A total of 118 consecutive patients with a fracture of the distal radius were treated with a volar locking plate; 50 patients had no ulnar styloid fracture, 41 had a basal ulnar styloid fracture, and 27 had a fracture of the tip of the ulnar styloid. There were no significant differences in radiological and clinical results among the three groups. The outcome was good and was independent of the presence of a fracture of the ulnar styloid. A total of five patients (4.2%) had persistent ulnar-sided wrist pain at final follow-up. Nonunion of the ulnar styloid fracture did not necessarily lead to ulnar wrist pain. Patients with persistent ulnar pain had a higher mean initial ulnar variance and increased post-operative loss of ulnar variance.

The presence of an associated ulnar styloid fracture of the ulnar styloid does not adversely affect the outcome in patients with a fracture of the distal radius treated by volar plating.

Fractures of the distal radius are common in the elderly. Various surgical techniques are available to treat these unstable fractures of the distal radius, such as percutaneous pinning, external fixation, and internal fixation with various types of plate. Recently, encouraging results have been reported following the use of volar locking plates and we have reported better correction with early recovery of hand function when using volar plates than after intrafocal pinning. Arthroscopy of the wrist at the time of fixation of intra-articular distal radial fractures may improve the outcome.

The treatment of an associated ulnar styloid fracture remains controversial. It may be treated non-operatively or by external fixation, pinning or plate fixation. Anatomical and biomechanical studies indicate that the triangular fibrocartilage complex and its attachments to the ulnar styloid are important in maintaining the stability of the distal radio-ulnar joint. Disruption of the triangular fibrocartilage complex insertion into the foveal region of the distal ulna can produce instability. Fractures of the ulnar styloid may be associated with instability of the distal radio-ulnar joint and a poor outcome. Others, however, have found that a fracture of the ulnar styloid has no impact on the anatomical, radiological or functional result when it accompanies a distal radial fracture. We attempted to determine whether the presence of an associated fracture of the ulnar styloid affects the outcome of patients with a distal radial fracture when treated with a volar locking plate.

Patients and Methods
A total of 118 consecutive patients (118 wrists) with a dorsally angulated, unstable fracture of the distal radius which had been treated by internal fixation with a volar locking plate between October 2004 and June 2007 were included in the study. There were 28 men and 90 women with a mean age of 64.1 years (25 to 94). The right wrist was injured in 58 patients and the left in 60. The mean time from injury to surgery was 1.5 days (0 to 11). The mean follow-up was 14.9 months (6 to 38). The indications for internal fixation included dorsal tilt > 5°, radial inclination angle < 20°, and ulnar variance contralateral > 2 mm when compared with the side, and/or an intra-articular step of > 1 mm. No ulnar styloid fractures were treated surgically. We excluded patients with ipsilateral upper extremity injuries, a nonunion of a previous ulnar styloid fracture or a different type of distal radial fracture, those with systemic, multiple-organ or head injuries, those who had previously undergone surgery for a fracture of the distal ulna, and those who had undergone surgical treatment more than two weeks after the injury.
The DRV locking plate system (Mizuho Medical Department Instrument Company, Tokyo, Japan)26,27 was used in 29 patients between November 2004 and October 2005, and the Volar Distal Radius Plating System (Stellar plate, Japan Universal Technologies, Inc, Tokyo, Japan) in 89 patients between November 2005 and September 2007. We changed system because the Stellar plate could be delivered more rapidly by the company. There were no marked differences in implant design between the two. The study was approved by the Ethics Review Committee, and consent was obtained from each patient.

