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Original Article

The Headless Compression Screw – Technical challenges in scaphoid fracture fixation

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ABSTRACT

Background: The Headless Compression Screw® (HCS) is a cannulated screw that is used for scaphoid fracture fixation. The screw generates compression across the fracture site prior to being countersunk below the articular surface.

Methods: We performed a retrospective review of 56 consecutive scaphoid fixations using this device in patients with both acute and chronic fractures.

Results: Union rates were 100% in acute and 87% in chronic fractures. 16% of patients required screw removal for protrusion.

Conclusion: Despite placement of the screw in line with technical guidance, protrusion was significant and can be a source of ongoing morbidity.

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1. Introduction

Scaphoid fractures are increasingly being managed surgically with specifically designed implants and evolution of different techniques.^{1–6}

The Headless Compression Screw® (HCS, Synthes Inc, West Chester, PA, USA) is a cannulated self-drilling, self-tapping, non-variable pitch screw available in 2.4 mm and 3 mm diameters that can be used in the management of scaphoid fractures. The proximal thread length is fixed and the distal thread length increases with screw length, although standard and short thread lengths are available. Compression of the fragments is achieved before the screw head is countersunk beneath the level of the articular cartilage into the subchondral bone.

The HCS system has been used at our institution since 2010 for the fixation of both acute scaphoid fractures and scaphoid non-unions with bone grafts. A percutaneous technique is used in acute cases when appropriate and an anterograde screw placement is used for proximal pole and proximal waist fractures to ensure that screw alignment is perpendicular to the fracture site. In non-union surgery, the choice of graft is dependent of the pathology. Iliac crest graft is used in simple non-unions. Vascularised grafting is used when there are poor prognostic factors: proximal pole non-union, avascular necrosis demonstrated on gadolinium enhanced dynamic magnetic resonance imaging (MRI), previous failed surgery, non-union for more than 5 years. Vascularised grafts include either pedicled 1:2 supratrochanteric artery⁷ or free vascularised medial femoral condyle.⁸ This paper reviews the outcomes

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of scaphoid surgery using the HCS in our institution and also addresses the technical challenges experienced.

2. Patients and methods

A retrospective review of all patients who had the HCS used for scaphoid fracture fixation between June 2010 and June 2012 was carried out by evaluation of theatre logbooks, implant logbooks, case notes and radiological investigations. All patients in this study had their surgery carried out by the senior authors using a standard technique⁹ and mini C-arm guidance or by senior hand surgery fellows under their direct supervision. The standard technique used was as recommended by the implant manufacturer. A 1.1 mm guidewire is placed across the fracture site in the optimum position. During retrograde fixation, when necessary a trapezium burr is used to optimise the entry point. Measurement is taken using the standard guide with imaging to ensure that the depth gauge is in contact with the scaphoid. The screw length is chosen after deductions for the fracture gap, the head length and the degree of countersinking required. If the fragment into which the screw tip will engage is small, a short thread length is chosen to minimise the risk of screw threads bridging the fracture or graft and to minimise the risk of joint penetration. The screw is passed with compression achieved prior to advancing the screw into its final position beneath subchondral bone, and continuous screening on the mini C-arm used to assess adequate placement.

The size of the scaphoid fragments, screw diameter, screw length and thread length were recorded in all cases through standardised measurements on the GE PACS imaging system. Follow-up records and imaging were examined to identify time to union and any complications including screw protrusions.

There were four categories of patients:

Group 1. Acute fracture treated with percutaneous fixation

Group 2. Acute fracture treated by open reduction and internal fixation (ORIF)

Group 3. Chronic fracture treated with ORIF and non-vascularised bone graft

Group 4. Chronic fracture treated with ORIF and requiring vascularised bone graft (Fig. 1)

2.1. Acute fracture fixation

Undisplaced acute proximal pole fractures have a high rate of non-union (30%)¹⁰ and as such fixation is the preferred management technique. Displaced waist fractures should be reduced and fixed. If satisfactory closed reduction is achieved, then fixation can be through a percutaneous technique. Undisplaced waist fractures were offered the choice of percutaneous fixation or cast treatment, and those opting for surgical management were included in the study. The advantage of percutaneous fracture fixation is minimal disruption to stabilising ligaments and carpal blood supply permitting faster rehabilitation.

