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Scaphoid fracture non-union: a systematic review of surgical treatment using bone graft

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D. O. Ferguson, V. Shanbhag, H. Hedley, I. Reichert, S. Lipscombe and T. R. C. Davis

Abstract

This systematic review assesses the quality and outcomes of published articles concerning bone graft surgery for scaphoid fracture non-union. Searches of the CENTRAL, MEDLINE, EMBASE, CINAHL and AMED databases captured 2710 articles. Each article was screened and 144 met our inclusion criteria. Data regarding source, study design, population, intervention, comparator and outcomes were extracted. There were 5464 scaphoid non-union outcomes within the 144 studies. Mean reported union rates for vascularized and non-vascularized bone graft were 84% and 80%, respectively. Avascular necrosis was diagnosed in several ways and, when present, the vascularized bone graft union rate was 74% compared with 62% with non-vascularized bone graft. Reported union rates vary considerably. These differences may be due to patient factors, fracture factors, treatment factors or study design failures or bias. We recommend that future researchers take into account the deficiencies of previous studies and use the suggested minimum data set in future studies.

Level of evidence: II

Keywords

Scaphoid, non-union, surgery, avascular necrosis, bone graft

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Introduction

The treatment aims for patients with scaphoid fracture non-union are pain relief, improved hand function and prevention of late onset painful post-traumatic osteoarthritis. These aims are usually, but not always, achieved by treatment that results in scaphoid union. Insertion of a bone graft into the non-union is a standard technique for achieving union, but is not always successful. Numerous different techniques of bone grafting, including different sites of harvest, different fixation techniques and use of vascularized bone graft (VBG) or non-vascularized bone graft (NVBG), have been described. Reported success rates, in terms of achieving union of the non-union, vary considerably and there is no clear evidence that one surgical technique is superior to another. Reports of surgical treatment typically use 'union' of the non-union as the primary outcome measure, as it is a good surrogate for improved pain levels and hand function.

This is a systematic review of the outcome of bone graft surgery for scaphoid fracture non-union. The primary question we attempt to answer is 'does one type of surgery provide superior results to another?'. The secondary question is 'what is the quality of the published literature on the outcome of bone graft surgery?'.

Method

Our study design was published by Davis et al. (2012), on the PROSPERO database – an international prospective register of systematic reviews, hence the PRISMA analysis is not shown in detail in this article. Searches of the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE (Ovid) (from 1966), EMBASE (from 1966), CINAHL (from 1982) and AMED (from 1985) were performed using broad search terms ('Scaphoid' in 'Title AND Abstract' with 'NO LIMITS') to generate a list of possible studies, without

Department of Trauma and Orthopaedic Surgery, Nottingham University Hospitals, Nottingham, UK

Corresponding author:
T. R. C. Davis, Queens Medical Campus, Nottingham University Hospitals, Nottingham NG7 2FT, UK.
Email: Tim.Davis@nuh.nhs.uk

Table 1. Inclusion and exclusion criteria.

Study aspect	Inclusion criteria	Exclusion criteria
Types of studies	1. Retrospective and prospective case series 2. Controlled clinical trials 3. Quasi-randomized and randomized controlled trials 4. Minimum sample size of ten 5. Non-blinded and blinded studies 6. Any European language	1. Sample size smaller than ten 2. Studies reporting the outcomes of non-surgical methods (electromagnetic field therapy, ultrasound) 3. Articles not available through the British Library or our institutions online journal access
Types of participants	1. Adult men and women (age greater or equal to 16 years) who underwent a surgical procedure to achieve union following a scaphoid fracture non-union	1. Paediatric cases (age less than 16 years) 2. Patients with only acute scaphoid fractures
Types of interventions	1. Any surgical intervention for the treatment of the scaphoid non-union, including vascular and non-vascular bone grafts, fixation with any implant, including screws or Kirschner wires, and open, minimal invasive or arthroscopic techniques	

risk of missing suitable articles. A similar search was performed using 'navicular' instead of 'scaphoid' to identify publications in the German-language literature. Both searches were performed in June 2012.

