WRIST AND HAND

Arthroscopic assistance does not improve the functional or radiographic outcome of unstable intra-articular distal radial fractures treated with a volar locking plate

A RANDOMISED CONTROLLED TRIAL

There is no consensus on the benefit of arthroscopically assisted reduction of the articular surface combined with fixation using a volar locking plate for the treatment of intra-articular distal radial fractures. In this study we compared the functional and radiographic outcomes of fluoroscopically and arthroscopically guided reduction of these fractures.

Between February 2009 and May 2013, 74 patients with unilateral unstable intra-articular distal radial fractures were randomised equally into the two groups for treatment. The mean age of these 74 patients was 64 years (24 to 92). We compared functional outcomes including active range of movement of the wrist, grip strength and Disabilities of the Arm, Shoulder, and Hand scores at six and 48 weeks; and radiographic outcomes that included gap, step, radial inclination, volar angulation and ulnar variance.

There were no significant differences between the techniques with regard to functional outcomes or radiographic parameters. The mean gap and step in the fluoroscopic and arthroscopic groups were comparable at 0.9 mm (standard deviation (SD) 0.7) and 0.7 mm (SD 0.7) and 0.6 mm (SD 0.6) and 0.4 mm (SD 0.5), respectively; \( p = 0.18 \) and \( p = 0.35 \).

Arthroscopic reduction conferred no advantage over conventional fluoroscopic guidance in achieving anatomical reduction of intra-articular distal radial fractures when using a volar locking plate.

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Fractures of the wrist are increasingly being managed surgically,\(^1\) and several authors have described the merits of using arthroscopy in the treatment of intra-articular fractures of the distal radius.\(^2\)\(^-\)\(^10\) Arthroscopy is less invasive than arthrotomy and provides a magnified view of the articular surface. On the other hand, this technique is technically demanding requiring additional time, equipment, training, expense and experience. Fluoroscopy is, however, technically easier and a more readily available means of assessing reduction of the articular surface. We believe that fluoroscopic reduction with a high-quality image intensifier is comparable with arthroscopic reduction.

Volar locking plates have been reported to offer better outcomes than external fixation combined with percutaneous pin fixation,\(^11\)\(^-\)\(^13\) as they allow the intra-articular step to be minimised.\(^14\) These studies raise the possibility that the outcome following arthroscopically assisted reduction could be even better when combined with volar locking plating. However, the techniques of fixation described in previous studies demonstrating the merits of arthroscopic reduction involved external fixation only.\(^8\)\(^-\)\(^10\) In this study our aim was to determine whether fluoroscopically assisted reduction offered comparable functional and radiographic outcomes with arthroscopically assisted reduction combined with fixation using a volar locking plate for the treatment of intra-articular fractures of the distal radius.

Patients and Methods

Between February 2009 and May 2013, 74 of 85 patients with an unilateral unstable intra-articular fracture of the distal radius who met our criteria were assigned randomly into either a fluoroscopic or an arthroscopic reduction group (Fig. 1). The mean age of these 74 patients was 64 years (24 to 92). All fractures were stabilised by a volar locking plate, and the groups were compared with respect to functional and radiographic outcomes. One of the authors (HY) performed the random allocation by opening a sealed envelope containing an equal number of cards labelled for treatment by one of the two methods. The patients
The indications for open reduction and internal fixation included AO type C\textsuperscript{15} fracture of the distal radius with articular displacement following manipulation involving a gap or step deformity $\geq 2$ mm on CT scans with or without a volar tilt $< 0^\circ$; radial inclination $< 10^\circ$; and radial shortening $> 4$ mm.

Exclusion criteria were: age $< 20$ years; inability to give informed consent; pathological fractures; a history of osteoporosis, drug or alcohol abuse; open fractures; bilateral fractures; any associated soft-tissue or skeletal injuries to the same limb, or severe multisystem injuries that would have a confounding effect on the assessment of outcome; pre-existing osteoarthritis (OA) of the wrist or disability; $> 14$ days between injury and surgery; fractures not conforming to AO type C; and an associated ulnar fracture other than of the ulnar styloid.

The study had ethical approval and was registered at the University Hospital Medical Information Network Clinical Trials Registry (UMIN000014052). All patients gave informed consent.

**Patient characteristics.** The demographic data of patients, including age, gender, type of fracture, interval between injury and operation, and dominant hand were recorded. The type of fracture was ascertained from CT scans in all patients (Table I).