Post-operative management in all acute fixation cases involved immediate gentle mobilisation, with a review at 2 weeks for wound evaluation and commencement of physiotherapy, and 6 weeks for X-ray evaluation.

2.2. Chronic fracture non-union fixation

Scaphoid non-union can lead to carpal instability dissociative and early osteoarthritis. Fixation is indicated to relieve pain, restore function and slow down the progression of osteoarthritis. Anatomical reduction restores scaphoid length and alignment and therefore restores carpal kinematics. Structural autologous bone graft aids restoration in length as well as providing osteoinductive and osteogenic potential. The additional use of vascularised bone graft was preferred in cases of avascular non-union or longstanding non-unions with adverse prognostic features. Post-operative immobilisation in plaster cast was continued for 6 weeks. Computed tomographic imaging was obtained if there was no evidence of union by 3 months on plain radiographic imaging.

Fig. 1 – Patient groups.

Table 1 – Patient group demographic.

	Group	N	Mean age (range)	Male:female
1.	Acute fixation – percutaneous	12	30 (19–53)	11:1
2.	Acute ORIF	14	30 (20–45)	13:1
3.	Non-union ORIF + bone graft	19	25 (17–35)	16:3
4.	Non-union ORIF + vascular bone graft	11	26 (19–33)	11:0

Table 2 – Patient group complication summary.

Group	Description	Sample size	Non-union	Metalwork complication
1	Acute; percutaneous fixation	12	0	1
2	Acute; ORIF	14	0	1
3	Chronic non-union; structural bone graft	19	1	6
4	Chronic non-union; vascularised bone graft	11	2	6
Total		56	3	14

2.3. Outcomes

The two outcomes reviewed in this study were union rates and complications related to the implant including the need for further surgery.

3. Results

During the study period, the HCS was used for the fixation of 26 acute fractures and 30 scaphoid non-unions with or without vascularised bone graft (Table 1). Amongst the acute scaphoid fracture fixations (groups 1 and 2), the mean follow-up period was 21 weeks (8–84 weeks). Eight patients were lost after 15 weeks follow-up. All fractures united, but two patients (2/26) required removal of screws due to ongoing pain and radiological evidence of screw protrusion.

Twenty-nine (29/30) of the non-unions had a mean follow-up period of 42 weeks (range 6–105 months) with one patient failing to attend a post-operative follow-up appointment. Five patients were lost after 20 weeks. Twenty-seven (27/30) cases progressed to union, and six patients (6/30) required removal of prominent metalwork.

There were no complications of bleeding, infection or neurovascular injury. There were no chronic regional pain syndromes, but there were 9/56 cases that required removal of

the HCS owing to screw protrusion. One patient had the screw removed due to ongoing pain in the wrist and despite an appropriately sited HCS and the symptoms were only alleviated when the screw was removed. Details of patient outcome are given in Table 2.

Of the nine cases where symptomatic screw protrusion was identified, eight were in open procedures with image intensifier control, six involved the screw head, and three involved the tip. Evaluation of the fragment sizes and the screw length by CT scan at post-operative follow-up (Table 3) suggests that five patients received an inappropriate length of screw for their fragment sizes. Seven cases occurred in patients undergoing treatment for non-union, as such this suggests a 23% (7/30) protrusion or cut-out rate in scaphoid non-unions managed with HCS compared with an 8% (2/26) incidence in acute fracture fixations ($p = 0.11$, Fisher's exact test [single-tailed]).

4. Discussion

The HCS is a non-variable pitch screw that obtains its compression through masking the screw head inside a specialised cannulated screwdriver which abuts against the bone during initial insertion. Step 1 involves threading the head of the selected screw into a compression sleeve. The screw, sleeve, and driver assembly is then inserted into

Table 3 – Penetrating screws length compared to CT measurements of fragment length.

