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Fragment-specific fixation for complex intra-articular fractures of the distal radius: results of a prospective single-centre trial

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Abstract
The goal was to evaluate the efficacy of 2.4 mm column-specific plating for intra-articular distal radius fractures. In total, 105 patients with AO type C distal radius fractures were operated on using the locking distal radius system, Synthes. Follow-up assessments including clinical (wrist and forearm range of motion, grip strength), radiological (articular step, radial length and inclination, volar tilt, and ulnar variance), and functional scores (Disabilities of the Arm, Shoulder, and Hand; Patient Rated Wrist Evaluation) were made at regular intervals until 1 year. Union was obtained in all patients. Articular surface was anatomically reconstructed in 74 patients (70.5%). Clinical and functional evaluation showed significant continuous improvements over the first year. C1 fractures had a better chance of anatomical reduction compared with C2 and C3 fractures. Fracture type, quality of reduction, and presence of degenerative changes did not show a significant effect on functional outcome scores. Column-specific fixation of the distal radius can achieve satisfactory results in complex intra-articular fractures.

Keywords
Distal radius, intra-articular fractures, distal radius columns, locked plating

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Introduction

Management of distal radius fractures has undergone a radical change over the past two decades. Though closed treatment is still widely followed, operative management is currently favoured for displaced intra-articular fractures where anatomical reduction and stable fixation are key for a satisfactory long-term outcome, especially in young and active patients. Internal fixation of these fractures has found widespread acceptance with the advent of locking plates, and satisfactory results have been previously reported. Improved knowledge of anatomy, better understanding of fracture biomechanics, better imaging techniques, and availability of newer implant designs (Harness et al., 2006; Chen et al., 2007) have also contributed to improved outcomes following internal fixation.

The use of anatomically precontoured self-locking plates has reduced soft tissue complications and improved fixation strength in osteoporotic bones (Medoff and Kopylov, 1998). The conventional 3.5 mm plating system has limited plate options, and it is difficult to fix small subarticular fragments, which can limit the surgeon's ability in handling complex intra-articular fractures. The 2.4 mm low profile plating system consisting of different plate configurations to fix the specific fractured columns has expanded the armamentarium needed to deal with complex fractures of the distal radius (Benson et al., 2006). Promising initial results with these systems have been reported for both intra- and extra-articular fractures. With this background, we initiated a prospective trial to study their effectiveness in complex intra-articular fractures of the distal radius.

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Methods

In total, 105 consecutive patients were enrolled in the study, which was conducted prospectively over 24 months (February 2008 to January 2010) at a single tertiary care centre. Mean age of patients was 43 (22–68) years, and the study group involved 62 males and 43 females. Inclusion criteria included any unilateral displaced intra-articular fracture of the distal radius in patients with closed physes. Informed written consent was obtained from all patients who participated in the trial, and the institutional review board approved the study. Fractures were classified according to the AO (Muller et al., 1990) system (types C1, C2, and C3 were included). Pathological fractures, patients with pre-existing arthritis compromising wrist function, open fractures, patients with fractures presenting more than 1 week after injury, and fractures in polytrauma patients with concomitant upper limb injuries that may have had an adverse impact on functional outcome were excluded.

Pre-operative data

Pre-operative assessment included a detailed history and clinical examination. In total, 103 patients were right-handed and the injury involved the dominant hand in 78 patients. The majority of patients ($n = 71$, 68%) had sustained a low-velocity fall, and the remaining 34 patients had a high-velocity injury; 23 due to road traffic accidents and 11 due to fall from a height. Thirteen patients had concomitant bony injuries in the lower limb, and 8 patients had fractures in the contralateral upper limb.

Pre-operative upper limb and wrist function before injury was retrospectively evaluated using the Disabilities of the Arm, Shoulder, and Hand (DASH) and Patient Rated Wrist Evaluation (PRWE) questionnaires. A DASH score of 0 represents no disability and 100 represents maximum disability (Dowrick et al., 2006). PRWE (Macdermaid et al., 1998) consists of 15 questions that specifically evaluate wrist function. A score of 0 indicates normal wrist function and 150 indicates maximum disability.

