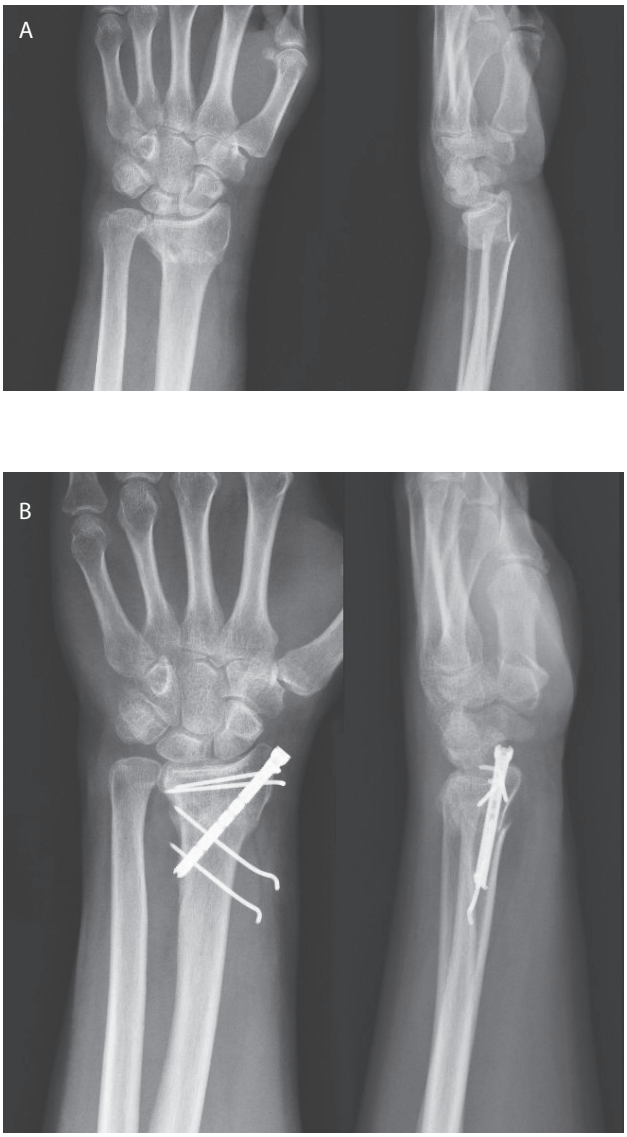

FIGURE 1. A type A3 fracture of the distal radius. Postero-anterior and lateral radiographs of the fracture (patient B.N.) A) after injury; B) at 3 months after intramedullary X-screw fixation.

The mean injury-surgery interval was 6 days (range, 2 to 10; SD, 2.4). Four patients had distal radius fractures without joint involvement and 14 had fractures with intra-articular injury. The fractures were due to falling after a stumble while walking (83.7 %) or were sustained in sports activities (16.3 %). The APTUS group included 50 patients with a distal radius fracture treated by the multidirectional angle-stable plate Aptus Radius (Medartis, Basel, Switzerland) (Figure 2). The mean age of the group was 48.9 years (range, 22 to 77; SD, 15.3). The mean injury-surgery interval was 6.1 days (range 0 to 22; SD, 3.8). Nine fractures were without and 41 with joint involvement. They were due to falling after a stumble (62.0 %) or were sustained in association with sports activities (36.0 %) or in motor car accidents (2.0 %). Both the XSCR and APTUS groups were matched as for gender, injured body side and AO fracture type, but differed

