Prediction of outcome of non-operative treatment of acute scaphoid waist fracture

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ABSTRACT

Fifteen per cent of acute fractures of the scaphoid waist fail to unite if treated non-operatively in plaster, resulting in persistent loss of function. Suspected risk factors for non-union include proximal fracture fragment avascularity and assessments of fracture displacement and comminution. This series of studies investigated whether one can accurately identify which scaphoid waist fractures will unite with plaster treatment. They suggest that proximal fracture fragment vascularity is not a predictor of outcome. In contrast, assessments of fracture displacement on magnetic resonance imaging (MRI) and computed tomography (CT) but not scaphoid series radiographs can be used to predict outcome. Undisplaced fractures are benign and unite reliably with 4–8 weeks' treatment in plaster. Displaced fractures with 3mm or more gapping have a significant non-union rate if treated in plaster and might be better treated operatively. Use of MRI/CT may allow reliable, cost effective treatment of acute fractures through the scaphoid waist.

KEYWORDS

Scaphoid – Fracture – Plaster cast – Displacement – Computed tomography – Radiography – Blood supply

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The aim of treatment of scaphoid waist fractures is to achieve union. This is because one can then expect restoration of normal, painless wrist function within 6–12 months with no risk of late onset wrist osteoarthritis if the fracture unites. In contrast, there is often persistent pain and loss of wrist movement and function if the fracture fails to unite. Additionally, there is then a significant risk of symptomatic post-traumatic osteoarthritis in future years.

It is often difficult to decide whether a scaphoid fracture has united¹ but research suggests that 85% or more of scaphoid waist fractures unite with treatment in a below elbow plaster cast for 8–12 weeks.² This is still the standard management of these fractures in the UK. About 50% of units continue to use a scaphoid plaster, which immobilises the thumb but others, Nottingham included, use a Colles type plaster, which leaves the thumb free and allows better function.³

Although non-operative treatment of scaphoid fractures is the standard in the UK, it is becoming increasingly fashionable to treat these fractures operatively. It is argued that this benefits the patient because it avoids the need for lengthy immobilisation of the wrist in plaster. However, it has never been shown that operative treatment improves the union rate. Furthermore, there is no doubt that, in the

hands of mere mortals, operative fixation has a significant complication rate that is mainly due to problems with screw placement. Finally, in the current financial climate, one has to ask if operative fixation of a fracture that usually unites with plaster treatment is cost effective. Although it is claimed that it is cost effective, operative fixation at best only reduces indirect costs, and only if non-operative treatment in plaster is continued for many weeks.⁴

Surgeons who favour operative fixation highlight the 15% non-union rate with treatment on plaster² as a reason for operative fixation. In contrast, those who favour plaster treatment argue that 85% of the operations performed by enthusiasts are unnecessary as these cases would have united had they been immobilised in plaster. Perhaps the ideal way to treat scaphoid waist fractures would be to select fractures that are unlikely to unite with plaster treatment and offer those patients operative fixation and treat the remainder, which are likely to unite with non-operative treatment, in plaster.

This raises the question that is the topic of this lecture: can a surgeon accurately predict which scaphoid waist fractures will unite, and which will not unite, with treatment in below elbow plaster? The published literature in 1990 suggested the answer was 'yes' as fracture type,

displacement and comminution as well as proximal fracture fragment vascularity were all claimed to influence the union rate. However, my review of this literature concluded there was little evidence to support these claims. I therefore performed with co-workers the following studies to investigate whether these factors do actually predict the union rate.

Study 1

The first study concerned fracture displacement, type and comminution.⁵ The radiographs of 151 acute scaphoid fractures that had been treated non-operatively in a below elbow plaster for 8–12 weeks and had been followed up for 6 months were collected. This group of fractures had an 89% union rate. All the original scaphoid series x-rays of these fractures were coded and all identity markings including the patients' names were masked. These x-rays were given to Observer 1, who was blinded to the outcomes of each fracture. He categorised each fracture according to fracture type, amount of displacement and comminution. He also used his years of experience to predict from these radiographs whether the fracture would unite. Observer 2 then repeated the same procedure on the same x-rays, without knowledge of Observer 1's assessments.