The reference management system RefWorks (Refworks, Cambridge, UK) was used to manage the search results and articles were sorted alphabetically by author name after removing duplicate entries. A total of 2710 articles were captured by our search strategy; these were divided into four groups and allocated to four authors (DOF, SL, VS, HH). Each author independently reviewed the title, abstract or descriptor of each article in their allocation to identify potential studies for review using a checklist of the criteria for inclusion (Table 1).

Each author divided the screened articles into three folders – 'accept', 'reject' and 'unsure'. Each author's 'rejected' articles were screened independently by one of the other three authors and any article subject to a difference of opinion was moved to the 'unsure' folder. Further duplicate entries were removed from the reference list. The senior author (TD) then reviewed the 'unsure' folder of each author and moved articles into either the 'accept' or 'reject' folder. The authors combined their lists of potential studies and produced an 'agreed shortlist' of 482 articles.

Four authors independently reviewed the full text of the agreed shortlist articles and identified those suitable for inclusion using the selection checklist (Table 1). A fifth author (IR) reviewed all the German language articles identified from their English abstracts. Disagreements were resolved by referral to the senior author (TD) and discussed. A total of 144 of the 482 articles were considered suitable for entry into our research database (Table 2).

Data regarding source, study design, population, intervention, comparator (if present) and outcome, commonly abbreviated to PICO (Moher et al., 2009) were extracted from the 144 articles and entered into our database by five authors (Table 3). Comparator (group) data were extracted only when the union rates for two or more treatments were detailed in a study. For example, a study reporting separate union rates for VBG and NVBG were treated as two separate groups of data within the database. We defined our levels of evidence in accordance with the Oxford Centre for Evidence Based Medicine (2011) (Figure 1). We found that several studies contained two or more subgroups of fractures that received different treatments and so modified our database to allow additional analysis. There were a few studies that reported the outcome of both acute fractures and non-unions of fractures of the scaphoid. These studies were discussed, and only included if 70% or more of their cases were of non-union. We decided to include studies where we believed the risk of bias from acute fractures was low when calculating the union rate. One such study reported 'subacute' fractures that were 2–24 weeks old. We attempted to calculate a fracture union rate for each study and subgroup, although it was sometimes unclear how many patients had been recruited with follow-up. Disagreements were resolved by consensus after an additional review by the senior author (TD).

Results

A total of 144 articles met the entry criteria for this systematic review. One was published before 1970, four in the 1970s, 29 in the 1980s, 36 in the 1990s and 55 in the 2000s (Supplementary Table 1). A total of 19 were published during 2010–2012. There were no Level 1 studies, five Level 2, 21 Level 3, 117 Level 4 and one Level 5 studies.

Table 2. The process of accepting and rejecting studies.

Stage	Description	Accept	Unsure	Reject	Total
1	Database Search (AMED, CINHAL, MEDLINE, EMBASE).	4652	0	0	4652
2	1st deduplication.	2710	0	1942	4652
3	Title, abstract and keyword screening (1st round).	433	112	4107	4652
4	Unsure folder sorted by senior author. 2nd deduplication.	482	0	4170	4652
5	Articles accepted/rejected based on our inclusion/exclusion criteria.	144	0	4508	4652

Table 3. Non-union study data collected. Each cell in the table represents a section of the database that was completed for each study.

Source	Study design	Population	Intervention	Outcome
Title	Prospective, retrospective	Number of patients	Initial treatment of acute fracture	Radiological
Author	Inclusion and exclusion criteria	Number of fractures	Post-operative immobilization after non-union surgery	Clinical
Year	Type of study	Age, gender, occupation	Implants used	Functional scores
Level of evidence	Recruitment process	Hand dominance	Graft used	Bias factors
	Definition of union and non-union	Occupation	Approach used	Conclusions
	Fracture classification	Mode of injury		
	Follow-up length	Comorbidities		
	Method of assessing union	Number of subgroups		

Level of Evidence	Description
1	High quality randomised controlled trial
2	Poor quality randomised controlled trial or prospective study
3	Case control study
4	Retrospective case series
5	Expert opinion

Figure 1. Levels of evidence, according to Oxford Centre for Evidence Based Medicine, 2011.