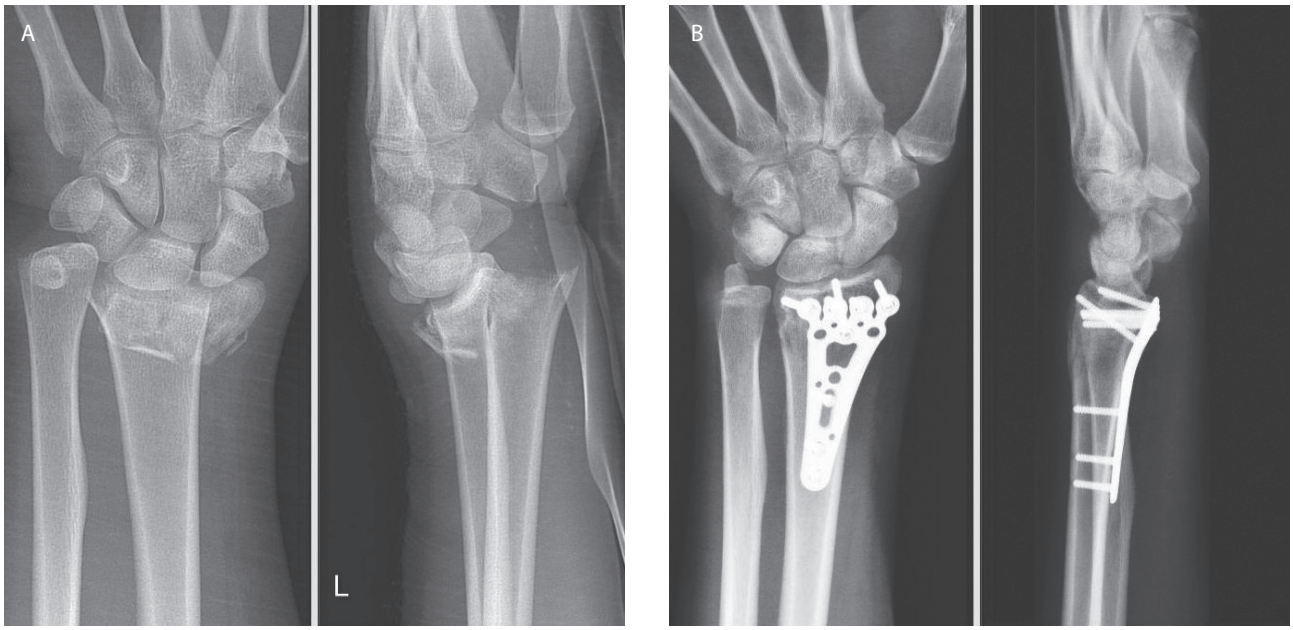

FIGURE 2. A type C1 fracture of the distal radius. Postero-anterior and lateral radiographs of the fracture (patient V.H.) A) after injury; B) at 3 months after Aptus radius locking plate fixation.

TABLE 1. Patient characteristics.

Patient characteristics		APTUS (n = 50)	X-SCREW (n = 18)	*p* value
Age at the time of injury, mean (range) years		48.5 (22-77)	61.0 (40-75)	<0.05
Gender	Men	15	2	0.2
	Women	35	16	
Injured side	Right	25	6	0.28
	Left	25	12	
	Dominant	27	6	0.27
	Non-dominant	23	12	
AO fracture type	A2	2	2	0.54
	A3	7	2	
	C1	14	4	
	C2	10	6	
	C3	17	4	
Injury-to-surgery interval, mean (range) days		6.1 (0-22)	5.6 (2-10)	0.68

significantly in patient age. Patient characteristics are shown in Table 1. Lower number of fractures treated by intramedullary method compared to group of plate osteosynthesis was given a narrower indication extent of X-screw implant.

