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ORIGINAL STUDY

Complications and functional outcome following fixation of complex, intra-articular fractures of the distal radius with the AO Pi-Plate

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This study investigates the efficacy of the AO Pi-plate in the treatment of complex, intra-articular fractures of the distal radius.

We retrospectively analysed the clinical and radiological results of 19 consecutive patients who underwent open reduction and internal fixation for dorsally displaced, intra-articular fractures of the distal radius using the AO Pi-plate. The final functional outcome was assessed using the Gartland & Werley scoring system.

The average follow-up period was 34.3 months. Wrist movement was restored to a near normal range in all the patients. The functional outcome as measured by the Gartland & Werley scoring system showed excellent and good results in 15 (88%) of the patients. The implant was removed in 4 (23%) of the patients due to extensor tenosynovitis and restriction of flexion.

This study demonstrates that although the functional outcome following fixation of complex distal radius fractures with the AO Pi-plate is good, there is a risk of developing extensor tenosynovitis and limitation of flexion. We recommend that the implant be used sparingly and if used then elective removal of the implant should be considered after fracture union.

Key words : distal radius fractures ; internal fixation ; Pi-plate.

INTRODUCTION

The management of complex, intra-articular fractures of the distal radius has continued to pose a therapeutic challenge to orthopaedic surgeons. Various techniques ranging from closed manipulation and immobilisation to internal fixation have been tried, but all the methods seem to have their own problems *(5, 6, 26)*. In the past decade, open reduction and internal fixation has become the preferred option for many surgeons *(13)* despite the technique being associated with multiple problems such as limited fracture exposure, inadequate reduction of the comminuted fragments and failure to restore joint surface congruity *(2, 9)*. Furthermore, internal fixation using dorsally placed implants can irritate the overlying extensor tendons, leading to implant removal to avoid tenosynovitis and tendon rupture *(8)*. The problems associated with achieving rigid internal fixation in this area stimulated the development of the low profile, dorsally placed AO Pi-plate.

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Since its introduction, there have been a handful of reports specifically examining its efficacy and follow-up periods have been limited *(3, 7, 12, 21)*. Amongst these handful of reports, there is a significant amount of controversy regarding its use *(7, 11, 17)*. In fact, a recent randomised controlled trial had to stop enrolment of patients into the study due to higher complication rates of the AO Pi-plate and the authors have recommended that it should not be used (*11)*.

In an attempt to resolve this controversy, we report our experience associated with the AO Pi-plate for treatment of complex distal radius fractures with a mean follow-up of 34 months.

PATIENTS AND METHODS

All patients who underwent an open reduction and internal fixation of the distal radius with an AO Pi-plate (Synthes Ltd.) were identified from our database. All patients were operated upon by the senior author. A total of 19 patients were identified but only 17 attended the review. All the patients underwent a clinical and radiological examination after obtaining appropriate informed consent. All the fractures were classified according to the AO classification system by an independent observer. Fracture stability was determined using the Lafontaine scoring system where a presence of more than two of the following features indicated instability *(18)*.

1. Dorsal angulation of more than 20°
2. Dorsal comminution
3. Intra-articular radio-carpal fracture
4. Associated ulnar fracture
5. Age > 60 years

Clinical outcome measures included assessment of range of motion and grip strength. Grip strength was assessed bilaterally using the Jamar dynamometer with an average of three attempts. Radiographic assessment of radial inclination, palmar tilt, radial height and articular surface step-off was also performed by an independent observer. Functional outcome was measured using the Gartland & Werley scale *(10)*.

Surgical Technique

Surgery was performed under general anaesthesia with an arm tourniquet. A dorsal longitudinal incision was used, centered on the Lister's tubercle. The extensor retinaculum was divided exposing the third extensor compartment and the extensor pollicis longus tendon. Subperiosteal dissection of the second and fourth extensor compartment was carried out and the fracture site exposed. The fracture was reduced anatomically ensuring no residual articular step. The Pi-plate was applied dorsally after contouring and shortening according to the shape of the distal radius. The distal screws were inserted first. It was not necessary to fill all the holes in the transverse limb for adequate fixation. Subsequently the proximal screws were inserted into the two proximal limbs of the plate. The extensor retinaculum was sutured over the plate. The patient was provided with a light bandage for two weeks and active digital motion was encouraged. We did not routinely splint the wrist in a plaster cast. All patients received active digital motion exercises under supervision of a physiotherapist. Oedema control measures such as elevation in a Bradford sling were included in the post-operative protocol.

RESULTS

There were eight females and nine males with a mean age of 44 years (range : 19 to 77) in the study. The average follow-up period was 34.3 months (range : 6 to 55). Twelve fractures occurred in the dominant hand. Ten fractures were considered high-energy injuries resulting from skiing, fall from a height and road traffic accidents. None of the patients suffered any ipsilateral forearm injury that would complicate rehabilitation of the wrist.

Six patients underwent Pi-plate fixation as a secondary procedure due to failure of maintaining reduction with an external fixator (one patient), K-wires (two patients) and manipulation and immobilisation in a plaster cast (three patients). Bone harvested from the iliac crest was used to supplement fixation in five patients.