Indication for surgery	Screw direction	Screw size ^a	Location of penetration	Fragment length ^b
ORIF + NVG (waist #)	Antegrade	3–24:8	Screw head	13:13
ORIF + VG (proximal #)	Antegrade	2.4–20:8	Screw tip	16:16
ORIF + VG (proximal #)	Antegrade	2.4–20:8	Screw head	13:15
ORIF + VG (waist #)	Antegrade	3–24:7	Screw head	14:15
ORIF + VG (waist #)	Antegrade	3–26:10	Screw tip	15:15
ORIF + VG (waist #)	Antegrade	2.4–22:4	Screw head	10:12
PF (acute-waist #)	Retrograde	2.4–22:5	Screw tip	11:12
ORIF (acute-distal #)	Retrograde	3–24:8	Screw head	No CT scan
ORIF+VG (waist #)	Antegrade	2.4–20:4	Screw head	17:15 (screw buried)

ORIF – open reduction and internal fixation, VG – vascularised graft, NVG – non-vascularised graft, PF – percutaneous fixation.

^a Diameter (mm) – Screw length (mm):Thread length (mm).

^b Thread end (coronal:sagittal) – determined on CT Scan.

Fig. 2 – The Headless Compression Screw.
Courtesy of Synthes.

the scaphoid along a 1.1 mm guidewire. In step 2, once the distal threads have crossed the fracture site entirely, the compression sleeve acts as a conventional lag screw head to achieve compression of the fracture gap. Step 3 involves holding the compression sleeve stationary while exchanging the compression sleeve handle with a cannulated screwdriver that threads into the compression sleeve. This second screwdriver will disengage the screw head from the compression sleeve and countersink the head flush or 2 mm beneath the cortical surface of the scaphoid, with the assistance of traffic light markings. The screw head threads measure 2 mm in length, and require a further 2 mm to bury the head fully into the subchondral bone. The distal screw threads increase with screw length although short thread versions are available. The distal thread length is related to the overall screw length as follows: 4 mm thread length come in overall screw lengths between 9 and 23 mm, 5 mm thread length is available for 24–26 mm screws and 6 mm thread length available for 27–29 mm screws (Fig. 2).

There are several considerations when determining which screw is to be used for fixation. The manufacturers instructions suggest that screw length may need to be adjusted to allow for fracture gap, countersinking the screw head and any obliquity of the screw trajectory to the bone surface. Typical length adjustments are such that the screw is undersized by 4 mm allowing for the fracture compression and burying the screw head under the bone surface.

Fig. 3 – Diagrammatic representation of HCS use in acute fracture without bone graft, showing that the threads have passed fully into the fracture gap. However, once the fracture gap has closed, the screw may be too long to allow proper burial of the head.

This principle is appropriate in simple cases of acute scaphoid fracture fixation where there are two fragments. The following equation applies for determining the screw length in such cases as derived from the product literature:

$$\text{Screw Length} = (\text{Proximal fragment} + \text{Distal fragment}) \\ - (\text{Fracture gap} + \text{Screw head})$$

The distal fragment length is not inherently known but an intra-operative determination is required to ensure that any screw placed has all threads that have passed fully into the fracture gap to allow for compression (Fig. 3). In addition, the fracture gap is not accurately known but is usually estimated at between 1 and 2 mm. Two of the cases in Table 3 demonstrate screw protrusion in acute fractures both at the head (see Fig. 4a) of the screw suggesting that either the head was not appropriately buried or had back-out post-operatively (see later).

Seven cases in Table 2 used bone graft, which introduces a “third fragment” (Fig. 5). This requires an adjustment to be made to the calculation when estimating screw length using the HCS for fixation of scaphoid non-unions:

Fig. 4 – X-rays demonstrating screw protrusion at (a) screw head and (b) screw tip.