Pre-operative postero-anterior and lateral digital radiographs were taken in all patients. An independent radiologist and the senior author (ASG) read all radiographs, and disagreements were resolved through consensus. Three-D computerized tomographic (CT) scan of the involved wrist was obtained in all patients before surgery to quantify articular step-off and depression, for metaphyseal comminution, and to plan the surgical approach and modes of fixation. The surgery was done under supraclavicular block in 98 patients and general anaesthesia in 7 patients. The surgical approach, need for bone grafts/substitutes and number of plates to be used were planned as per the pre-operative CT examination, but decisions on table were left to the discretion of the treating surgeon. The implant used was the 2.4 mm locking distal radius system (LDRS, Synthes, India).

The modified Henry's approach using the interval between the flexor carpi radialis and radial artery was used when access to the volar distal radial cortex was required, and, if needed, a radial column plate was added through the same incision. Fractures with severe dorsal comminution were approached dorsally through the third compartment of the extensor retinaculum. Plating of the radial column, if needed, was approached between the first and second dorsal compartments. After the procedure, the extensor pollicis longus was exteriorized using the retinacular flap raised from the distal part of the retinaculum. A combination approach was used in complex fractures with dorsal and volar comminution. Radial column plates, if deemed necessary, were always used in combination with volar or dorsal plates.

Follow-up visits were conducted at 3 weeks, 6 weeks, 3 months, 6 months, and 1 year. At first follow-up visit, graded and supervised mobilization of the wrist and forearm was initiated after removal of the plaster or fixator. Posteroanterior and lateral X-rays of the involved wrist were taken immediately after surgery and at each follow-up visit. X-rays were assessed for articular congruity, loss of reduction, and fixation, hardware integrity, progress in union, and appearance or progression of arthritic changes. DASH and PRWE scores, wrist range of motion (ROM), forearm rotation, and grip strength were recorded at 6 weeks, 6 months, and 1 year. ROM was measured using a goniometer, and grip strength was measured using a dynamometer (Ekata, Kolkata, India) in kilograms and recorded as a percentage of the contralateral wrist.

Statistics

Statistical analysis was done using Stata, Version 11 for Windows. Categorical variables were expressed as absolute and relative frequencies and tested for significance using Pearson's chi-square test. Continuous variables were expressed as mean and standard deviation and analyzed using *t* tests. Random effects regression models fitted using the xtreg command were used to study the effect of fracture subtype and quality of reduction on DASH and PRWE scores. Risk of a non-anatomical fracture reduction with different fracture subtypes was studied by calculating odds ratio using logistic regression analysis. The *p* value was 2-sided, and significance was set at $p < 0.05$.

Results

There were 41 AO type C1 fractures, 31 C2 fractures, and 33 C3 fractures. The majority of patients were operated on using a volar approach (90, volar approach; 11, dorsal approach; 4, combined approach). A volar intra-articular plate alone was used in 58 patients (55%). A total of 158 plates were used in 105 patients (1.5 per patient). Bone graft substitute (JECTOS) was used in four patients. Wrist spanning external fixator was used in six patients to provide additional stability.

Functional outcome

In total, 78 patients (74%) were working prior to injury, and 75 (96%) of them returned to their original occupation at a mean of 58 (21–122) days. Three patients were lost to follow-up at 6 months, and there was a further loss of four patients at 1 year. A total of 98 patients were available for final follow-up 1 year after surgery.

The mean pre-injury DASH score was 2 (SD 1.7) and PRWE score was 0.74 (SD 1.1). There were significant improvements in DASH and PRWE scores between the contiguous timeframes of testing over the 1 year study period. However, scores at 1 year did not reach baseline values (Figure 1). Fracture subtypes and quality of reduction did not show a statistically significant effect on follow-up DASH and PRWE scores: $p = 0.753$ (fracture type) and 0.17 (quality of reduction) for DASH; $p = 0.75$ (fracture type) and $p = 0.09$ (quality of reduction) for PRWE. Similar trends in improvement were seen in mean grip strength, flexion-extension arc of the wrist, and forearm rotation (Figure 2) over 1 year.