The 118 patients were divided into three groups: 50 had no fracture of the ulnar styloid, 41 had a fracture of the base of the ulnar styloid (base group), and 27 had a fracture of the tip of the ulnar styloid (tip group). We divided fractures into base and tip based on the midpoint of the height of styloid process.28 The mean age of the base group was 65.5 years (25 to 89), and that of tip group was 57.3 years (22 to 81). There was no significant difference in age between the groups (chi-squared test). For the base group, the gap distance at the fracture site was < 2 mm in 35 patients and > 2 mm in six, whereas for the tip group, the gap distance was < 2 mm in nine patients and > 2 mm in 18. The demographic characteristics of the patients are given in Table I. According to the AO classification,29 there were 60 type A fractures (extra-articular fractures involving neither the radiocarpal nor the radio-ulnar joint) of which 29 were A2 and 31 A3 and 58 type C fractures (complex articular fractures affecting the joint surface and metaphyseal area) of which 17 were C1, 31 C2 and 10 C3.

Surgery was performed under brachial plexus block. A longitudinal skin incision was made next to the tendon of flexor carpi radialis which was retracted medially with the flexor pollicis longus muscle. The radial border of the pronator quadratus muscle was divided longitudinally. The volar aspect of the radius was exposed subperiosteally. The plate was placed directly onto the radius after reduction of the fracture, using the condylar stabilising method.30 No bone graft was used. After fixation, the pronator quadratus was repaired and the wound closed. The mean duration of surgery was 62 minutes (40 to 125). No plaster cast was used. Active exercises were started as comfort permitted. Formal physiotherapy started four or five days after surgery and continued for three months.

The patients were reviewed each week for four weeks, and thereafter at six and eight weeks, three and six months, and at final follow-up. Deformity was assessed on standard anteroposterior and lateral radiographs by measuring the angles of volar tilt and radial inclination and the degree of ulnar variance using criteria described previously.31,32 These measurements were made at the first visit, immediately after surgery and at final follow-up. Union of the ulnar styloid fractures was evaluated at final follow-up. All measurements were accurate to 0.01 mm or 0.01° by use of a semi-automatic image analysis system (Toshiba Diagnostic Viewer system, Tokyo, Japan). The range of movement of the wrist and forearm, grip strength, and the presence of ulnar wrist pain were recorded at each visit. The Disability of the Arm Shoulder and Hand outcome (DASH) score33 was recorded regularly (at one, two, four, eight, 12 and 24 weeks) and at final follow-up. Patient-related hand performance was evaluated using the criterion of Cooney et al.34 The bone mineral density of the lumbar spine (L2 to L4) was measured by dual-energy X-ray absorptiometry (QDR-4500, Hologic Inc., Bedford, Massachusetts) at the first visit.

### Statistical analysis

Results were expressed as means (SEM). Differences were evaluated using the Mann-Whitney U test for age, period from injury to surgery, duration of follow-up, bone mineral density, grip strength, DASH score, and each parameter of deformity of the radius at each time point, and the chi-squared test for gender, injured side, proportion of patients with AO type C, and proportion of patients with ulnar styloid fractures. A p-value of < 0.05 was considered significant. All statistical analyses were performed using Stat-View 5.0 software (Hulinks Inc, Tokyo, Japan).

<table>
<thead>
<tr>
<th>Table I. Demographic data</th>
<th>No fractures of ulnar styloid group</th>
<th>Fractures of ulnar styloid</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases</td>
<td>50</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>Mean age (yrs)</td>
<td>66.2</td>
<td>65.5</td>
<td>57.3</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male:female</td>
<td>13:37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right:left</td>
<td>22:28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean period from injury to surgery (days)</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean follow-up period (mths)</td>
<td>15.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
At the final follow-up, all 118 radial fractures had united, whereas only 22 of the 68 (32.4%) associated ulnar styloid fractures were united. The union rate in the tip group (11 of 27, 40.7%) was significantly higher than that in the base group (11 of 41 patients, 26.8%, chi-squared test, p < 0.05). With regard to the gap distance, the union rates were 16.7% (one of six) for cases of > 2 mm and 28.6% (10 of 35) for cases of < 2 mm in the base group, and the respective rates in the tip group were 16.7% (three of 18) and 88.9% (eight of nine). Patients with a gap distance of > 2 mm on the initial radiographs tended not to unite.