Operative techniques

All patients were operated on with intravenous infusion of a second generation cephalosporin antibiotic before a tourniquet was applied. The X-screw is a form of intramedullary osteosynthesis of the distal radius based on combination of a special screw with threaded Kirschner wires. A 3-mm incision was made on the radial side over the radial styloid process. After reduction, the fracture was temporarily fixed with a Kirschner wire. A cannulated screw was inserted over the wire and tightened to further compress the fragments and hold the reduction. Once the screw was anchored, no further correction of fracture position was possible. Osteosynthesis was completed with an adequate number of wires inserted by aimer device from small incisions. The wrist was immobilized with a dorsal plaster splint for 2 weeks in type A3 fractures and for 4 weeks in type C fractures. Type A2 fractures were not immobilized. Supervised rehabilitation of the hand and wrist started at 5 post-operative weeks. The multidirectional angle-stable plates Aptus radius were applied from the flexor capri radialis (FCR) approach as follows: access to the radius was gained between the radial vascular bundle and the FCR tendon. The pronator quadratus muscle was dissected from the anterior surface of the radius, shifted medially in a flap and secured with a hook. Fluoroscopy-guided reduction of the fracture was performed and fragments were temporarily fixed with Kirschner wires. Subsequently, the plate itself was applied.

TABLE 2. Functional ranges of motion of the wrist joint and grip strength.

Group	Side	Volar flexion (degrees)	Dorsal flexion (degrees)	Radial deviation (degrees)	Ulnar deviation (degrees)	Pronation (degrees)	Supination (degrees)	Grip strength (kg)
		Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
APTUS	Injured side	53.40 ± 10.42	60.00 ± 9.24	25.60 ± 9.07	37.40 ± 10.06	88.60 ± 4.52	84.80 ± 10.54	20.48 ± 7.59
	Uninjured side	63.00 ± 9.94	66.60 ± 9.60	26.60 ± 7.17	40.00 ± 9.03	89.40 ± 3.13	87.20 ± 7.29	23.52 ± 6.30
	p value	<0.05	<0.05	0.54 *	0.17 *	0.3 *	0.18 *	<0.05
XSCR	Injured side	52.22 ± 8.08	55.56 ± 8.56	20.00 ± 0.00	21.11 ± 11.32	83.33 ± 10.85	78.89 ± 14.10	12.22 ± 6.25
	Uninjured side	63.33 ± 4.85	67.78 ± 4.28	23.33 ± 4.85	34.44 ± 5.11	90.00 ± 0.00	88.89 ± 3.23	16.56 ± 1.82
	p value	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

* Parameters with corresponding values of both extremities

TABLE 3. Radiographic findings.

Group	Extremity	Radial height (mm)	Radial inclination (degrees)		Volar tilt (degrees)	Ulnar variance (mm)	Articular surface step-off (mm)
		Mean ± S.D.	Mean ± S.D.	SD	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
APTUS	Injured side	11.86 ± 1.76	25.00 ± 2.25	2.25	9.12 ± 5.28	-0.68 ± 2.25	0.18 ± 0.43
	Anatomical standard	12.00 ± 0.00	23.00 ± 0.00	0.00	12.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	p value	0.58 *	<0.05	<0.05	<0.05	<0.05	0.18 *
XSCR	Injured side	10.67 ± 1.19	21.44 ± 2.96	2.96	9.11 ± 14.10	2.89 ± 3.41	0.56 ± 0.98
	Anatomical standard	12.00 ± 0.00	23.00 ± 0.00	0.00	12.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	p value	<0.05	<0.05	0.39 *	<0.05	<0.05	<0.05

* Parameters with corresponding values of both extremities

The extremity was immobilized in a brace. In less serious cases, supervised rehabilitation was started at 3 weeks and, in more complex fractures, at 5 weeks post-operatively.