Radiological outcome

Union was achieved in all patients (Figures 3–6). The articular surface was anatomically reconstructed in 74 patients (70.5%). Of the 31 patients with non-anatomical articular reductions, nine patients had an initial articular step > 2 mm. Overall, 88% of C1 fractures were reduced anatomically compared with 65% and 55% for types C2 and C3, respectively. The odds of a good reduction are 0.25 (0.077–0.83) for C2 fracture and 0.17 (0.05–0.53) for C3 fracture compared with the C1 subtype. The chances of a good reduction in C2 and C3 subtypes are significantly less than that of group 1 by 75% and 83%, respectively.

In the immediate post-operative radiographs, the mean radial length was 10 (SD 1.9) mm; radial inclination, 19.4° (SD 2.8°); volar tilt, 7.4° (SD 3.4°); and ulnar variance, 0.6 (SD 1.2) mm. There were no significant changes in these values at final follow-up (Figure 7). Follow-up loss in radial inclination and radial length were significantly lower at 1 year with the addition of radial column plate ($p < 0.01$ for radial inclination; $p < 0.032$ for radial length) compared with the use of volar or dorsal plates alone. Radiological evidence of arthritis, grade 1 according to the grading system of Knirk and Jupiter (1986), was seen in 3 patients at 6 months and 11 patients (11.2%) at 1 year. Eight of the 11 patients (73%) had initial malreduction of the articular surface. Radiological presence of arthritis did not significantly alter the 1-year DASH ($p = 0.12$) and PRWE ($p = 0.3$) scores compared with patients without arthritis.

Complications

Loss of reduction was seen in five patients (5.1%). There were unaddressed dorsal comminution in four cases,

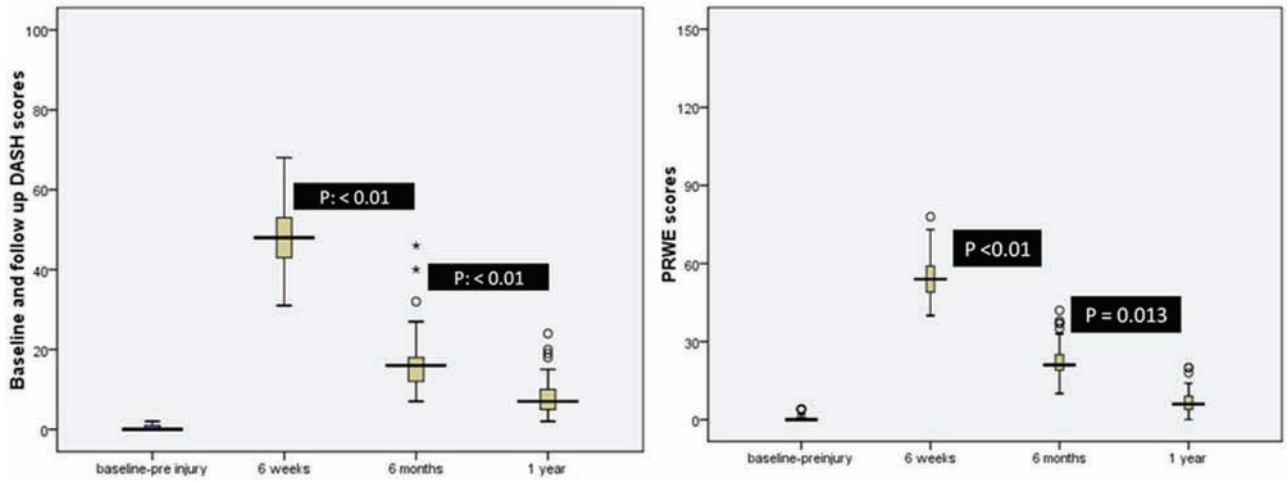

Figure 1. Box plots showing baseline and follow-up DASH and PRWE scores. *p* values indicate significant improvement in scores between contiguous timeframes of assessment.