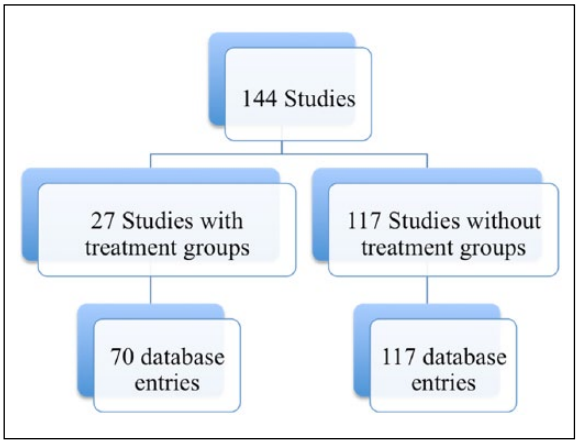

Figure 2. Flowchart showing how data from studies entered the database.

Study design

A total of 13 studies were prospective, 125 were retrospective and for six it was unclear or not stated. The method of identifying potential recruits (i.e. review of operating theatre or clinic logs) was described in only 50 studies, and only 88 described their inclusion criteria. A total of 27 studies underwent treatment subgroup analysis, according to different treatment modalities (i.e. Russe inlay graft or trapezoidal graft with internal fixation). Thus, although there were 144 studies, there were 43 additional database entries of fracture non-unions that reported the outcomes of specific treatments. We created a single database entry for each specific treatment subgroup where adequate data were provided within the article. We entered a single database entry for the whole study if data could not be separated (Figure 2). Most studies described just one treatment method and so had just one database entry. A total of 187 entries were made into our database.

Patient demographics

The majority of the 144 studies reported mean patient age (127), gender (119) and hand dominance (102), but only a minority described mechanism of injury (39), occupation (28), smoking status (17) and comorbidities (11).

Treatment of the original fracture

The initial treatment of the acute scaphoid fracture was described in 90 of 144 studies. There were 80 studies that reported two or three different initial treatments among their patients, such as no initial treatment, plaster immobilization or operative treatment. In five studies the initial treatment was always plaster cast immobilization.

Definition and diagnosis of non-union

Of the 144 studies, 112 described the imaging used to diagnose the non-union before surgery. Wrist radiographs were used in 70 studies, some of which may have utilized scaphoid views but this was not stated. Scaphoid series radiographs were definitely used in another 34, magnetic resonance imaging (MRI) without enhancement in 10, MRI with enhancement in five and computed tomography (CT) scans in 14 studies. Thirty-two studies failed to report which imaging modality was used. Ninety-six studies relied upon one imaging modality only, whereas 11 and five used two and three modalities, respectively, but not necessarily in every case.

Only 17 of the 144 studies described their definition of non-union, which was based upon radiographs in 14 studies. Seven of these studies relied upon scaphoid series radiographs and three reported using CT scans to assist the diagnosis of non-union. The definition of non-union was failure of union after 12 weeks in four studies, 20 weeks in one study, 24 weeks in seven studies and 1 year in five studies. However, the radiological features, e.g. absence of crossing trabeculae, required to make a diagnosis of non-union were not described in any study. Only seven reported their definition of delayed union, which was 8 weeks or less in three studies, between 8 and 12 weeks in one study, between 12 and 24 weeks in another study and more than 24 weeks in two studies. The time from injury to non-union surgery was recorded in 116 of the 144 studies, and the time from radiological diagnosis of the fracture non-union until surgery was reported in eight.

At operation the non-unions were categorized as either fibrous or synovial in 27 of the 187 database entries, but not described in the remainder. The period of post-operative immobilization was described in 111 database entries.

Site of fracture non-union

A total of 73 studies described how the fractures were categorized as waist, proximal or distal pole fractures, with 65 dividing the scaphoid into proximal, middle and distal thirds. Two articles defined the proximal and distal poles as the proximal or distal fifth (20%) of the scaphoid, respectively.

Definition of avascular necrosis

The method for diagnosing avascular necrosis (AVN) (i.e. proximal fragment sclerosis, MRI changes or macroscopic appearance at surgery) was only described in 40 studies. Eight of these relied solely upon the appearance of the fragment at surgery, 15 relied solely upon radiographs and five used both. Twelve studies relied upon MRI scans, six with contrast and six without.

