Displaced fracture of the waist of the scaphoid

A displaced fracture of the scaphoid is one in which the fragments have moved from their anatomical position or there is movement between them when stressed by physiological loads. Displacement is seen in about 20% of fractures of the waist of the scaphoid, as shown by translation, a gap, angulation or rotation. A CT scan in the true longitudinal axis of the scaphoid demonstrates the shape of the bone and displacement of the fracture more accurately than do plain radiographs. Displaced fractures can be treated in a plaster cast, accepting the risk of malunion and nonunion. Surgically the displacement can be reduced, checked radiologically, arthroscopically or visually, and stabilised with headless screws or wires. However, rates of union and deformity are unknown. Mild malunion is well tolerated, but the long-term outcome of a displaced fracture that healed in malalignment has not been established.

This paper summarises aspects of the assessment, treatment and outcome of displaced fractures of the waist of the scaphoid.

Fractures of the waist of the scaphoid are common in young men, usually occurring as a result of a fall on the outstretched hand or sudden forced dorsiflexion of the wrist. Between 85% and 90% of fractures of the waist of the scaphoid will unite in a below-elbow plaster cast, but those with displacement have a higher incidence of nonunion and unite in a humpback position. An undisplaced fracture will heal anatomically when immobilised in a below-elbow plaster cast, owing to its bony configuration and intact supporting soft tissues, even if immobilised only for four weeks; however, in a displaced scaphoid fracture the fragments have moved from their anatomical position, or there is movement between them when stressed.

There is high variability in the reported rates of displacement in scaphoid fractures, depending on the radiological investigation and the criteria for displacement used. When radiographs alone are used the reported rate is around 20%. Forward et al observed malunion in 26 of 42 fractures (62%) at one year as judged by CT, suggesting that in most cases the fracture was initially displaced or displaced during healing. Some authors have used progressive displacement in plaster as a measure of instability. However, out of 247 fractures treated in a plaster cast, only six (3%) became displaced, and nonunion was seen in two of these.

The scaphoid braces both the proximal and distal rows of the wrist. Carpal stability depends on the shape of the bones, the ligaments (palmar carpal, interosseous and transverse carpal), the tendons (flexor carpi radialis), proprioception, muscle balance and the joint capsules. Injury to or constitutional laxity of these tissues may promote displacement of the fractured scaphoid.

A fractured scaphoid can return to its original position moulded between the distal articular surface of the radius and the capitate. Such a configuration will allow the fracture to heal with its anatomy unaltered. When competent, soft tissues will retain rotatory alignment of an undisplaced fracture. When there is an associated intra-articular fracture of the distal radius or radial styloid, the fracture of the scaphoid is less stable.

The degree of flexion of the scaphoid on radial deviation varies between patients. In individuals with joint laxity there is more flexion of the scaphoid in the sagittal plane (the row type wrist). In contrast, in those with no laxity the scaphoid rotates in the coronal plane, with little flexion or extension. This could influence the stability of a scaphoid fracture.

Why worry about displaced fractures of the scaphoid?

When radiographs are used to measure displacement, the reported incidence of nonunion...
is variable owing to a lack of standardisation of the definition of displacement. A large prospective study showed a rate of nonunion of 14% in 74 displaced fractures of the waist of the scaphoid treated in a below-elbow plaster with the thumb free. This is slightly higher than the 10% rate of nonunion in undisplaced fractures treated non-operatively in a plaster cast.2

In two small studies nonunion was seen in five of ten fractures of the waist of the scaphoid with a 1 mm gap or step treated with a cast. Eddeland et al observed nonunion in 23 (92%) of 25 scaphoid fractures with displacement > 1 mm, compared to 17 (19%) of 93 fractures with < 1 mm displacement. However, none of the patients with a nonunion had been immobilised for the first four weeks, so the reported high incidence may reflect inadequate treatment.

The high variability in reported rates of nonunion could be due to difficulty in seeing the extent of healing across the fracture on radiographs. In a study of 49 fractures of the waist of the scaphoid treated non-operatively in a below-elbow plaster cast, nonunion was noted in three of the nine displaced fractures when MRI was used to measure intra-scaphoid angulation. Radiographs alone failed to detect displacement in three of the fractures that did not unite.