**Operative procedures.** Surgery was performed under regional anaesthesia by an author (HY), or a surgeon under his supervision. The fracture was reduced and fixed with an anatomically designed volar locking plate system according to the surgeon’s preference. An Acu-Loc VDR Plate (Acumed, Hillsboro, Oregon) was used in 55 patients and a 2.4 mm Variable Angle LCP Two-Column Volar Distal Radius Plate (Synthes GmbH, Oberdorf, Switzerland) in 19. The plate was introduced under fluoroscopic guidance before the articular surface was reduced.\textsuperscript{16} It was fixed to the radius proximally using a single conventional screw into the elliptical hole in the stem of the plate. Reduction was carried out with Kirschner (K-)wires placed into the fracture under fluoroscopy (Premier Encore, Hologic, Bedford, Massachusetts). Fluoroscopic images were obtained to evaluate articular reduction, including standard posteroanterior (PA) and lateral views and

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**Fig. 1**

Patient flow chart.
arthroscopic assistance does not improve the functional or radiographic outcome

Table I. Demographic data

<table>
<thead>
<tr>
<th></th>
<th>Fluoroscopic group (n = 34)</th>
<th>Arthroscopic group (n = 36)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (yrs) (SD)</td>
<td>63 (16)</td>
<td>64 (14)</td>
<td>0.70†</td>
</tr>
<tr>
<td>Female patients (n, %)</td>
<td>25 (74)</td>
<td>29 (81)</td>
<td>0.48†</td>
</tr>
<tr>
<td>Fracture type (AO Type)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>3 (9)</td>
<td>4 (11)</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>14 (41)</td>
<td>10 (28)</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>17 (50)</td>
<td>22 (61)</td>
<td></td>
</tr>
<tr>
<td>Mean time interval</td>
<td>4.4 (3.4)</td>
<td>4.0 (2.5)</td>
<td>0.91†</td>
</tr>
<tr>
<td>between injury and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>operation (days) (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant-side fracture</td>
<td>13 (38)</td>
<td>16 (44)</td>
<td>0.60†</td>
</tr>
<tr>
<td>(n, %)</td>
<td>22 (65)</td>
<td>17 (47)</td>
<td>0.14†</td>
</tr>
<tr>
<td>Ulnar styloid fracture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n, %)</td>
<td>26 (76)</td>
<td>27 (75)</td>
<td>0.89†</td>
</tr>
<tr>
<td>Plate system (n, %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acu-Loc</td>
<td>8 (24)</td>
<td>9 (25)</td>
<td></td>
</tr>
<tr>
<td>VATCP</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SD, standard deviation
* The Mann–Whitney U test
† Fisher’s exact test
VATCP, 2.4 mm variable-angle LCP 2-column volar distal radius plate (Synthes GmbH)

anatomical PA (11° tilt) and lateral (23° tilt) views.17 No patient underwent arthroscopy.

In the fluoroscopic group, only fluoroscopy was used to confirm the reduction. In the arthroscopic group, arthroscopy of the wrist was undertaken after the fluoroscopically guided reduction with a 2.7 mm 30° angle arthroscope using standard 3 to 4 and 4 to 5 intercompartmental portals and the 6R and/or 6U portal technique.9 The fracture was reduced arthroscopically regardless of the extent of articular displacement using the joystick method, the hooking and lifting method, and/or the cramping method.18,19

In both groups, after reduction and temporary fixation with K-wires, locking screws were placed adjacent to the subchondral bone. No additional fixation of small fragments with K-wires, screws or a small plate was performed. No bone grafting was used. Fractures of the ulnar styloid and/or tears in the triangular fibrocartilage complex (TFCC) with apparent instability of the distal radioulnar joint (DRUJ), when present at the completion of radial fixation, were treated surgically with K-wires or bone anchors in two patients in the fluoroscopic group and four patients in the arthroscopic group. In the fluoroscopic group, tears of the TFCC with ulnar styloid fracture were confirmed by sight by the treating surgeon. These patients were included in the analysis. A total of 14 patients (39%) in the arthroscopic group had a soft-tissue injury, including tears of the TFCC (13 patients) and of the scapholunate ligament (one). We found tears of the TFCC with instability of the DRUJ (four patients), which were treated surgically. We also found tears of the TFCC without instability of the DRUJ (nine patients). We did not treat them surgically. Our indication of surgical treatment of the TFCC rear was only that with instability of the DRUJ.