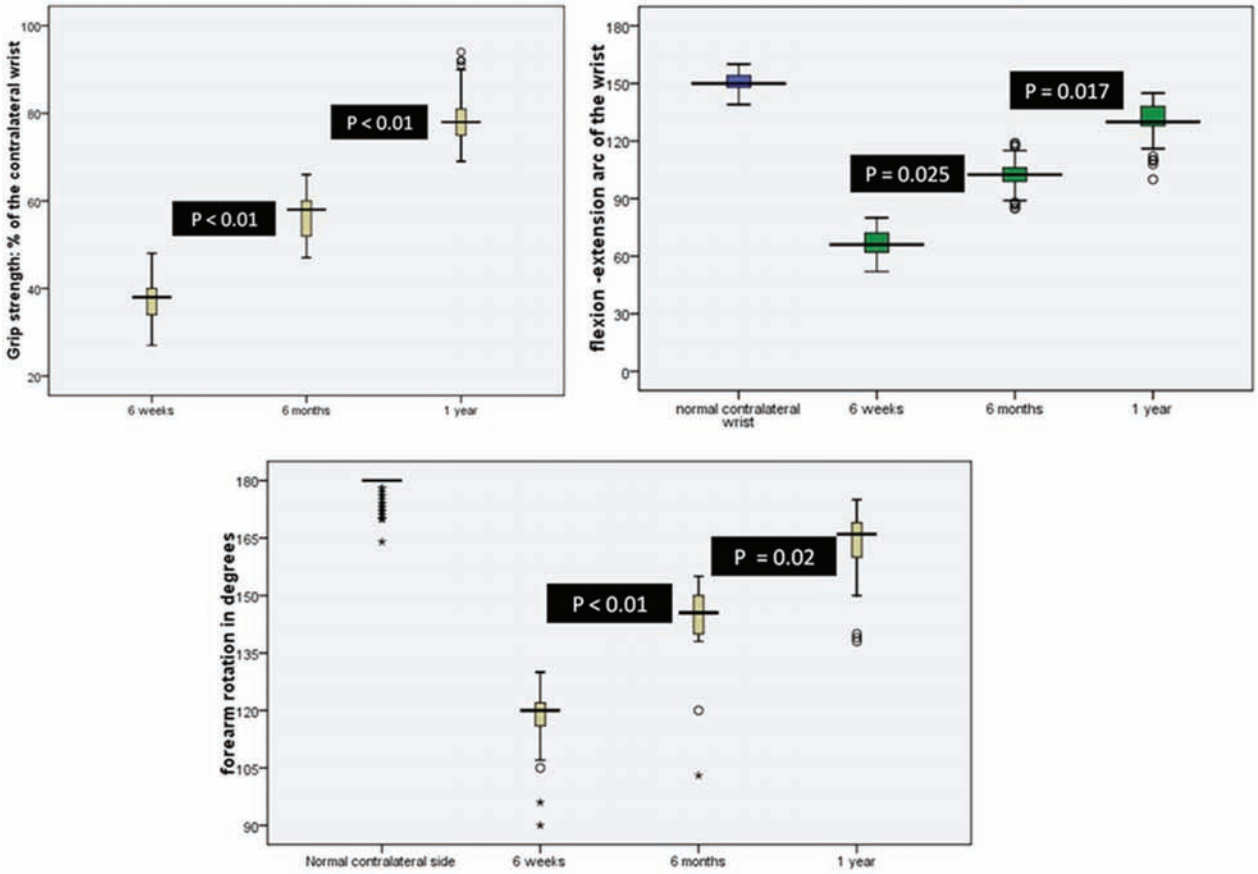

Figure 2. Wrist and forearm range of motion and grip strength over 1 year post-surgery show continuous improvement as evident from the *p* values.