Type of surgery

Of the 144 studies, 34 reported the outcomes of treatment with VBG, 67 the outcomes of NVBG and four the outcome with both types of graft. Eighteen reported outcomes using no bone graft at all. The remaining 21 studies reported multiple graft types with a single combined union rate. Of the 187 database entries, iliac crest bone graft was used in 54, distal radius in 58 and both iliac crest or distal radius in 20. There were 33 database entries with unspecified graft donor sites, three with other donor sites (medial femoral condyle, or thumb or index metacarpals) and 19 describing treatment without bone graft.

Length of follow-up

We considered an 'adequate' length of clinical or radiological follow-up to be more than 12 weeks. Adequate clinical follow-up was reported in 107 of the 144 studies; the mean duration was 45 months (range 1–456). Adequate radiological follow-up was documented in 118 studies, but the precise duration was often unclear.

Clinical outcome assessment

Clinical outcomes of the non-union surgery were assessed in 80 of the 187 database entries with 12 different patient reported outcome measures (PROM). Pain was assessed on a visual analogue scale in 52 of the database entries. Thus a PROM was not used in 107 database entries and a visual analogue score (VAS) was not used in 135. Neither a PROM nor a VAS was used in 94 database entries, while both were used in 41. Most studies that utilized a PROM or VAS reported overall scores for all the scaphoids, rather than separate scores for those that had united and those that had not united.

Clinical assessments of outcome, such as ranges of wrist movement and grip strength, were reported in 66 studies. They were measured by the treating surgeon in nine studies and one of his team in another nine studies. An independent observer performed the measurements in five studies. In the remaining studies, it was

not stated who performed these outcome assessments. Ranges of wrist movement results were stated for before and after surgery in 15 studies, but no clear comparison groups were identified.

Radiological outcome assessment

Only five studies stated that the assessors were blinded to the radiological outcome. Union or persistence of the non-union after surgery was assessed radiographically using only standard (postero-anterior and lateral) radiographs in nine of the 144 studies, scaphoid series radiographs in 53 and 'unknown' radiographs in 64. It was always assessed with CT scans in 15 studies, and CT scans were obtained in instances when there was uncertainty as to whether the scaphoid had united in 21 studies. A total of 21 studies did not record whether any radiographs were obtained. It was not possible to report whether the union rate was influenced by the type of imaging used to determine union as multiple imaging modalities and radiographic views were frequently used in the same study. Dorsal intercalated segment instability deformities were also assessed radiologically, and reported in 42 of the 144 studies. The assessor of the radiological outcome was reported for 26 of the 144 studies (30 database entries). It was the treating surgeons in seven studies, a member of the surgical team in eight studies and a radiologist or independent observer in 11. The assessor was recorded as blinded to the clinical outcome in only nine studies.

Definition of union following non-union surgery. Several different criteria were used to determine when a scaphoid non-union had successfully united, some of which were used in combination. A total of 24 studies stated that union had been achieved when trabeculae were seen to cross the bone/bone graft interface, usually on radiographs. Bridging trabeculae traversing the graft into the proximal and distal fragments was stated in three studies. The complete disappearance of a bone interface line or gap on the radiographs was used in eight studies and on CT in four studies. Lack of local tenderness was used as an assessment in six studies, while pain on stressing or moving the wrist was used in one. A further single study stated union had occurred if there was stability after the scaphoid screw had been removed. Three other studies stated union had occurred if there were no signs of the scaphoid screw loosening.

Smoking. It was not possible to examine the influence of smoking on union rates as the majority of studies described only the proportion of smokers at the time of patient recruitment, rather than how many of the smoking population actually united. Reported union rates varied from 17% to 100% for non-unions treated with NVBG and 27% to 100% treated with VBG.