Post-operative protocol. All patients had the same post-operative rehabilitation protocol under the direct supervision of an author (HY), regardless of any requirement for ulnar surgery. The wrist was immobilized in a short-arm volar plaster splint, and the patient was encouraged to perform active shoulder, elbow and finger movements and rotational exercises of the forearm. At the first post-operative visit, approximately three days after the surgery, active wrist range of movement (ROM) exercises were initiated. A ready-made removable short-arm splint was applied and the patient was instructed to wear this at all times, except during exercises. At six weeks after the surgery, gentle passive wrist exercises were started as guided by a physiotherapist, and the patient was weaned from the splint. At nine weeks, gentle strengthening exercises were encouraged. Lifting heavy objects or load-bearing was not recommended until 12 weeks post-operatively or when union of the fracture was established. Rehabilitation was completed at 12 weeks.

Functional outcomes. The active ROM, including flexion–extension of the wrist and rotation of the forearm, was measured with a goniometer at six, 12, 24 and 48 weeks post-operatively by an independent examiner (YK and TS) not directly involved in the care of the patients and unaware of the group assignments. Grip strength was determined using a Smedley Hand Dynamometer (Sakai Co., Tokyo, Japan) with the shoulder in 0° of flexion with the elbow flexed at 90° with the subject in the sitting position20 in both hands at the same visit. The results for the affected wrist and hand were recorded as a percentage of those in the contralateral arm. The disability/symptom scale of the Japanese Society for Surgery of the Hand version of the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire21 was administered at six and 48 weeks post-operatively.

Radiographic outcomes. Computed radiography was used to assess reduction using radial inclination, volar tilt and ulnar variance. Articular incongruity (gap and step) was assessed the images for all patients, and inter-observer reliability of the articular reduction (gap and step) was determined by calculating intra-class correlation coefficients (ICC) with 95% confidence intervals (CI).
Complications. Complications were defined as any adverse event related to the surgery or the injury that required operative intervention or hospital admission.

Statistical analysis. A sample size calculation was undertaken at 48 weeks using the DASH score as the primary outcome. Secondary outcomes were the other functional outcomes and radiological parameters. An 11-point difference in mean DASH score was considered a minimal clinically important difference. The sample size calculation showed that 34 patients in each group were sufficient to detect those differences with a standard deviation (SD) of 16, power of 0.8 and \( \alpha \)-value of 0.05. Allowing for a 10% loss to follow-up, a minimum of 74 patients needed to be randomised into the analysis.

The patients were evaluated using per-protocol analysis. Statistical analysis was performed on the functional and radiographic outcomes. Continuous variables were compared using the Mann–Whitney U test. If the difference was shown to be significant, Bonferroni correction was performed for multiple comparisons. Fisher’s exact test was used to compare the distribution of ordinal and categorical measurements, such as complications and AO fracture type. All analyses were two-tailed, and \( p < 0.05 \) was deemed significant.

Results

Three patients in the fluoroscopic group were lost to follow-up, and one in the arthroscopic group could not be assessed because of fibromyalgia treated elsewhere after the allocation. These patients were excluded from the analysis. The mean age of the 70 patients who were analysed was 64 years (24 to 92), and there were 16 men (23%) and 54 women (77%). The AO fracture subtype was C-1 in seven patients (10%), C-2 in 24 (34%), and C-3 in 39 (56%). The mean interval between injury and operation was 4.2 days (0 to 14). The dominant hand was affected in 29 patients (41%). There were no significant differences between the groups with regard to age, gender, AO fracture type, interval between injury and surgery, injury to the dominant side, fracture of the ulnar styloid or distribution of the type of plate (Table I).

Functional parameters. The movements of the wrist, grip strength and DASH scores did not differ significantly between the groups at any time post-operatively (Table II).

Radiographic parameters. There were no significant differences in gap or step deformities, volar angulation, radial inclination or ulnar variance between the groups (Table II). ICCs for gap and step were 0.91 (95% CI 0.85 to 0.94, \( p < 0.01 \)) and 0.90 (95% CI 0.84 to 0.93, \( p < 0.01 \)), indicating high inter-observer reliability.
Complications. No patient had a major complication such as penetration of the articular surface by a screw, compartment syndrome, sensory impairment, infection, complex regional pain syndrome or nonunion. One patient in the arthroscopic group had ulnar impingement following a malunion, resulting in radial shortening and positive ulnar variance.

Discussion
In this study we found no significant differences between the techniques with regard to functional outcomes or radiographic parameters. The results support the proposal that intra-operative fluoroscopy alone allows the satisfactory assessment of reduction of the joint surface for intra-articular distal radial fractures when fixation is undertaken with a volar locking plate. Routine supplementary arthroscopically assisted reduction adds no demonstrable benefit.