Examination of the results showed that neither observer's assessment of fracture classification, whether using the Herbert or the Russe system, predicted union. Furthermore, neither fracture displacement nor comminution affected the union rate. Observer 1 correctly identified 7 out of the 16 scaphoid fractures that failed to unite but also thought that another 33 fractures would not unite. Observer 2 identified 14 of the 16 fractures that failed to unite but also believed another 113 fractures would fail to unite! Thus, neither of the observers' assessments were both sensitive and specific. The conclusion of this study was that fracture features, including displacement and comminution, as shown on plain x-rays do not determine the union rate.

Study 2

The blood flow to the proximal pole of the scaphoid is precarious and avascularity of the proximal fragment of a scaphoid fracture has been cited for many years as a cause of non-union. However, until recently, it has been impossible to measure. Scaphoid blood flow can now be estimated using magnetic resonance imaging (MRI) with gadolinium enhancement. If the proximal fracture fragment has a blood flow, it will take up gadolinium and will enhance and lighten on the MRI. If it has no blood flow, this will not occur and the proximal fragment will appear dark. With dynamic MRI one can select the proximal fracture fragment as an area of interest and, after the intravenous injection of gadolinium, assess the change of pixel density in this region over time. This provides an uptake curve, from which parameters such as percentage enhancement can be measured that reflect blood flow.

This technique was used in a study in which acute scaphoid fractures were recruited and underwent

dynamic MRI with gadolinium enhancement at 7–14 days after injury.⁶ All were treated in a below elbow plaster cast for 8 weeks, regardless of the MRI findings which were not shown to the treating surgeon. All underwent computed tomography (CT) at 12 weeks to assess union. Thirty-two patients were recruited to the study. Twenty-eight of their fractures united and 4 failed to unite, giving a union rate of 85%.

Figure 1 shows the percentage enhancement that occurred in the proximal and distal fracture fragments after intravenous injection of gadolinium. Each triangle and circle represents one scaphoid fracture and the y-axis indicates the proximal fragment blood flow. Fractures lying on the x-axis have a very poor blood flow to the proximal fragment which may be avascular. Thus if proximal fragment blood flow predicts non-union, one would expect the non-unions to be found here. In fact, the circles represent the fractures that failed to unite and three of these four fractures had a very good proximal fracture fragment blood flow. Furthermore, all the fractures that appeared to have avascular proximal fracture fragments united. The conclusion of this study is therefore that loss of proximal fragment blood flow as measured with dynamic gadolinium enhanced MRI is not the cause of fracture non-union.

Study 3

The above two studies looked at all the parameters that the books suggest cause non-union and found that none of

Figure 1 Percentage enhancement (parameter that reflects blood flow) measurements in proximal and distal fracture fragments of acute scaphoid waist fractures during dynamic gadolinium enhanced magnetic resonance imaging. Each triangle represents a scaphoid fracture that united. The four circles represent the four scaphoid fractures that did not unite.

Figure 2 Acute scaphoid fracture: Careful assessment of scaphoid series radiographs suggests the fracture is displaced (A). The severity of displacement is much easier to assess on computed tomography of the same fracture (B). This shows clearly that the fracture is very displaced with 90° flexion of the distal fragment and virtually no bone-on-bone contact.

them predict the union rate. However, it is not always easy to assess displacement on scaphoid series x-rays even if one performs careful measurements and it is much easier to assess this on CT (Fig 2). This problem with assessment of displacement on scaphoid series radiographs was highlighted by a study in which blinded assessments of fracture displacement were made from scaphoid series radiographs and MRIs of a series of scaphoid fractures.⁷ It revealed that only three of the nine fractures that were displaced according to the MRI were identified as displaced on the plain x-rays (sensitivity: 33%). Moreover, only three of the seven fractures categorised as displaced on the scaphoid series x-rays were actually displaced (positive predictive value: 43%).

Consequently, it was investigated whether fracture displacement as assessed with MRI predicts the union rate. CT would have been used but it was not so readily available at the time. In this study, 49 acute scaphoid waist fractures underwent MRI at 2 weeks following injury. This was high quality imaging obtained in the sagittal and coronal planes, and not reconstructions from transverse images. The results of the MRI were not shown to the treating surgeons and all the fractures were treated non-operatively in plaster for 8–10 weeks. They then underwent x-rays to assess union and also CT if there was uncertainty as to whether union had occurred.