A total of 12 patients (10.2%) developed post-operative complications, including three with tendon injuries (extensor pollicis longus in two and flexor pollicis longus in one), two with a nerve palsy (carpal tunnel syndrome in one, and involvement of the superficial palmar branch of the median nerve in one), one with flexor tendonitis of the thumb, one with an incomplete injury of the radial artery, and five with symptoms relating to the plate (loosening of a cortical screw in two and protrusion of a distal locking screw into the wrist joint in three). None had a deep infection or complex regional pain syndrome.

**Radiological findings.** The mean volar tilt angle was 12.6° (1° to 20°) immediately after surgery and 11.9° (5° to 20°) at final follow-up in the no-fracture group (Fig. 1a). The respective values of the base and tip groups were 11.1° (5° to 25°) and 10.3° (5° to 20°), and 9.7° (4° to 21°) and 9.3° (0° to 21°). The mean radial inclination angle was 24.2° (15° to 30°) immediately after surgery and 23.9° (13° to 30°) at final follow-up in the no-fracture group (Fig. 1b). The respective values of the base and tip groups were 24.3° (14° to 32°) and 24.0° (14° to 30°), and 23.3° (14° to 30°) and 23.1° (17° to 28°). There were no significant differences in volar tilt and radial inclination among the three groups (Mann-Whitney U test, p > 0.05). Maintenance of volar tilt and radial inclination was noted in all patients. For the mean ulnar variance (mm), the loss of correction occurred between immediately after surgery and final follow-up (Fig. 1c) the change being -0.4 to 0.5 in the no-fracture group, 0.1 to 1.1 in the base group, and -0.4 to 1.4 in the tip group.

**Range of movement and grip strength.** The movements returned satisfactorily in all groups. There were no significant differences in the range of movement at each time point among the three groups (Mann-Whitney U test, p > 0.05). Recovery of grip strength was expressed as a per-

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Graphs showing changes in the deformity of the radius on radiographs according to a) volar tilt, b) radial inclination and c) ulnar variance. There were no significant differences in these parameters between the three groups at each time point (Mann-Whitney U test, p > 0.05).

Graph showing changes in post-operative grip strength. There were no significant differences between the three groups at each time point (Mann-Whitney U test, p > 0.05).

**Results**

At the final follow-up, all 118 radial fractures had united, whereas only 22 of the 68 (32.4%) associated ulnar styloid fractures were united. The union rate in the tip group (11 of 27, 40.7%) was significantly higher than that in the base group (11 of 41 patients, 26.8%, chi-squared test, p < 0.05). With regard to the gap distance, the union rates were 16.7% (one of six) for cases of > 2 mm and 28.6% (10 of 35) for cases of < 2 mm in the base group, and the respective rates in the tip group were 16.7% (three of 18) and 88.9% (eight of nine). Patients with a gap distance of > 2 mm on the initial radiographs tended not to unite.

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**Range of movement and grip strength.** The movements returned satisfactorily in all groups. There were no significant differences in the range of movement at each time point among the three groups (Mann-Whitney U test, p > 0.05). Recovery of grip strength was expressed as a per-
percentage of the opposite uninjured side (Fig. 2). At the final follow-up, grip strength was 90.8% in the no-fracture group, 92.5% in the base group and 94.7% in the tip group. There was no significant difference between the groups in grip strength at each time point (Mann-Whitney U test, p > 0.05).

DASH score and self-rated hand performance. The mean DASH score improved substantially in each group (Fig. 3). There were no significant differences in the scores between the three groups (Mann-Whitney U test). The hand performance was rated excellent in 86 (73%), good in 26 (22%) and fair in six (5%).