Two prospective randomised controlled studies9,10 and one retrospective case-matched study8 have compared fluoroscopic and arthroscopic reduction with an external fixator for intra-articular fractures of the distal radius. Doi et al9 described a better outcome in arthroscopically assisted procedures (34 patients, 42 in the fluoroscopic group), but fixation was obtained in the arthroscopic group with an external fixator and in the non-arthroscopic group (fluoroscopy and limited arthrotomy) with a conventional non-locking volar plate. These differences in technique might have contributed to the findings. Varitimidis et al10 reported better results in their arthroscopic group (20 of 40 patients), but external fixation was used in both groups. Using external fixation, Ruch et al10 found that their arthroscopic group (15 of 30 patients) had better movement of the wrist but no significant differences in grip strength or radiographic outcomes. Recently, a number of studies11-13 have reported better outcomes using a volar locking plate system for the treatment of unstable distal radial fractures rather than external fixation. The benefits of this technique include fixed-angle fixation in patients with osteopenia,24 straightforward surgical dissection, less risk of contracture of the fingers and the potential for early mobilisation. In our study with locked volar plates, arthroscopic reduction did not improve the articular reduction or the outcome. We believe this is because they had already been essentially reduced under a high-quality image intensifier when the plate was inserted before commencing the arthroscopy.

Arthroscopic reduction of intra-articular distal radial fractures has several potential advantages over fluoroscopic reduction.6,7,25 Augé and Velázquez6 assessed the adequacy of reduction fluoroscopically by arthroscopic visualisation combined with external fixation. Lutsky et al17 evaluated articular reduction arthroscopically following fluoroscopically assisted volar plating. Both authors found that arthroscopic evaluation of the articular reduction was superior to the fluoroscopic method. However, they measured articular deformities in different ways for each method of reduction. The deformities in the fluoroscopic group were evaluated radiographically, but those in the arthroscopic group were performed arthroscopically. CT might be more suitable than radiographs for comparing reduction between the two techniques.22 Doi et al9 evaluated the articular deformities of an arthroscopic group using CT, but 30% of their fluoroscopic group did not have CT scans. In our study, the CT scans in both the fluoroscopic and arthroscopic groups showed acceptable reduction.

Anatomical reduction might be disrupted during the insertion of the stabilising screws, and initial reduction is sometimes lost because of osteoporosis, especially in the elderly. We believe that the goal of surgical treatment of intra-articular distal radial fractures is anatomical reduction. We compared the articular reduction between the groups at 12 weeks and found that the gap was somewhat larger than the step. In some patients with osteoporotic bone the articular gap might be overestimated, as the bony defect could be considered to be a gap on CT examination.

In this study, the sample size was not calculated based on the articular displacement, although there were no statistical differences in the parameters between the groups. As we now know the SD of the articular displacements (SD 0.7), if we define the minimum important difference for articular displacement as 0.5 mm, a sample size of 62 patients would be required to provide a power of 0.8. This suggests that our study had enough statistical power to assess the articular displacement.

This study had several limitations. First, in addition to a relatively short follow-up, we are unable to say whether the choice of technique of reduction affected the risk of OA. We believe that follow-up of 48 weeks is long enough to evaluate function. ROM and grip strength reached a plateau by 48 weeks, and DASH scores are known to improve slowly.26 Secondly, we did not evaluate the time to union of the fracture in either group, although all patients had intra-articular union on CT at 12 weeks. Thirdly, we did not assess soft-tissue injuries. Effective reconstruction of the soft-tissues, including carpal ligaments and the TFCC, might be related to a good outcome. In this regard, arthroscopy can be used to identify associated ligamentous injuries with a minimum of soft-tissue disruption.22,27 Fourthly, we randomised the patients using sealed envelopes. This method can lead to an imbalance in patient characteristics, although there were no significant differences between the groups. Lastly, the patients were relatively older than in previous studies.8-10 Their mean age was 64 years, and previous reports have shown that in patients aged > 65 years articular reduction does not correlate with outcome.28 In contrast, it is reported that step off of the radiocarpal joint is related to outcomes in elderly patients.29 The findings might be different in younger patients.

Our findings do not support the use of arthroscopically assisted reduction when using fixation with a volar locking plate for intra-articular fractures of the distal radius, as fluoroscopic confirmation of reduction is adequate.
Supplementary material

Data at 12 and 24 weeks for range of movement of the wrist, grip strength and DASH scores, are available alongside the online version of this article at www.bjj.boneandjoint.org.uk

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H. Yamazaki: Study design, Performing surgeries, Writing the manuscript.
S. Uchiyama: Revision of the manuscript.
M. Komatsu: Data analysis.
S. Hashimoto: Data analysis.
H. Kato: Revision of the manuscript.
Y. Kobayashi: Data collection.
T. Sakurai: Data collection.

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References