Fig. 5 – Diagrammatic representation of HCS use in a fracture with bone graft.

$$\begin{aligned} \text{Screw Length} = & (\text{Proximal fragment} + \text{Distal fragment} \\ & + \text{Bone graft}) - (\text{Fracture gap 1} \\ & + \text{Fracture gap 2} + \text{Screw head}) \end{aligned}$$

Based on the manufacturers recommendation, this would suggest that whatever screw length is measured should have 6 mm subtracted to ensure that it is buried properly. Whenever this procedure is part of an open reduction, it would be reasonable to suggest that an intra-operative evaluation could be carried out to determine the fragment and graft dimensions as well as two fracture gaps.

The distal fragment length and the distal screw thread lengths are critical. In order to provide compression at the bone graft–distal fragment interface, all screw threads should pass fully into this gap. It is preferable to use the short distal screw thread length option. After the threads pass the distal interface, the screw needs to advance at least another 6 mm (fracture gaps, plus burial of screw head flush with or 2 mm beneath subchondral bone) and this poses a risk of distal screw penetration into the scaphoid-trapezium-trapezoid (STT) complex articulation.

Small distal fragments are a particular challenge and using this method of compression with a bone graft and perpendicular screw placement, the minimum fragment size that may be fixed using the HCS is 10–12 mm (4 mm minimum screw thread length distally + 2 mm fracture gap + 2 mm head length + optional 2 mm recession of head). In such cases, the screw will be at the distal bone surface with no margin for error.

Three of the screw protrusions were at the tip, suggesting that initial hold in the distal fragment was insufficient and subsequent collapse pushed the tip of the screw through the distal subchondral bone (see Fig. 4b). In contrast, six of the screw protrusions occurred at the proximal insertion point with the screw head. At surgery, the screw head was observed to be appropriately buried, suggesting an early loss of fixation.

One potential cause is that the method of compression using the compression sleeve screwdriver abutting against the scaphoid damages the subchondral bone plate around the insertion point, particularly if excessive compression is achieved. One cannot accurately measure or limit the compression force using this system and the best assessment of adequate compression is obliteration of fracture gap on screening. Excessive force may cause either microfractures or local osteonecrosis, with resorption around the head–bone

interface culminating in loss of fixation. Further resorption around the graft will exacerbate this screw protrusion.

There is another potential cause for this proximal screw cut out and loss of compression. When the guidewire is inserted, the screw length is estimated from the depth gauge measurement of wire within the bone minus the allowance for screw head insertion and fracture gap. Typically, this will be a deduction of around 6 mm in non-union cases with bone graft. The drill should be inserted to the full length of the wire in order to ensure that the screw advances fully into the distal fragment to achieve compression. Advancing the guidewire after measurement may prevent wire removal during drilling and loss of fracture reduction. Failure to drill the correct length may result in overzealous attempts at compression and stripping of the self-tapping threads in the bone, particularly if the bone is hard. The HCS manual¹⁰ reports that over-compression may be a problem in poor quality bone but does not mention the risk from under-drilling, where failure to advance may either impede compression or risk screw head protrusion.

In our initial usage of the HCS, we have noted screw protrusion rate of 23% (7/30) in scaphoid non-unions managed with HCS compared and 8% (2/26) in acute scaphoid fractures. In a previous small study on the early results of the HCS in scaphoid fractures, this problem was not reported.⁶ Our practice has now been modified to determine the distal fragment size pre- or intra-operatively before applying the above formula and selecting the most appropriate screw size in terms of both thread and overall length.

Key points

- An accurate pre-operative estimation should be made of the distal fragment length to ensure that the distal thread fully cross the fracture gap.
- Allow for fracture gap in screw sizing.
- Allow 4 mm for the screw head to be buried and recessed beneath subchondral bone.
- Advance the guidewire after measuring length, to avoid displacement when drilling the full length.
- Avoid overcompression.
- For distal fragment lengths less than or equal to 10 mm, consider retrograde screw insertion direction or an alternative system for fixation.

Ethical approval

This was a retrospective review of data already held by the institution; no patients were contacted during the course of this study. All radiographic images and patient data have been anonymised in compliance with UK Data Protection Laws.

Conflicts of interest

The authors have none to declare.

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