Follow-up examination

Clinical findings were evaluated immediately after surgery and then at 2, 4, 8 and 12 weeks and 3, 6 and 12 months of follow-up. Radiographs were obtained within the visits at 4 and 8 weeks and 3, 6 and 12 months. The clinical outcome was evaluated using international scores at one-year follow-up. The range of wrist motion (volar flexion, dorsal flexion, radial deviation, ulnar deviation, supination and pronation) was measured with a goniometer and grip strength was assessed with a hand dynamometer (Vigorimeter, Martin, Tuttlingen, Germany). The values were compared with those obtained for the uninjured side. We were aware of different muscle strength between the dominant and non-dominant hand but, because of a significant similarity of this characteristic in both groups (p=0.27), this was not taken into consideration. Antero-posterior and lateral radiographs were examined for radial height, radial inclination, ulnar variance, volar tilt and articular surface step-off. The findings were compared with the standard anatomy of the distal radius to avoid X-ray exposure in the contralateral wrist. The values of radial height, radial inclination, ulnar variance and volar tilt in lateral projection described by Ruedi et al. [12] were taken as the standard anatomical parameters. In all patients the results were evaluated using the scoring systems of Gartland and Werley [13], Castaing [14] and the Disability of the Arm, Shoulder and Hand (DASH) questionnaire [15].

Statistical analysis

The data obtained were statistically evaluated (t-test and chi-square test) at the 0.05 level of significance using Statistica 8 (StatSoft, Incorporation, Tulsa, Oklahoma, U.S.A.) and SPSS Statistics 17 (SPSS Incorporation, Chicago, Illinois, U.S.A.) software programs.

RESULTS

Functional outcomes

In the XCSR group, in comparison with the contralateral wrist, the following values were achieved: volar flexion, 82.5%; dorsal flexion, 82.0%; radial deviation, 85.7%; ulnar deviation, 61.3%; pronation, 92.6%; supination, 88.8 % and grip strength, 73.8%. These values ware not comparable with those of the uninjured side. In the APTUS group, the values achieved were as follows: volar flexion, 84.8%; dorsal flexion, 99.9%; radial deviation, 96.2%; ulnar deviation, 93.5%; pronation, 99.4%; supination, 97.2 % and grip strength, 87.1%. These values were comparable with those of the uninjured side in radial deviation, ulnae deviation, pronation et supination. The results are summarized in Table 2.

Radiographic findings

Radiographs obtained at a one-year follow-up showed complete bony union in all fractures of both groups. In

TABLE 4. Scoring systems.

Scoring system	Castaing (points)	Gartland Werley (points)	DASH (points)
	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
APTUS	5.26 ± 4.22	5.86 ± 6.24	10.05 ± 7.71
XSCR	6.22 ± 5.82	4.44 ± 3.73	12.12 ± 8.48
p value	0.45*	0.37*	0.35*

* Parameters with corresponding values of both extremities

the XSCR group, only the volar tilt was fully restored. The other parameters were significantly different from the anatomical standards. The radiographic findings did not meet the criteria for successful treatment [10] in four patients (22.2%), of whom one had an insufficient radial height and three had no satisfactory radial inclination.

In the APTUS group, all fractures were completely healed but only the radial height was comparable with the anatomical standard; the other parameters were significantly different ($p<0.05$) (Table 3). However, the criteria of a successful outcome [10], were fulfilled in all fractures in this group.

Scores

The XSCR group showed 55.6 % excellent and good results on the Castaing scoring system and 77.8 % on the Gartland-Werley score. The average DASH score was 12.1 points. In the APTUS group, excellent and good results were achieved in 76.0 % and 84.0 % of the patients assessed using the Castaing and Gartland-Werley scores, respectively. The average DASH score was 10.1 points. The results are presented in Table 4 and Figures 3 and 4.

