

Operative treatment of distal radial fractures with locking plate system—a prospective study

Kenny Kwan · Tak Wing Lau · Frankie Leung

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Abstract The aim of this study was to determine the results of operative treatment of distal radial fractures with a 2.4-mm locking plate system in a single tertiary teaching hospital. Seventy-five patients were recruited into the study between May 2004 and November 2006. There were 41 males and 34 females, with a mean age of 51. Seventy-five percent of patients had AO type C fractures. All patients were allowed free active mobilisation of the wrist joint immediately after surgery. They were followed up at two weeks, three months, six months, one year and two years. Assessments of pain, motion, grip strength, and standard radiographs were performed. The Gartland and Werley functional scores, the modified Green and O'Brien score, and the disabilities of the arm, shoulder and hand (DASH) scores were recorded. The radiographic results at the final follow-up showed a mean of 18° of radial inclination, 5° of volar tilt, 1.3-mm radial shortening, and no articular incongruity. Twenty-nine percent of patients showed grade 1 osteoarthritic changes and 6% had grade 2 changes in their final follow-up radiographs. An excellent or good result was obtained in 98% and 96% of patients according to the Gartland and Werley, and modified Green and O'Brien scores, respectively. The mean DASH score was 11.6, indicating a high level of patient satisfaction. Internal fixation of distal radial fractures with a

2.4-mm locking plate system provided a stable fixation with good clinical outcomes and patient satisfaction.

Introduction

Open reduction and internal fixation of distal radial fractures with an angular stable locking plate applied to the volar surface has gained vast popularity recently [1, 4, 12, 13]. It provides a stable fixation of osteoporotic bones, leading to anatomical restoration of the articular surface and extra-articular alignment [11]. It also facilitates immediate free mobilisation of the wrist joint. However, there are few systematic studies in the literature evaluating the efficacy of locking plate fixation using objective and subjective assessments.

We performed a prospective case study in a single tertiary teaching hospital to document the outcomes of open reduction and internal fixation of distal radial fractures over a two-year period. Our objective was to study the efficacy of this method of fixation by assessing its ability to maintain radiographic reduction and evaluating its functional outcome using validated measures over time.

Materials and methods

Between May 2004 and November 2006, we treated and prospectively evaluated the outcomes of operative treatment of 82 patients with distal radial fractures using the angular stable 2.4-mm locking plate fixation (Synthes, Switzerland). The indication for surgery was a displaced fracture of distal radius after an unsuccessful closed reduction or articular disruption. Patients were not excluded based on age, medical co-morbidities or bone quality, but patients with an operative

K. Kwan (✉) · T. W. Lau
Department of Orthopaedics and Traumatology,
Queen Mary Hospital,
102 Pokfulam Road,
Hong Kong Island, Hong Kong
e-mail: k.kwan@doctors.org.uk

F. Leung
Department of Orthopaedics and Traumatology,
University of Hong Kong,
Pokfulam, Hong Kong Island, Hong Kong

procedure performed one month after the initial injury and polytraumatised patients with an injury severity score [2] of >16 were excluded from the study.

Patient demographics and characteristics

Seven of the 82 patients were not available for follow-up after two weeks and were excluded from the study. Of the 75 patients, 41 were men and 34 were women, with a mean age of 51 years (range, 13–82 years). The majority of the patients (74 out of 75) were right-hand dominant. The cause of injury was a low energy mechanical fall in 49 patients (65%), work-related in 14 patients (18%), road traffic accident in six patients (8%) and sports-related injury in seven patients (9%). According to the Müller-AO comprehensive classification, 18% of the fractures were type A, 7% were type B, and 75% were type C. Associated ulnar injuries were involved in ten patients: nine patients had ulnar styloid fractures, four of which occurred at the ulnar styloid base with displacement, and one had a distal ulna shaft fracture. Confirmed triangular fibrocartilage complex (TFCC) tears were found in five patients, and concomitant injuries in six patients (two with rib fractures, one with fracture of distal phalanx of the middle finger, a scaphoid fracture in one, one scapula fracture, and one with clavicle and patella fractures). There were no open fractures.

Operative details

The time from injury to surgery ranged from zero to 27 days, with a mean of six days. A standard volar approach over the flexor carpi radialis (FCR) tendon was used with the interval of dissection between the FCR and the radial artery. The pronator quadratus was lifted from the radial border, and the muscle was retracted ulnarly. The volar aspect of the distal radius and the fracture were identified. In seven cases (9%) where the articular reduction could not be achieved through the volar approach, a separate dorsal approach through the third and fourth dorsal compartments was made. Wrist arthroscopy was only performed in cases of instability of the distal radio-ulnar joint (DRUJ) intra-operatively after fixation of the distal radius to visualise the status of TFCC. The TFCC is attached to the ulnar styloid base and a displaced fragment can lead to DRUJ instability and contribute to a poor functional outcome. Therefore, ulnar styloid base fractures with a displacement of more than 2 mm were also fixed with tension band wiring. The 2.4-mm locking plate system used in this study is composed of low profile titanium-alloy plates and screws with different shapes. Its design allows smaller fragments to be addressed individually, decreases irritation of tendon and soft tissues, and permits a more distal placement of the plate. We used a combination of the

juxta-articular volar plates, and right-angle L, T and straight plates, which are pre-contoured to support the radial and intermediate columns (Figs. 1 and 2). All procedures were performed by the senior authors (FL and TWL) or under their supervision.