At the end of the study, the MRI was assessed independently by two observers, who were blinded to all patients' details and whether or not the fracture had united. According to their assessments, 40 fractures were minimally displaced, 7 were moderately displaced and 2 were severely displaced. All the undisplaced fractures united but only five of the moderately displaced and one of the severely displaced fractures united. Hence, 3 of the 9 displaced fractures failed to unite compared with none of the 40 undisplaced fractures. This suggests that displacement

is an important determinant of the outcome of scaphoid fractures.

The conclusion of the above three studies is that acute scaphoid waist fracture outcome with treatment in plaster cannot be predicted by measurement of the proximal fragment blood flow or assessments of displacement or comminution made from scaphoid series plain x-rays taken at the time of injury. However, it appears that outcome can be predicted by assessment of fracture displacement on MRI and CT. Thus perhaps such tomography should be used to decide fracture treatment and distinguish between fractures that would best be treated operatively and those that can be treated safely non-operatively?

The findings of these studies also led me to think whether undisplaced scaphoid fractures, like undisplaced fractures at other sites, are benign injuries that unite rapidly without complication. Perhaps they have been overtreated for years because of our inability to differentiate them readily from displaced fractures with scaphoid series? Perhaps undisplaced scaphoid fractures, like undisplaced distal radius fractures, can be treated adequately by immobilisation in plaster for only 4 weeks?

Study 4

The above two studies were tested in a study of acute scaphoid fractures that were visible on standard scaphoid series x-rays taken within 48 hours of injury.⁸ All were immobilised in a below elbow plaster for 4 weeks. CT was then performed in their coronal and sagittal planes using thin slices so that the cross-section of the fracture could be seen clearly. Interestingly, in many cases there was already evidence of fracture union (Fig 3). The CT was used to distinguish between displaced and undisplaced fractures, and the plan was that all undisplaced

Figure 3 Week 4 computed tomography of an undisplaced fracture that shows evidence of union

Figure 4 Coronal and sagittal slices from week 4 computed tomography of an undisplaced scaphoid fracture. There is no evidence of union and bone resorption has occurred at the fracture site. This fracture failed to unite.

fractures were to come out of plaster and be mobilised at 4 weeks whereas the patients with displaced fractures were to be offered surgery or a further 4-week period of immobilisation in plaster. Our patients in Nottingham wished almost universally to continue with plaster treatment.

We had great trouble following up these fractures after

plaster removal to determine whether they had united. This is because they occurred predominantly in young men who are notably unreliable for failing to attend clinic. However, there were 59 fractures with sufficient follow-up for confirmation of union and 6 of these failed to unite, giving an overall 11% non-union rate.

Of the 59 fractures that were followed up, 45 were un-

displaced and 26 of these came out of plaster at 4 weeks. Five were immobilised for 5–6 weeks as the patients could not attend a 4-week appointment. For the remainder, the extended treatment in plaster (7–8 weeks) usually occurred due to the surgeon in the 4-week clinic being unable to bring himself to discard the plaster at 4 weeks. This was because of the fearsome reputation of the scaphoid for failing to unite. Of the 26 undisplaced fractures that came out of plaster at 4 weeks, all but one united. All of the undisplaced fractures that were immobilised in plaster for 5–8 weeks united. In addition, all 37 of the 43 undisplaced fractures that were classed as united on the 4-week CT actually went on to unite firmly.

Thus, both fracture displacement and the appearance of fracture union on the 4-week CT correlate strongly with 'eventual union'. Figure 4 shows the 4-week CT of the one undisplaced fracture that did not unite. Although it was undisplaced, knowing what I know now, I would have treated it in plaster for a few more weeks or offered operative fixation although whether either would have affected the outcome is uncertain.

The conclusion of this study is that the majority of undisplaced fractures, which comprised 75% of the scaphoid waist fractures, unite with non-operative treatment in plaster even if this is only in place for 4 weeks. One could therefore question whether there is any benefit to operative treatment of these fractures.