According to the AO classification, there were ten C3.1 fractures, four C3.2 fractures, two

Table I. - Mean range of active movement in degrees (mean values are shown in bold with the range in brackets below)

Final Review	Range of Movement
Extension	**61** (45-90)
Flexion	**54.1** (20-90)
Radial Deviation	**15.9** (0-20)
Ulnar Deviation	**21.7** (10-30)
Supination	**82** (60-90)
Pronation	**87.9** (60-90)

C2.2 fractures and one B2.2 fracture. The average Lafontaine stability score was 2.8. All the patients had a score of more than two points, which indicated fracture instability.

All patients achieved clinical and radiographic union within six months of surgery. Nine of the 17 patients achieved union within three months. The mean post-operative range of active movements of the wrist is shown in table I. The average final grip strength was 67% of the uninjured hand. The pre and post-operative radiographic parameter measurements are summarised in table II. The summary of the results of functional assessment is shown in table III.

Table II. - Measurement of radiographic parameters (mean values are shown in bold with the range in brackets below)

Radiological Parameters	Pre-op	Post-op
Radial Length (mm)	**4.7** (1-9)	**7.9** (3-12)
Palmar Tilt (degrees)	-**20.5** (0- -35)	5.3 (-9-20)
Radial Inclination (degrees)	**9.5** (-10-21)	18.2 (6-30)
Intra-articular Step Off	**2** (1-4)	0 (0-1)

Table III. - The functional outcome according to Gartland & Werley scales at final review

Outcome	Number of patients
Excellent	9
Good	6
Fair	2
Poor	0

The radiographic reduction achieved at the time of surgery was maintained in all patients except one. We did not find any radiographic evidence of degenerative changes at the wrist in any of our patients at final review. There was one case of flexor pollicis longus tendon rupture. Four patients were diagnosed to have extensor tenosynovitis at a mean of 6.3 months (range : 4 to 8). All of them required implant removal due to persistent pain, swelling and restriction of flexion. There were no cases of implant breakage, screw loosening, infection, non-union, extensor tendon rupture or complex regional pain syndrome. There were no cases of donor site morbidity in the patients who had supplemental bone graft.

DISCUSSION

The management of displaced fractures of the distal radius has evolved since the original description of this fracture by Abraham Colles in 1814. The perception of early 1800s that 'the limb will enjoy perfect freedom in all its motions and be completely exempt from pain at some remote period of time' has been challenged by present day thinking that the wrist joint does not tolerate any articular surface incongruity and extra-articular malalignment without major loss of function *(23)*.

Knirk and Jupiter *(16)* have clearly demonstrated that >/= 2.0 mm of displacement of the distal radius articular surface results in post-traumatic osteoarthritis in the majority of cases. Studies have also shown that shortening of the distal end of the radius by small amounts (2.5 mm) and/or increasing the dorsal tilt of the distal radial articular surface can result in a substantial increase in the axial load transmitted to the ulna *(22)*. Furthermore, as the dorsal tilt increases, the incongruity of the distal radioulnar joint increases and tightens the interosseous membrane, thereby limiting forearm rotation *(1, 15)*. These findings suggest that malunion of extra-articular fractures is biomechanically unsound and can lead to post-traumatic arthritis, mid carpal instability, decreased wrist motion, decreased grip strength and pain *(20, 24)*. Applying this evidence, current goals for optimum management of these fractures are to achieve anatomic

reduction, stable fixation and early rehabilitation *(23)*.

The AO Pi-plate was designed to achieve the above mentioned goals and overcome the complications of internal fixation in this area which approached 50% in some series *(2)*. The design of the plate allows an internal means of support for both intra and extra-articular reconstruction. It has a distal juxta-articular band which serves to control articular comminution and two thin longitudinal proximal limbs for extra-articular reconstruction (fig 1). The juxta-articular band provides holes for 2.4 mm self-tapping screws or 1.8 mm buttress pins that are recessed into the plate to minimise irritation of extensor tendons. The versatile nature of the plate thereby allows the possibility of anatomical reduction, stable fixation and early rehabilitation of complex distal radial fractures.

Our results compare favourably with other studies on the use of the Pi-plate for complex distal radius fractures *(3, 7, 17, 21)*. The assessment of the post-operative range of movement of the wrist revealed that it continued to improve throughout the follow-up period and culminated in a mean recovery of 61° of extension and 54° of flexion.

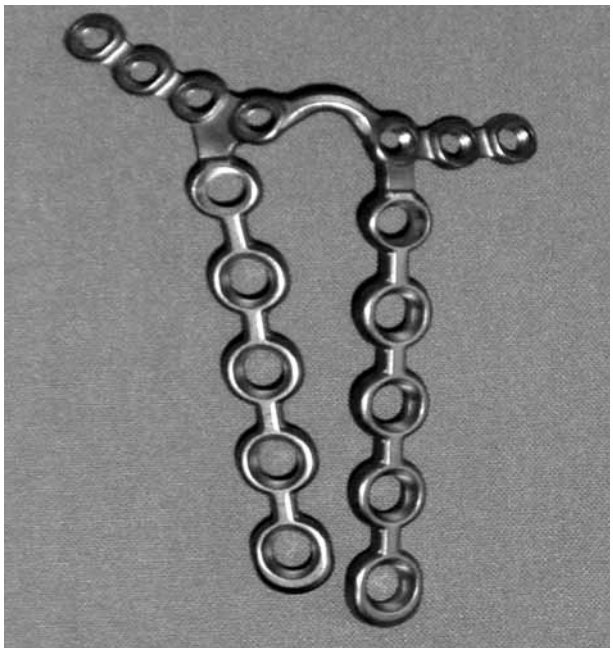

Fig. 1. — The AO Pi plate.