Figure 3. AO type C3 fracture with severe fragmentation of the volar cortex. Follow-up X-rays following orthogonal plating shows reasonable articular reduction and restoration of radial height and angle.

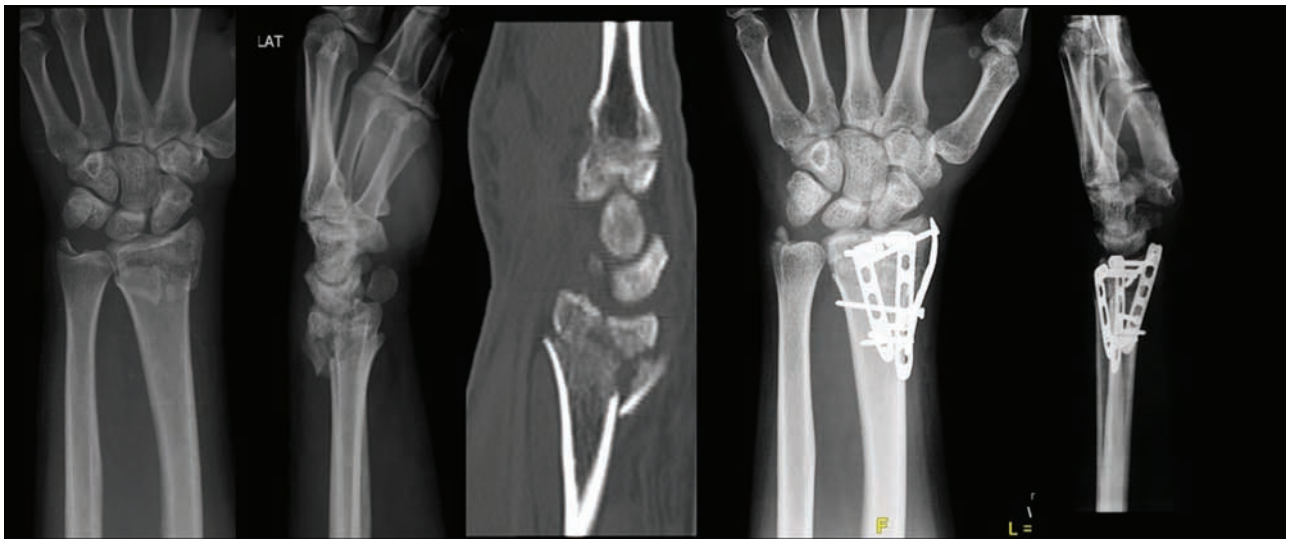

Figure 4. Intra-articular fracture involving both cortices with dorsal comminution and carpal subluxation. Final result shows good articular restoration and some loss of volar tilt.