Displaced fractures comprised 25% of the fractures in this study. There had a non-union rate of 30% and hence might benefit from operative fixation. However, if the policy were to operate on all displaced fractures, ten operations would be required to prevent three non-unions, which may not be cost effective.

Study 5

The outcome of displaced fractures of the scaphoid waist with non-operative treatment was investigated further using 31 scaphoid waist fractures whose 4-week CT demonstrated they were displaced.⁹ The maximum gap between the two fracture fragments was measured on the 4-week CT and this was usually (but not always) on the dorsal aspect of the scaphoid fracture (Fig 5).

All of the fractures with a gap of less than 2mm united and about half of those with a gap of between 2mm and 3mm united. If the gap was greater than 3mm, over half of the fractures failed to unite. Statistics confirm that the size of the fracture gap is a determinant of union. This should not surprise anyone who has treated fractures at any other site. Based on this finding, I would argue that displaced fractures with a displacement of 2mm or less can be treated reliably in plaster for 8–12 weeks. Those with more than 2mm displacement are more likely to develop a non-union with non-operative treatment and might be better treated operatively.

Study 6

However, there is concern about allowing fractures to unite

Figure 5 Measurement of the maximum gap between the two fracture fragments

with displacement as this will result in malunion, which may be detrimental to the clinical outcome.¹⁰ This concern was investigated in a study in which patients with acute scaphoid waist fractures were treated non-operatively in a plaster for 8–12 weeks before undergoing CT to assess union and malunion.¹ Malunion was assessed from the CT using the height-to-length ratio, which appeared the most reproducible measure of this parameter. Patients were recalled at 1 year for a clinical assessment that was performed by an assessor who was totally unaware of the radiological outcome and whether the fracture had (or had not) united with malunion.

Nineteen fractures were classed as having united with no malunion and 23 as having malunited. There were no differences in their 1-year subjective outcomes as assessed with the PEM (Patient Evaluation Measure) and DASH (Disabilities of the Arm, Shoulder and Hand) scores or their ranges of wrist motion or grip strengths. Overall, the outcomes were very good and function in the injured wrist was almost as good as in the contralateral uninjured wrist. I conclude from this small study that malunion of the severity seen in scaphoid fractures treated in Nottingham has no major influence on the 1-year clinical outcome. I would not claim that these results are relevant to severe malunions but I consider that the effect of non-union on outcome is much greater than that of malunion.

Conclusions

On the basis of the above studies, I propose the following treatment plan for scaphoid waist fractures (Fig 6). I suggest that CT is performed for all scaphoid waist fractures, ideally in the first week after injury. I appreciate that this is impossible in many centres at the present time but it should become increasingly possible in the future. Depending on the findings of the CT, each fracture should be categorised as undisplaced or displaced. The undisplaced fractures can be treated safely in a below elbow plaster for 4 weeks or, if the clinician is worried, for longer and the vast majority will unite.

For the displaced fractures, I would segregate them according to maximum displacement as shown on the

CT. If the displacement is less than 2mm, treatment in a below elbow plaster for 8–12 weeks should produce a satisfactory outcome. If there is more than 3mm of displacement, I would recommend operative fixation in the hope that this would increase the chances of achieving fracture union.

If this treatment plan was adopted, rather than treating all waist fracture non-operatively or operatively you would treat 70% of cases in a below elbow plaster for 4 weeks, 12% in a below elbow plaster for 8–12 weeks and 18% with operative fixation. I would stress that the cases selected for operative fixation would probably not be easy because this treatment plan would send down the non-operative line most of the fractures that would be easy to fix, leaving the most comminuted, displaced and unstable fractures for fracture fixation.

The above research forms the basis on which I now manage scaphoid fractures although I appreciate the numbers in these studies were small. Future larger and better studies may produce different findings but blinded observers were used in all these studies in order to reduce bias. If you think I am wrong and all my research is flawed, that's fine but please don't just tell me or others that I am wrong. Instead go out and prove I am wrong by organizing or contributing to larger and better studies. That is the only way that we can progress our understanding of scaphoid waist fractures to the benefit of our patients.

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