One fracture was supplemented with Kirschner wire fixation, and one case required bone grafting. Out of the associated ten ulna fractures, four cases (5%) of displaced ulnar styloid base fractures with displacement of >2 mm were fixed with tension band wiring, and one case of a distal shaft fracture underwent internal fixation using a locking plate. TFCC repair was performed under arthroscopic guidance in three cases (4%) and the other two patients were treated conservatively. A Herbert screw fixation was undertaken in one case associated with scaphoid fracture.

All patients had a Redivac drain inserted, which was removed on the first post-operative day, and a light dressing was applied. Free active mobilisation of the wrist joint was initiated immediately, and the patients were discharged between two and five days post-operatively.

Follow-up protocol

All patients were followed up in a designated out-patient clinic two weeks after the operation for wound check and suture removal. Assessments by the physiotherapists and occupational therapists were performed during the visit. Thereafter, follow-up evaluations were done at three months, six months, one year and two years after the surgery. At each visit, measurements of wrist and forearm range of motion (pronation, supination, dorsiflexion, volarflexion, radial deviation and ulnar deviation) were taken using a standard goniometer. Grip strength was measured using a dynamometer and compared with that of the contralateral side.

Physician-rated functional outcomes were documented using the scoring system of Gartland and Werley [6] and the Green and O'Brien scale [8] as modified by Cooney et al. [5]. In addition, patient-rated outcomes were documented using the Chinese (QMH, Hong Kong Version, Institute for Work & Health, 2006) disabilities of the arm, shoulder, and hand (DASH) questionnaire.

Post-operative postero-anterior and lateral radiographs were taken during each visit. Measurements were recorded according to the criteria defined by Kreder et al. [10]. On the postero-anterior film, the radial length, radial angle, articular step-off and gap were measured. On the lateral film, the palmar tilt angle and articular step-off and gap were measured. Union of fracture was defined as trabecular bridging across the fracture site. Articular incongruity and osteoarthritis were assessed, as described by Knirk and Jupiter [9], at the one-year and two-year follow-up radiographs. Grade 0 indicated no osteoarthritis; grade 1 indicated

Fig. 1 Pre-operative radiographs of a 66-year-old woman with AO type C3.2 distal radius fracture due to a simple fall (**a**, **b**). Post-operative radiographs after dorsal fixation in the radial and middle column revealing that the articular congruity was restored (**c**, **d**)



joint spaces narrowing; grade 2 indicated marked joint space narrowing with sub-articular sclerosis; and grade 3 indicated a complete loss of joint space with bone-on-bone contact, marked sclerosis and osteophyte formation.

Statistical analyses

Continuous variables were described using means and standard deviations with ranges. Statistical analyses were performed using Student's *t* test and multivariate analysis of variance (MANOVA). *P* values of ≤ 0.05 were considered significant.

Results

Of the 75 patients included in the study, all (100%) were available for follow-up at three months, 71 (95%) at

six months, 68 (91%) at one year, and 51 (68%) at two years.

Radiographic evaluation

All fractures united at the three months follow-up. At final follow-up, there was a mean of 18° of radial inclination, 5° of volar tilt, 1.3-mm radial shortening, and no articular incongruity. The radial inclination and volar tilt did not show any significant change from surgery to final follow-up. There was an increase in radial shortening between the surgery and the final review. Articular congruity with less than 1-mm articular step-off was seen in the post-operative radiographs in 55 of 59 type B and C fractures and less than 1-mm articular gap in 49 of 59 type B and C fractures. At the final follow-up, 55 of 59 distal radius had less than 1-mm step-off, and 54 of 59 joints had 1 mm or less gap. No extra-articular (type A) fractures showed any articular

Fig. 2 Pre-operative radiographs of a 67-year-old woman with AO Type C3.1 distal radius fracture and ulnar styloid fracture with a “ski-slope” sign (a, b). Post-operative radiographs after volar fixation in the radial and middle column, and tension band wiring of the ulnar styloid (c, d)



incongruity in the immediate post-operative and final follow-up radiographs.

By the final follow-up, 22 patients (29%) had grade 1 osteoarthritic changes, and five patients (6%) had grade 2 changes according to the criteria of Knirk and Jupiter. Type B and C fractures had a greater tendency to be associated with osteoarthritic changes.

Clinical evaluation

At the final follow-up, the mean range of wrist motion consisted of 80 ± 9 degrees of pronation, 86 ± 7 degrees of supination, 57 ± 10 degrees of dorsiflexion, 51 ± 13 degrees of volarflexion, 18 ± 7 degrees of radial deviation, and 28 ± 7 degrees of ulnar deviation. The mean grip strength on the injured side was 83% (range, 9.6–138%) of that on the uninjured side. We found that the range of motion tended to

regain less with increasing age, but only reached statistical significance for supination ($p=0.05$) and ulnar deviation ($p<0.05$). All patients were able to return to domestic duties or to their occupations when examined at the one year follow-up.