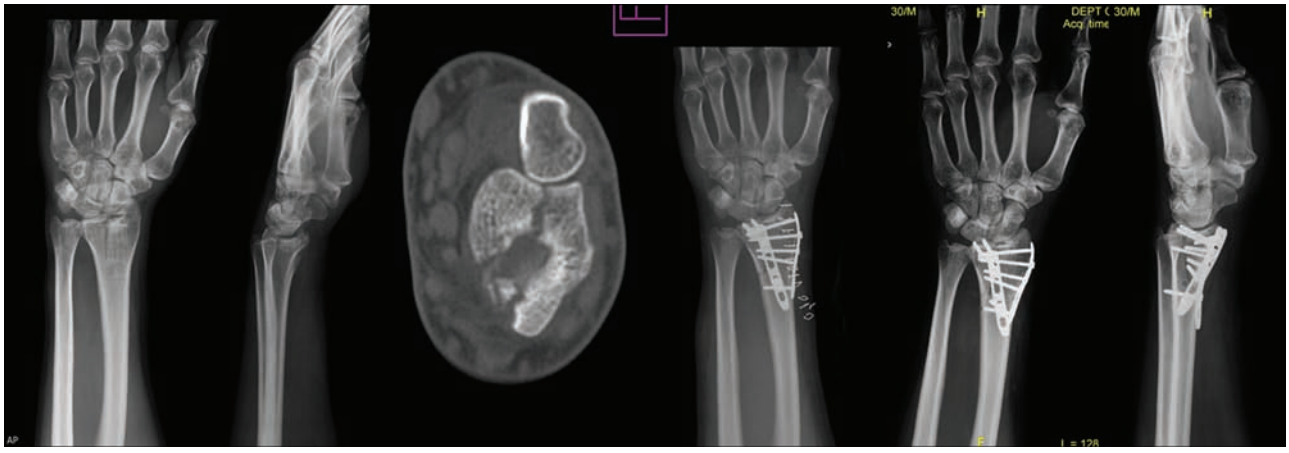

Figure 5. AO type C3 fracture with articular impaction and fracture of the volar lunate facet. Follow-up X-rays after articular elevation and fixation of radial and intermediate columns show anatomical reduction.

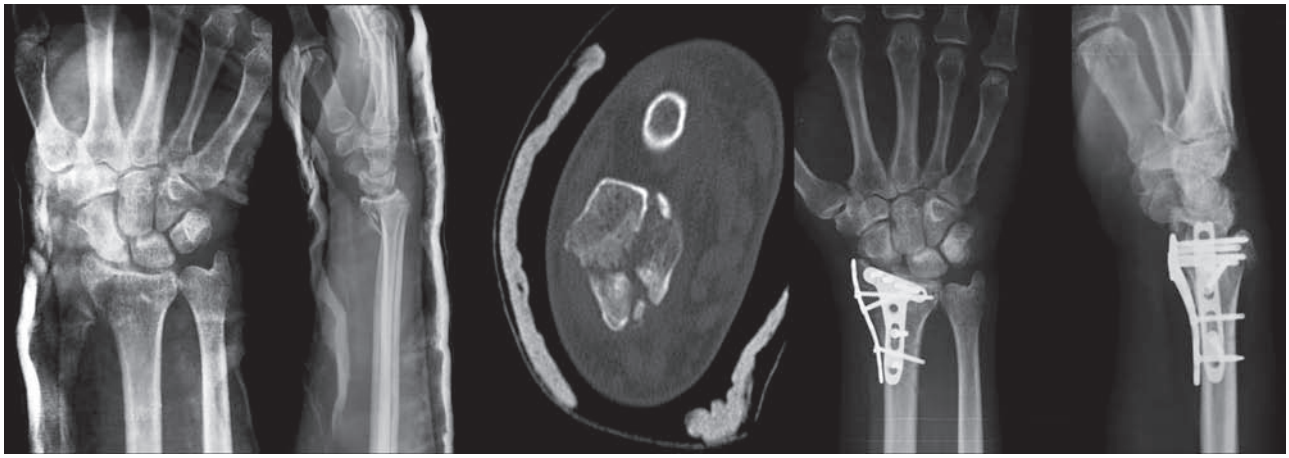

Figure 6. C3 fracture treated with volar and radial plates. Residual displacement of the dorso-ulnar fragment is evident.