Displacement of fractures of the waist of the scaphoid usually results in malunion, usually in flexion but sometimes with ulnar translation or pronation of the distal fragment. Shortening of the scaphoid as measured on the posteroanterior view can be due to rotation rather than displacement. The effect of malunion on the function of the wrist remains unclear. In a cadaver study, simulation of scaphoid malunion in flexion by even 5° reduced extension of the wrist by 24°, and the loss of extension was proportional to the angular deformity. The effect of malunion confirmed on longitudinal CT scans 12 to 18 weeks after injury was studied in 42 consecutive patients. At one year, no significant relationship was identified between the range of movement, grip strength and the Patient evaluation measure (PEM)20 and Disabilities of the Arm, Shoulder and Hand (DASH)21 scores, and with three measures of malunion, namely the height-to-length ratio, the dorsal cortical angle and the lateral intrascaphoid angle. A randomised study has also shown that early fixation of fractures of the wrist of the scaphoid offers no clear benefit over aggressive conservative management.

Malunited fractures of the wrist of the scaphoid can develop osteoarthritis in the long term. Amadio et al reported a significant impairment of function and the development of post-traumatic osteoarthritis following malunion of a fracture of the scaphoid. However, 20 of his 26 patients (77%) in the malunion group had been treated with open surgery and bone grafting to achieve union. Nonunion that has been treated is likely to have a poorer outcome than an acute fracture if both unite with the same degree of malunion. Jiranek et al compared 13 patients with malunion and a lateral intrascaphoid angle of > 45° and 13 with an acceptable position. Both groups had undergone Russe procedures for nonunion. There was no difference in symptoms or function between the groups, and 12 patients in whom the scaphoid nonunion had healed with malunion had returned to a high level of function despite the deformity.

### Assessment of displacement

The Russe classification uses the inclination of the fracture line to predict instability. Vertical oblique fractures (5%) are considered unstable owing to greater shear forces across the fracture site. The Herbert classification assumes that any bicortical fracture (type B) and its five subtypes, including subtypes B1 - oblique fractures of the distal third, B2 - displaced or mobile fractures of the waist, B3 - fractures of the proximal pole, B4 - a fracture dislocation and B5 - a comminuted fracture is unstable and likely to require surgery. The Mayo classification similarly produces criteria for instability, considering fractures with...
> 1 mm of displacement, a lateral intrascaphoid angle > 35°, bone loss or comminution, a perilunate fracture dislocation, dorsal intercalated segmental instability (DISI), malalignment and fractures of the proximal pole as unstable. This provides a more satisfactory guide for management, but the associated soft-tissue injuries are not considered.

Trans-scaphoid perilunate fracture dislocation is a very unstable injury. There is disruption of most, if not all, of the ligaments attached to the fracture fragments, and this can lead to malalignment and scaphoid nonunion, and is associated with a higher incidence of carpal instability and malalignment and scaphoid nonunion than fractures without dislocation.26

Displacement can be measured. The four bony features that suggest displacement are translation, a gap, rotation and angulation. A fracture is considered to be displaced if the offset (‘step-off’) is ≥ 1 mm at the radial or dorsal cortical surface on posteroanterior or oblique radiographic views.6 Any step seen on the radiograph suggests instability. A gap of > 1 mm between the fragments as seen in the sagittal or coronal planes is considered to indicate instability, and this may increase the risk of nonunion16 (Fig. 1). Radiographs may be used to identify a gap, a step or tilting of the lunate, but with only moderate interobserver reliability.3,27
Three-dimensional (3D) CT scans have confirmed rotational displacement in nine out of 25 patients on the axial top view, with pronation of the distal fragment relative to the proximal fragment. This may be obvious on radiographs of nonunion when the gap on one side is greater than that on the other.

Angulation and flexion at the fracture site in the sagittal plane can be measured using the dorsal cortical angle, the lateral intrascaphoid angle and the height-to-length ratio.

The mean normal dorsal cortical angle was 139° (SD 25) as calculated on CT scans in the long axis of the scaphoid. An angle > 160° is considered abnormal.

Lateral intrascaphoid angle. Amadio et al. used CT to study this angle (Fig. 3) and suggested a cut-off value of 35°. Patients with a lateral intrascaphoid angle above this value had a poor functional outcome. Other authors were unable to estimate the normal values because of poor interobserver reproducibility. It is extremely difficult to quantify the intrascaphoid angulation because of overlap from the other carpal bones. As any line drawn on the dorsal aspect of the scaphoid is a tangent to the flexed scaphoid, the position of the tangent is observer dependent.

Height-to-length ratios. The mean height-to-length ratios of normal scaphoids (Fig. 4) calculated on longitudinal CT scans is 0.60 (SD 0.04). Values > 0.65 are considered abnormal.

Extrascaphoid techniques. Excessive dorsiflexion (dorsal tilting) of the lunate on a lateral radiograph suggests malalignment. An angle > 80° may indicate displacement of the scaphoid fracture but can also result from an injury to the scapholunate (SL) ligament. It is an indirect sign of displacement, which may not always be seen on the initial radiographs as some patients can develop malposition of the carpus during the course of treatment.