Ulnar wrist pain and nonunion of ulnar styloid fractures. Ulnar-sided wrist pain improved gradually with time. The number of patients with ulnar pain was 16 (13.6%) at three months, ten (8.5%) at six months, six (5.1%) at 12 months, and five (4.2%) at final follow-up. There was no significant difference in the incidence between the three groups (no-fracture group: 6.0% (3 of 50), base group: 4.9% (2 of 41), tip group: 0% (0 of 27). There was no relationship between ulnar pain and union of the ulnar styloid fracture. Ulnar pain occurred in 6.0% of the no-fracture group (3 of 50), in none of those with united styloid fractures (0 of 22) and 4.3% of those with nonunion of styloid fractures (two of 46) (Fig. 4).

Comparison of patients with and without ulnar wrist pain. We compared the background factors between patients with and without ulnar wrist pain at the final examination (Table II). Only the initial ulnar variance and its final use of correction were significantly different between the two groups, being greater in those with pain (Table II).

Discussion
In this series of patients with a distal radial fracture treated with a volar locking plate the presence of an associated untreated fracture of the ulnar styloid was not associated with a worse outcome. This finding is consistent with those of Ekenstam et al,22 who reported no difference in outcome after operative or non-operative treatment for a fracture of the ulnar styloid associated with an extra-articular fracture of the distal radius, although a triangular fibrocartilage complex injury was found in all patients who had operative treatment. This suggests that there is no benefit to be gained by fixing a fracture of the ulnar styloid when stabilising a fracture of the distal radius with a volar plate. Shaw, Bruno and Paul,35 however, reported on the basis of a biomechanical study and primary repair of displaced ulnar styloid fractures, that this form of treatment stabilises the radio-ulnar joint. Patients in whom the ulnar styloid fracture can be reduced and maintained in supination can be treated effectively with external fixation in supination.36 Nakamura et al34 reported that a fracture of the ulnar styloid and triangular fibrocartilage complex injury leads to instability of the distal radio-ulnar joint, and that repair of the triangular fibrocartilage complex should be performed as well as fixation of the ulnar styloid fracture.

The radiological results in this series are comparable with those of previous reports.10-12 Reduction of the fracture of the ulnar styloid was not lost despite early postoperative mobilisation. The mean time from injury to surgery was 1.5 days and surgery was performed on the same day as injury in 46 of 118 patients (40.0%).

In our series, five patients (4.2%) had persistent ulnar wrist pain at the final follow-up and the incidence of ulnar pain was independent of union of the fracture of the ulnar styloid. Our results suggest that greater initial ulnar variance and loss of correction of that variance between immediately after surgery and final follow-up can predict persistent ulnar pain. A high-energy injury with a large ulnar variance value causing a triangular fibrocartilage complex tear has been reported to be related to a high rate of distal radio-ulnar joint instability.37 Persistent ulnar wrist pain might mainly be caused by dysfunction of the triangular fibrocartilage complex, incongruity of the distal radio-ulnar joint,34 or ulnocarpal abutment due to radial
shortening, rather than nonunion of the fractured ulnar styloid. Ulnar wrist pain gradually improves up to two years after surgery.³⁸

MR scans have shown that an intra-articular soft-tissue injury accompanies the distal radial fracture in 47.6% of cases,²⁶ 28.6% with scapholunate ligament rupture, 9.5% with triangular fibrocartilage complex disruption, 4.8% with extensor carpi ulnaris tenosynovitis and 4.8% with dorsal radiocarpal ligament tear. A fracture of the ulnar styloid is rarely associated with a triangular fibrocartilage complex tear.³⁹ Many soft-tissue lesions have been reported to be associated with intra-articular distal radial fractures at arthroscopy: triangular fibrocartilage complex lesions in 61.9%, scapholunate ligament lesions in 33.3%, and a lunotriquetral lesion in 4.8%.⁴⁰

There are two limitations of this study: there was no control group in which the ulnar styloid fracture was surgically treated, and we have no information about the soft-tissue element of the injury. We have, however, shown that the presence of an ulnar styloid fracture does not affect the outcome of a fracture of the distal radius which is stabilised with a volar locking plate. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References