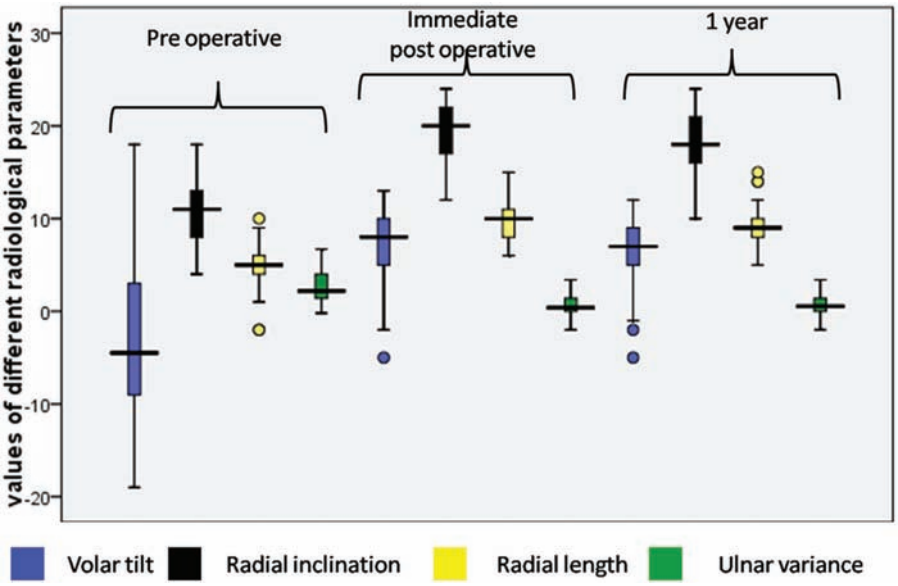

Figure 7. Box plot groups representing the tested radiological parameters. There was no significant difference between post-op and final follow-up values.

and one patient had volar carpal subluxation. Secondary surgical procedures were carried out in three patients: addition of a dorsal plate in one patient, volar plate repositioning in one patient, and corrective osteotomy and Sauve–Kapandji fusion in one patient for residual dorsal tilt and distal radioulnar joint arthritis. Three patients refused revision surgery.

There were no incidences of tendon rupture. Eight cases (8.1%) of tendinitis were seen: six flexor and two extensor. All cases settled with conservative treatment. Flexor tendinitis was causes by prominent volar plate due to dorsal fracture settling or poor initial plate placement. Superficial skin infection was seen in five patients, and there were no incidences of deep infection. Reflex sympathetic dystrophic changes were seen in three patients and were treated appropriately.

Discussion

The results of internal fixation of distal radius fractures over the past two decades have shown consistent improvement with the availability of improved fixation systems (Rozental and Blazar, 2006). Fragment-specific fixation systems use low profile plate designs intended to fix individual fragments and 2.4 mm recessed locking head screws to reduce soft tissue impingement. Dodds et al. (2002) have demonstrated the biomechanical advantage of these column-specific systems.

Most of intra-articular fractures can be managed using the volar approach. Indications for dorsal or a combined approach would be a displaced dorso-ulnar fragment of the intermediate column, dorsal comminution, and presence of impacted articular fragments. Buttressing of the radial column significantly increases the stability of fixation, as shown by better preservation of radial inclination and length in our study.

Dorsal settling of the fracture, as reported in our study, can occur with the use of volar plates alone, especially in osteoporotic bones with dorsal comminution. Distal placement of volar intra-articular plates to improve subchondral purchase and addition of a dorsal buttress can help avoid this complication (Drobetz et al., 2006; Orbay and Fernandez, 2002). The volar lunate facet is very distal, and fractures involving the facet can be easily missed on X-rays (Andermahr et al., 2006). Presence of a displaced volar lunar facet fragment has to be appreciated on pre-operative CT scan and proper plate placement has to be ensured to avoid volar carpal subluxation (Harness et al., 2006).

The LDRS provides near anatomical dorsal plate designs, which significantly reduces the problems of tendinitis and attritional tendon ruptures reported with dorsal plate application (Cohen et al., 2006; Rikli and Regazzoni, 2000). We only had two cases of extensor tendinitis, and both were due to longer screws from the volar plate. The screws in the distal row of the volar plates should be unicortical and the proximal screws should be sized correctly to prevent dorsal soft tissue irritation. Flexor tendinitis can occur due to improper plate placement or dorsal fracture settling in osteoporotic bones. Appropriate contouring at the undercuts provided in the distal row can also prevent tendon

irritation due to prominent edges of the volar plates. Jupiter et al. (2009) have recently reported similar results with minimal tendon-related complications using a similar fixation system.

The study showed that fracture pattern has a significant influence on the quality of articular reduction achieved. The incidence of degenerative changes was also much higher in patients with malreduced joint surface. The patient reported functional scores failed to show any statistical difference with respect to articular malreduction or presence of arthritic changes. Longer follow-up of these patients may better explain the effects of articular malreduction on wrist function and progression of arthritic changes.