Anteroposterior intrascaphoid angle. This is the angle formed between lines drawn perpendicular to the distal and proximal articular surfaces of the scaphoid on the coronal/lateral views. The normal value on trispiral CT was 40° (32° to 46°) but the authors found it difficult to estimate the cut-off value as half of the patients with poor results had a normal anteroposterior intrascaphoid angle.

A CT scan in the true longitudinal axis of the scaphoid is more accurate in demonstrating the humpback deformity than are plain radiographs. The height-to-length ratio is considered the most reproducible of the three measures of angular malunion. It was found to be inaccurate and variable on both MRI and CT scan. This was true even for normal scaphoids, as the accuracy of measurement depends on the thickness of the slice and the plane of imaging (Table II). CT scans are poor at identifying ligament injuries.

Real-time linear ultrasonography identified movement at the fracture site in a total of 27 patients with ununited fractures. Movement observed at the time of surgery compared well with the ultrasonographic findings. The technique proved to be 100% specific for visualisation of movement at the fracture site, and is non-invasive. Ultrasonography is highly user dependent but improvements in the probes and software will make it easier to see movement at the fracture site.

Treatment
Displaced fractures of the waist of the scaphoid can be treated in a plaster cast, accepting the displacement and a
higher risk of nonunion or they can be treated surgically. Immobilisation in a cast for two months will result in union of between 80% and 85% of displaced fractures of the scaphoid, but inconvenience to the patient and restrictions at work when in a plaster cast have prompted surgeons to advocate internal fixation with a screw (Table III). Clay et al. studied 392 fractures of the waist of the scaphoid and found that the thumb did not need to be immobilised. The nonunion rate for displaced fractures was 14%, compared with 10% for transverse undisplaced fractures (Table III). Reduction of displaced fractures by flexion of the wrist and radial deviation in a long-arm cast has been suggested, but the length of the cast and the position of the wrist do not affect healing.

Displaced fractures can be treated by open realignment of the fragments followed by stable internal fixation using a headless screw. Usually, palm ar exposure of the scaphoid limits injury to its blood supply, but it is easier to address very proximal fractures through a dorsal exposure. Using an alignment jig can damage the scaphotrapezoid joint and the cartilage on the proximal scaphoid. Compression can exaggerate the flexion of the fractured scaphoid. A cannulated screw, which does not require the use of a jig, is now often used for open or percutaneous fixation. Central placement has been achieved more consistently with cannulated screws than with Herbert screws. The surgical risks are listed in Table II.

Displaced fractures are inherently unstable and can move during fixation with a screw. The rate of obtaining a satisfactory reduction using either closed or limited open techniques has not been evaluated. Distraction may lead to nonunion and translation may occur if the screws are

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**Table II. Treatment options for displaced fractures**

<table>
<thead>
<tr>
<th>Type</th>
<th>Malposition rate</th>
<th>Union rate</th>
<th>Osteoarthritis rate</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-operative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below-elbow cast</td>
<td>12% to 20%</td>
<td>82% to 90%</td>
<td>16% to 31%</td>
<td>Elbow stiffness*</td>
</tr>
<tr>
<td>Above-elbow cast</td>
<td>18% to 22%</td>
<td>70% to 87%</td>
<td>-</td>
<td>Nonunion (7% to 13%) time of contact sports (3 to 4 months)</td>
</tr>
<tr>
<td>Operative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open fixation</td>
<td>-</td>
<td>93%</td>
<td>4% to 39%</td>
<td>Nonunion (7%), scar problems, complex regional pain syndrome (3%)</td>
</tr>
<tr>
<td>Percutaneous fixation</td>
<td>-</td>
<td>100%</td>
<td>-</td>
<td>Wire breakage, nerve injury, potential need for metalwork removal*</td>
</tr>
<tr>
<td>Arthroscopy assisted fixation</td>
<td>-</td>
<td>100%</td>
<td>-</td>
<td>Scaphotrapezial and radioscapophoid joint damage (13.8%), infection (&lt; 1%), nerve injury (palmar cutaneous branch) (2%)</td>
</tr>
</tbody>
</table>

* rates not yet available

**Table III. Accuracy of radiological methods to identify displacement of fractures of the waist of the scaphoid**

<table>
<thead>
<tr>
<th>Type</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Positive predictive value (%)</th>
<th>Negative predictive value (%)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiographs</td>
<td>33 to 47</td>
<td>78 to 97</td>
<td>27 to 86</td>
<td>77 to 83</td>
<td>70 to 78</td>
</tr>
<tr>
<td>Radiographs (mean)</td>
<td>75</td>
<td>72</td>
<td>10</td>
<td>97</td>
<td>64</td>
</tr>
<tr>
<td>CT scans (mean)</td>
<td>72</td>
<td>80</td>
<td>13</td>
<td>98</td>
<td>80</td>
</tr>
<tr>
<td>Radiographs + CT scans (mean)</td>
<td>80</td>
<td>73</td>
<td>16</td>
<td>99</td>
<td>73</td>
</tr>
</tbody>
</table>