Table IV. - Comparison of the outcome according to the Gartland & Werley Scale

Outcome	Excellent	Good	Fair
Ring *et al. (21)*	27.2%	31.8%	40.9%
Campbell *(3)*	16%	44%	40%
Fawzy *et al. (7)*	17.3%	43.4%	30.4%
Heras et al. (Present Study)	52.9%	35.9%	11.76%

Supination improved to 82° and pronation to 88°. These results are an improvement on the results achieved by Ring et al *(21)*, where the range of extension was up to 45°, flexion 40°, pronation 76° and supination 65°. We believe that the patient's wrist function continues to improve for a period of 18 to 24 months and this is possibly the reason for better results in our series as compared to Ring et al *(21)*.

Post-operative radiographic measurements demonstrate that joint congruity was restored to normal in all, except three cases with residual steps of 1 mm. The extra-articular parameters including palmar tilt, radial height and inclination were improved uniformly. These radiographic improvements were maintained in all but one case in which the radial length decreased.

The functional outcome according to the Gartland & Werley scoring system is encouraging compared to other studies, as shown in table IV *(3, 7, 21)*. Fifteen (88%) of our patients achieved an excellent or good outcome as compared to 60% in the Campbell series, 58% in the Ring et al series and 61% in the Fawzy et al series *(3, 7, 21)*. We believe that these results were achieved partly due to an immediate and prolonged rehabilitation programme by specialist hand physiotherapists and partly due to the fact that we do not routinely splint the wrist in the majority of cases.

However, the versatility and flexibility of this implant is not without drawbacks. Although the low profile nature of the plate was designed to reduce the incidence of overlying soft tissue irritation, extensor tendon tenosynovitis remains a problem for a substantial number of patients *(14,*

19). Four patients in our study developed extensor tenosynovitis secondary to insertion of the plate. All of these patients required implant removal and were subsequently asymptomatic. Hahnloser et al *(12)* believe that the Pi-plate is bulky compared with the thin soft tissue coverage in this area and the juxta-articular band is responsible for irritating the extensor pollicis longus tendon leading to tenosynovitis. Richards at the AO institute believes that the main cause of tenosynovitis is titanium. Although titanium has distinct advantages over other biomaterials in avoiding the creation of connective tissue thickening and a fluid filled void between the implant and tissue *(25)*, it produces increased adhesion formation around the gliding surface of the overlying tendons, thereby causing inhibition of tendon excursion and reduced final motion of distal joints (personal communication). However, the reasons why some patients develop extensor tenosynovitis and some do not are still unknown. We believe that careful subperiosteal dissection and closure of the extensor retinaculum over the plate can reduce the incidence of extensor tenosynovitis, but not necessarily suppress it *(4)*.

There was one case of flexor pollicis tendon rupture in our study. This was due to the protruding end of a self-tapping screw on the volar surface of the radius which initially irritated and subsequently ruptured the tendon. This patient required implant removal and flexor tendon reconstruction and went on to make an uneventful recovery. Our implant removal rate for extensor tenosynovitis and limitation of flexion was 23% which is higher than Ring et al *(21)* (18%) and Campbell *(3)* (12%). Our study also shows that the minimum follow-up required for the patients who have this implant is one year, as extensor tenosynovitis can develop as late as eight months after surgery.

Finally, we believe that the Pi-plate is an effective implant which allows complex fractures of the distal radius to be treated by internal fixation with good functional results but not without complications. Articular congruity is essential for avoiding post-traumatic osteoarthritis. This has been reflected in our results where there were no cases of radiological arthritis. However, extensor tenosynovitis associated with restriction of flexion remains a problem. It is worthwhile to consider elective removal of the implant at fracture union as suggested by Fitoussi and Chow *(9)* and also by Jupiter (personal communication), or to consider a volar placed implant that avoids these complications completely.

We acknowledge that this is a small series but it does add to the literature data on the Pi-plate and shows a significant rate of extensor tenosynovitis with the use of this implant.

CONCLUSIONS

The satisfactory functional outcome achieved in the majority of patients in our study has strengthened the case for open reduction and internal fixation of complex, intra-articular fractures of the distal radius.

The dorsally placed, AO Pi-plate is an effective implant for restoring intra and extra-articular alignment of complex, intra-articular fractures of the distal radius.

There remains a risk of developing extensor tenosynovitis along with limitation of flexion and hence this implant should be used cautiously and perferably only by experienced surgeons.

Patients need to be followed up for at least a year as extensor tenosynovitis can develop as late as eight months after fracture fixation.

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