To our knowledge, no paper has been published that has evaluated the efficacy of this system exclusively in complex intra-articular fractures. Limitations of the study include a relatively short follow-up period and lack of controls to draw definitive conclusions. The beneficial effects of good articular reduction and the long-term effects of degenerative changes on wrist function can be determined only in long-term randomized control trials. The strengths of the study include homogenous fracture subtypes in a relatively large volume of patients and excellent follow-up rates. The study was performed at a single centre and three experienced surgeons performed the operations. Multiple objective and subjective measures were used to assess functional outcomes. PRWE was used to assess wrist function without the confounding effects of the DASH scores (MacDermid et al., 1998).

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The study was approved by the institutional review board and informed consent forms were obtained from all patients.

Conflict of interests

None declared.

References

Andermahr J, Lozano-Calderon S, Trafton T, Crisco JJ, Ring D. The volar extension of the lunate facet of the distal radius: a quantitative anatomic study. J Hand Surg Am. 2006, 31: 892–5.

Benson LS, Minihane KP, Stern LD et al. The outcome of intra-articular distal radius fractures treated with fragment-specific fixation. J Hand Surg Am. 2006, 31: 1333–9.

Chen NC, Jesse B, Jupiter J. Management of distal radial fractures. J Bone Joint Surg Am. 2007, 89: 2051–62.

Cohen MS, Turner TM, Urban RM. Effects of implant material and plate design on tendon function and morphology. Clin Orthop Relat Res. 2006, 445: 81–90.

Dodds SD, Cornelissen S, Jossan S et al. A biomechanical comparison of fragment-specific fixation and augmented external fixation for intra-articular distal radius fractures. J Hand Surg Am. 2002, 27: 953–64.

Dowrick AS, Gabbe BJ, Williamson OD, Cameron PA. Does the disabilities of the arm, shoulder and hand (DASH) scoring system only measure disability due to injuries to the upper limb? J Bone Joint Surg Br. 2006, 88: 524–7.

Drobetz H, Bryant AL, Pokorny T, Spitaler R, Leixnering M, Jupiter JB. Volar fixed-angle plating of distal radius extension fractures: influence of plate position on secondary loss of reduction—a biomechanic study in a cadaveric model. J Hand Surg Am. 2006, 31: 615–22.

Harness NG, Ring D, Zurakowski D, Harris GJ, Jupiter JB. The influence of three-dimensional computed tomography reconstructions on the characterization and treatment of distal radial fractures. J Bone Joint Surg Am. 2006, 88: 1315–23.

Jupiter JB, Marent-Huber M; LCP Study Group. Operative management of distal radial fractures with 2.4-millimeter locking plates. A multicenter prospective case series. J Bone Joint Surg Am. 2009, 91: 55–65.

Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. J Bone Joint Surg Am. 1986, 68: 647–59.

MacDermid JC, Turgeon T, Richards RS, Beadle M, Roth JH. Patient rating of wrist pain and disability: a reliable and valid measurement tool. J Orthop Trauma. 1998, 12: 577–86.

Medoff RJ, Kopylov P. Immediate internal fixation and motion of comminuted distal radius fractures using a new fragment specific fixation system. Orthop Trans. 1998, 22: 165.

Muller ME, Nazarian S, Koch P, Schatzker J. *The comprehensive classification of fractures of long bones*. Berlin, Springer-Verlag, 1990.

Orbay JL, Fernandez DL. Volar fixation for dorsally displaced fractures of the distal radius: a preliminary report. J Hand Surg Am. 2002, 27: 205–15.

Rikli DA, Regazzoni P. The double plating technique for distal radius fractures. Tech Hand Up Extrem Surg. 2000, 4: 107–14.

Rozental T, Blazar P. Functional outcome and complications after volar plating for dorsally displaced unstable fractures of the distal radius. J Hand Surg Am. 2006, 31: 359–65.