* Sensitivity, the number of true positives / (Number of true positives + Number of false negatives)
† Specificity, the number of true negatives / (Number of true negatives + Number of false positives)
‡ Positive predictive value, (sensitivity – prevalence)/(sensitivity – prevalence + (1 – specificity) – (1 – prevalence))
§ Negative predictive value, (specificity – (1 – prevalence))/(1 – sensitivity – (prevalence + specificity) – (1 – prevalence))
¶ Bhat et al, MRI scans used as measurement of choice
** Lozano-Calderón et al, wrist arthroscopy used as measurement of choice
placed eccentrically in either fragment. Rotation of the fragments during tightening of the screw may be countered using a derotation wire. Correction of the intrascaphoid angulation at operation is demanding owing to the difficulty of visualising the scaphoid on fluoroscopy. A study comparing fixation using a Herbert screw with immobilisation in a below-elbow plaster cast, at a mean of 7.75 years after fracture, showed that a humpback deformity was more frequent following fixation in four out of 28 cases (14%) than after non-operative treatment (two out of 31 cases, 6%), with an odds ratio of 2.4 (confidence interval CI) 0.4 to 14.3 comparing the two outcomes. Palmar positioning of the screw was associated with increased intrascaphoid angulation.

Percutaneous arthroscopic fixation is associated with a steep learning curve. Complications include intra-operative breakage of the equipment such as the screw and guide wires, and eccentric placement of the screw or its being too long. The screw may protrude into the joint or, as it is advanced, impact against the opposite cortex, causing distraction of the fracture. Eccentric placement may lead to poor stability and at least four threads of the screw should engage each fragment. Dorsal tendons can be damaged by percutaneous wires.

Outcome
The long-term outcome of a displaced fracture of the waist of the scaphoid which has healed with malalignment following treatment in a plaster cast has not been established. When both displaced and undisplaced fractures were studied together, 20% of patients had some pain and tenderness between 1.7 and 2.6 years, but grip strength and movement were nearly normal.

In displaced fractures the radiological outcome does not correlate with the clinical result. A retrospective review of 63 patients at a mean of 54 months after non-operative treatment reported dorsal intercalated segment instability in five (8%), but there was no association between this malalignment and the functional results. Osteoarthritis developed in approximately one third of these patients, mainly at the radioscaphoid and scaphotrapezial joints. This was related to the age of the patient and the presence of a humpback deformity. However, no correlation was noted between osteoarthrosis and pain, grip strength or work capacity.

Lindström and Nystöm observed osteoarthritis in 5.2% of wrists at a minimum follow-up of seven years after any fracture of the scaphoid that had healed in a plaster cast. However, Düppe et al found marked radiocarpal osteoarthritis in only 2% of 47 patients with a healed fracture, but it was far more common after a nonunion, occurring in five of nine patients (56%). Whether operative intervention lowers the risk of osteoarthritis after a displaced scaphoid fracture is not known. At a mean follow-up of 93 months, no statistical difference (p = 0.2) was found in the rate of radio-scaphoid osteoarthritis after surgical fixation and cast treatment in 71 patients with an acute fracture of the scaphoid. Even in surgically treated trans-scaphoid perilunate injuries, a recent study has shown poor correlation between arthritis and functional scores and the consequences of these injuries were well tolerated at a mean of 13 years.

The benefits of osteotomy for correction of malunion remain uncertain. Lynch and Linscheid reviewed five corrective patients who had undergone an osteotomy between 1.5 and 19 years late and found improvements in grip strength but correction did not prevent the development of osteoarthritis. Other authors remain cautious about osteotomising a bone that has difficulty in healing in the first place.

This review has summarised current views on the management of this common fracture. Many questions remain unanswered. What is the best treatment for the individual patient? Does ultrasound identify movement at the fracture site? Which displaced fractures will heal? How well do we reduce the deformity of the scaphoid when we fix it? What is the state of the ligaments after the displaced fracture has healed? What happens in the long term after scaphoid malunion? Is the incidence of arthritis altered if a displaced scaphoid fracture is reduced and fixed? We assess the displaced fracture with a gap of more than 1 mm with CT scan. We consider surgery for displaced scaphoid fractures causing DISI deformity and trans-scaphoid perilunate dislocation. If the displacement is not corrected by traction alone we prefer an arthroscopy to reduce the displacement and temporarily fix with a 0.9 mm Kirschner wire before fixation with a headless screw.

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