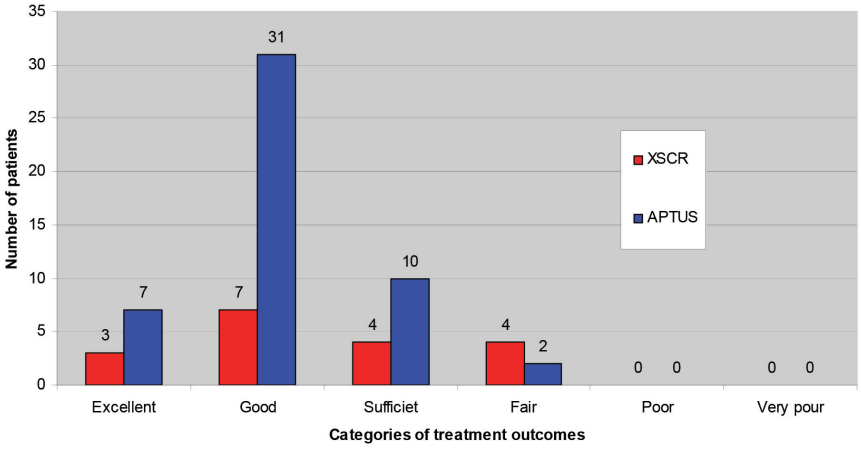

FIGURE 3. Functional outcome evaluation using the Castaing score.

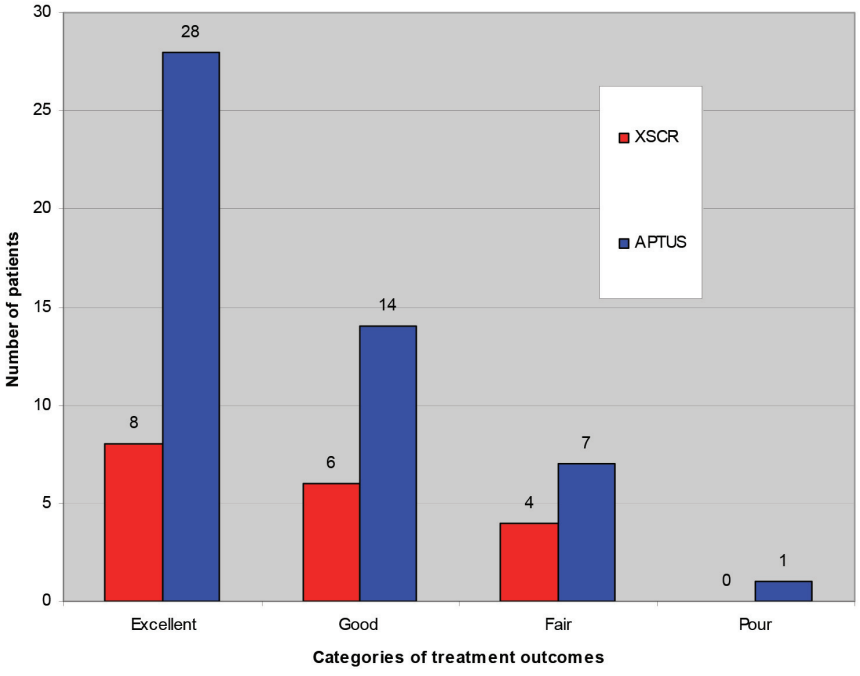

FIGURE 4. Functional outcome evaluation using the Gartland-Werley score.

Complications

Secondary fragment displacement during healing was found in six patients of the XSCR group (33.3%). It occurred in osteopenic patients with grossly comminuted fractures (types C2 and C3). But in the end, these patients found the functional state of their wrists and hand satisfactory and underwent only hardware removal. Partial migration of Kirschner wires was recorded in four patients (22.2%) in this group, but did not result in loss of correction. In the APTUS group, secondary fragment displacement was recorded in two osteopenic patients (4.0%) with grossly comminuted fractures (types A3 and C3). Temporary irritation of the sensitive branch of the radial nerve in two patients (11.1%) of the XSCR group resolved spontaneously without any therapy. Temporary irritation of the median nerve was recorded in one APTUS patient (2.0 %) who had paresthesia of the distal phalanx of the third finger. It subsided spontaneously within 3 months after surgery with no need to indicate electromyography examination or any therapy. No tendon injury was found in the XSCR group. One APTUS patient (2.4%) suffered a rupture of the

TABLE 5. Complications and their management.