According to the score of Garland and Werley, 68 (91%) patients had excellent results and five (7%) had good results. According to the modified Green and O'Brien scores, there were 66 (88%) patients with excellent results and six (8%) patients with good results. Seventy (93%) DASH questionnaires were available for analysis. Five patients did not respond to the questionnaires. The mean DASH score for the disability/symptom module was 11.6 ± 14.6 and for the work module it was 14.5 ± 22.5 . Age affected the functional outcome of fixation, i.e. both the Garland and Werley and the modified Green and O'Brien scores were worse with increasing age ($p<0.01$). However,

no statistically significant effect was observed between age and the DASH score ($p=0.73$).

We did not find any statistical difference in any parameters between low and high energy fractures.

Complications

There were 11 complications reported in ten patients (13%). One patient was found to have a screw placed in the subchondral region and screw adjustment was performed the next day. Loss of reduction occurred in one patient at one month and required a revision fixation, and in two patients at three months and six months, respectively. There was one case each of DISI and VISI. Carpal tunnel syndrome was reported in three cases and open release was performed.

There were two cases of tendon irritation, with one involving the extensor pollicis longus, and the other flexor pollicis longus. Both were treated conservatively and the symptoms subsided.

In 33 patients (44%), the plating system was removed at a mean of 42.2 weeks (range, 17.7–101.3 weeks) after the initial operation.

Discussion

The importance of restoring the anatomical alignment and articular congruity is well-recognised in the fixation of distal radial fractures. Intra-articular incongruity has been shown to correlate with post-traumatic arthritis [2], whilst malalignment can lead to decreased grip strength, reduced range of motion and instability [6]. Internal fixation results in a better restoration and preservation of radial length and volar tilt compared with external fixation [11]. The advent of the locking plate system provides a more secure and reliable fixation for osteoporotic bones.

The smaller 2.4-mm implants have been designed to address the increasingly complex fracture patterns encountered in osteoporotic bones. The plates and locking-head screws are smaller than the traditional 3.5-mm system, so fracture fragments can be addressed individually. The smaller profile plates allow a more distal placement, hence a more subchondral fixation, with less tendon and soft tissue irritation. The smaller T- and straight plates permit a fragment-specific approach in accordance with the three-column theory in distal radius fracture fixation. In our series, whilst the majority of patients (69%) were treated with a single juxta-articular volar locking plate, 23 patients (31%) had either an additional radial styloid plate or individual columnar fixation. The availability of this type of fixation allowed improved stability in the fixation of more comminuted fractures.

Our series demonstrated there was no significant difference in the radial length and volar tilt comparing radiographs immediately following operation with those at final follow-up. Hence the radiographic reduction achieved post-operatively can be effectively maintained over time with this method of fixation. These results are comparable with other published studies using volar plating of distal radial fractures [1, 3, 7, 12, 13].

Both the Gartland and Werley and modified Green and O'Brien scores demonstrated that the overall physician-rated functional outcomes were satisfactory. The final DASH scores in our study were at the high end of the range compared with other series with patients treated with volar locking implants. This may reflect a higher proportion of complicated type B and C fractures in our study. All movements of the wrist and forearm, and the grip strength reached an excellent level according to the Gartland and Werley score.

When the range of motion was analysed according to age, there was a trend that the elderly patients seemed to regain less motion. This was reflected in the Gartland and Werley and the modified Green and O'Brien scores, which were scoring systems done by mainly objective evaluations. This age-related effect, however, was not seen in the patient self-assessment of the upper extremity disability using the DASH questionnaire.

Full restoration of hand function is the desired outcome of distal radial fracture fixation. Our results suggest that the evaluation of such outcome is not straight forward, since the objective parameters do not necessarily correlate with subjective evaluation. Although the elderly may not regain as much motion as younger patients, their demand may be less and their self-assessment of the disability is therefore less. The choice of traditionally-used evaluation outcome scores which consist of mainly objective parameters also may not truly represent the functional outcome as they lack the evaluation from the patient. Our complication rate was representative of the spectrum of anticipated problems with the locking plate system. It was of interest to observe the particularly high rate of implant removal, mostly initiated by the patients, despite the low-profile system used. It may be related to both flexor and extensor tenosynovitis which has been reported by different authors [1, 3].

The strength of our study is that all procedures were performed in a single centre by or under the supervision of two experienced surgeons; thus, the principle and concept of fixation were consistent. The follow-up evaluations were also conducted with the same group of surgeons and physiotherapists. In addition, we obtained a good follow-up rate with only 9% and 32% of patients lost to follow-up at one and two years respectively. Overall, we believe this study has demon-

strated a good clinical outcome with no loss of radiographic reduction using the 2.4-mm locking plate system in the fixation of distal radial fractures. However, a prospective randomised controlled trial is required to resolve whether this system of internal fixation is superior to other treatment modalities.

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