Complication	Group	Number of patients affected	Treatment
Loss of correction	APTUS	2	No treatment
	XSCR	6	Hardware removal
Implant migration, no loss of correction	APTUS	0	-
	XCSR	4	Hardware removal
Nerve irritation	APTUS	1 (median nerve)	Spontaneous resolution
	XSCR	2 (radial nerve)	Spontaneous resolution
Tendon rupture	APTUS	1 (extensor tendon)	Hardware removal, tendon transfer
	XSCR	0	-
Complex regional pain syndrome	APTUS	3	Medications (calcitonin and calcium)
	XSCR	2	Medications (calcitonin and calcium)

thumb extensor tendon caused by the tip of a screw projecting through the dorsal cortex of the radius. This was managed by hardware removal and transfer of the extensor indicis proprius tendon onto the distal part of extensor pollicis tendon. Complex regional pain syndrome developed in two XSCR (11.1%) and three APTUS (6.0%) patients. Treatment with intranasal calcitonin application and increased calcium intake resulted in subsidence of clinical and radiographic findings in 2 months. The complications and their management are shown in Table 5.

DISCUSSION

Restoration of the normal anatomy as a prerequisite for good wrist and hand function is currently taken as an imperative in the management of distal radius fractures. However, in unstable fractures refractory to conservative treatment there is still no clear evidence suggesting which method of osteosynthesis should be indicated for each of the fracture types. The functional outcomes of intramedullary osteosynthesis of the distal radius generally have very good scores, chiefly due to minimal invasiveness of the methods used [8]. With the intramedullary nail Targon DR, the resulting values for the range of wrist motion in all directions and for grip strength reached 90% to 100% of those measured on the uninjured side [6]. However, our XSCR patients achieved the 90% level only in pronation. The least satisfactory range of motion (ROM) was in ulnar deviation (61.3% of the healthy wrist value). Failure in direct relation with restoring ulnar deviation has to be considered radiographic results and inability to restore radial length (mean ulnar variance of 2.9 mm). Difficulties in anatomical restoration of normal volar tilt (12 degrees) with the use of nailing techniques have been published. In a study comprising 103 patients, Gradl et al. [6] reported achieving only a mean volar tilt of 2.05 degrees. The mean value of 9.1 degrees for volar tilt in our XSCR patients can be regarded as a very good result testifying for good stability of the X-screw implant in terms of radiographic parameter. On the other hand, radial height and radial inclination were not fully restored in these patients. However, problems with maintaining volar tilt while achieving good restoration of the other radiographic parameters have also been described for the Micronail [16]. The Castaing scores showed excellent and good results in 55.6 %, and the Gartland-Werley scores were excellent and good in 77.8% of the XSCR patients. Worse results with the Castaing scoring system were due to relative lengthening of the ulna. In the XSCR group, the most serious complication included loss of correction in 33.4% of the patients. This value is extremely high compared to the 4.0 % of the patients treated by plate osteosynthesis. Secondary displacement in the XSCR group was always associated with grossly comminuted fractures (A3, C3 and C2). This result should be taken into consideration when indicating complex fractures of the distal radius for intramedullary osteosynthesis. Kirschner wire migration did not prove a serious complication because it occurred after complete fracture union and was not associated with secondary fragment displacement. Paresthesia in the region innervated by a sensitive branch of the radial nerve resolved spontaneously. In the future this can be avoided by a careful operative technique involving good intra-operative visualization of the nerve. The absence of any injury to tendons is a great advantage of the intramedullary technique. Our experience with intramedullary osteosynthesis, as well as conclusions of other authors [6, 9] have shown that the major advantage of this technique is its good functional outcome. A full range of wrist motion at 4 post-operative months with use of a Micronail® implant has been described. This advantage is in contrasted to high complication rate and a narrow indication range regarding to AO fracture types [9]. In the APTUS group, the range of motion achieved in radial and ulnar deviation and in pronation and supination was comparable with that of the uninjured side; however, the values for both volar and dorsal flexion were markedly lower. A restricted ROM of only 80% to 90 % of that at the uninjured wrist has repeatedly been reported at 1-year follow-up in patients treated by the volar locking plate system [18, 19]. However, the hand/wrist functional status recorded at 1 year need not be final and may further improve. A previous study has shown that patients achieve most of their improvement in wrist motion range and grip strength by 6 months, but they may continue to improve up to around 18 months [20]. The functional outcomes assessed using the Gartland-Werley scores were excellent and good in 84.0% of the APTUS patients. This is in agreement with the results reported by Osada et al. [1] in 43 displaced intra-articular fractures treated with a volar locking plate system. Good functional

outcomes in the treatment of distal radius fractures using plate osteosynthesis are achieved in spite of a high incidence of complications [21]. Based on the criteria for successful treatment [10], our results are excellent and are similar to those described by other authors for the treatment of distal radius fractures with volar locking plates [22, 23]. In one APTUS patient, injury to the extensor pollicis longus tendon was caused by a screw penetrating through the dorsal corticalis. It was managed by implant removal and repair of the rupture with tendon transfer. This damage can be avoided by a careful operative technique with use of fluoroscopic guidance during screw insertion to prevent penetration of a screw through the dorsal corticalis of the distal radius. The loss of correction was the most serious complication. Two APTUS patients (2.4 %), women with osteopenia aged 73 and 76 years, experienced secondary displacement of type A3 and type C3 fractures, respectively. Revision surgery was not indicated; no patient wanted to have the implant removed. Koenig et al. performed a study to evaluate whether early internal fixation or non-operative treatment is preferred for displaced, potentially unstable distal radial fractures with initial adequate reduction. They found that internal fixation with a volar plate provided a higher probability of painless union for potentially unstable distal radius fractures. However, patients older than 64 years, who had lower risk of symptomatic malunion seemed to prefer non-operative treatment [24]. Our results of the APTUS group confirm this statement. Because due to poor bone quality even angle-stable plate does not sufficiently guarantees good stability for all bone fragments. On the other hand, the risk of fracture re-displacement in a plaster cast is higher in osteoporotic bone compared to healthy bone. Clayton et al. [25] identified a high correlation between bone mineral density and the severity of distal radius fractures. They found that the probability of early instability was 43 % in osteopenic patients and only 28 % in those with normal bone mineral density. But other authors reported on high stability of locking plate osteosynthesis for osteoporotic bone fractures [26]. The evaluation of our groups based on the scoring systems for the assessment of wrist functional state, both objective and subjective, as well as clinical and radiographic findings showed that the results achieved with either locking plates or intramedullary osteosynthesis were comparable and generally good. In terms of objective evaluation, the patients with locking plate osteosynthesis had a better ROM, i.e., the range was closer to that of the contralateral wrist, than the patients with intramedullary osteosynthesis. Radiographs demonstrated good restoration of radial height in the APTUS group and maintenance of adequate volar tilt in the XSCR group. Regarding complications, there was a high incidence of secondary loss of correction and implant migration in the XSCR group. Overall assessment it must be taken into consideration that the APTUS group included a significantly higher number of younger patients.

CONCLUSION

The overall evaluation based on the conventional scoring systems show that intramedullary osteosynthesis does not produce better treatment outcomes compared with plate osteosynthesis in indicated types of fractures. Our study showed that the minimally invasive application of intramedullary osteosynthesis in treatment of the distal radius fractures is only a relative advantage over surgical stabilisation using multidirectional locking plates. In intramedullary techniques good anatomical reduction and its maintenance while the implant is being inserted, is often difficult to achieve from through small incision without a direct visualisation of the fracture. Intramedullary techniques are also associated with frequent secondary displacement of bone fragments and implant migration.

DECLARATION OF INTEREST

The authors declare no conflict of interest.

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