Combined data from the 144 studies. Overall 6505 scaphoid non-unions were recruited for treatment within the 144 studies. There was sufficient follow-up data to calculate a rate of union for 5464. Of these, 4426 were thought to have united. Thus, 81% of all scaphoid non-unions receiving operative treatment were thought to unite. A total of 1041 scaphoid non-unions were either lost to follow-up or did not have sufficient data to calculate a rate of union. The location of the non-union within the scaphoid was recorded in 4191 instances: 1265 (30%) were within the proximal pole, 2639 (63%) within the waist and 287 (7%) within the distal pole. The location of the non-union was not recorded for the remaining 2314 cases. Rates of union were identified for 3327 of 3971 non-unions treated with NVBG (80% union rate) and all 902 treated with VBG (84% union rate (Table 4)). A large number of studies were retrospective case series in which more than one treatment method (i.e. Russe inlay graft or trapezoidal graft with screw fixation) was used and treatment-specific union rates were not reported. No fixation device was inserted to stabilize the graft in 968 cases; in 468 of these the Matti–Russe technique was used. The remaining 500 cases with no fixation used other forms of volar inlay graft, soft tissue arthroplasty (Boeckstyns et al., 1985) or VBG. Kirschner wires were inserted in 1183 cases and a Herbert screw or Accutrak screw in 1745 and 137 cases, respectively. Other fixation devices were used for a further 1098 non-unions. A total of 547 (43%) of the 1265 proximal pole non-unions were reported to have avascular necrosis of the proximal fragment.

Patients who had been treated unsuccessfully in plaster casts alone for their acute scaphoid fracture, went on to achieve union with surgery in 73% of cases. Patients who had undergone unsuccessful surgery for their acute fracture, who then went on to have non-union surgery, achieved union in 84%. The overall union rates when comparing dorsal and palmar approaches during non-union surgery were 76% and 84%, respectively. The dorsal approach is most commonly used to access proximal pole fractures, which is recognized as having a poor blood supply, and this may confound these figures. The rates of union were similar when analysing NVBG harvested from the iliac crest (83%) and distal radius (81%). There were insufficient data to report union rates according to gender, smoking status or high/low energy injuries.

Outcome of scaphoid non-union surgery with avascular necrosis. From 44 studies, 45 database entries detailed

Table 4. A comparison between VBG and NVBG database entries.

	Vascularized bone graft	Non-vascularized bone graft	Total
Number of database entries	34	120	154
Number of entries with union rates quoted	34	99	133
Mechanism of injury and smoking status recorded	2	0	2
Radiological follow-up >12 weeks	29	50	79
Imaging used to assess union			
Scaphoid series radiographs	14	23	37
Unknown radiographic views	14	39	53
Standard wrist radiographs	5	3	8
CT scan in all cases	5	5	10
CT scan in cases of uncertainty	7	9	16
Scaphoid saggital and coronal slices	3	0	3
Saggital and coronal reconstructions	1	1	2
Not stated	1	3	4
Performed a clinical follow-up	31	53	84
PROM used to assess outcome	24	31	55
Reported union rate range (min–max)	27–100%	17–100%	17–100%
25th centile of union rate	77%	73%	
50th centile of union rate	90%	86%	
75th centile of union rate	100%	94%	
Length of time since fracture (range–weeks)	2–276	1–360	
Total number of scaphoid fractures	902	3327	4229
Total number of united scaphoids	759	2676	3435
Percentage of scaphoids that united	84%	80%	81%
Proximal pole fractures	378	507	885

CT: computed tomography; PROM: patient reported outcome measures.

the results for scaphoid non-unions with associated avascular necrosis. A total of 21 entries used VBG and 19 used NVBG. Two entries to the database used both types of bone graft and three used none.

The mean ages of patients with AVN were similar in both VBG and NVBG categories (28 and 26 years, respectively). In the VBG category, there were 292 cases of AVN, with an average union rate of 74% (0–100%). The NVBG category had 236 cases of AVN, with an average union rate of 62% (0–100%). Finally, the 13 cases in the three database entries treated with screw fixation without bone graft had a mean union rate of 77% (67–100%). An overall union rate of 69% was calculated when all surgical treatment results for AVN were combined.

Discussion

This review found a lack of high quality evidence from which to draw accurate conclusions regarding the union rates for various scaphoid non-union treatments. Only five studies that matched our inclusion criteria provided level 2 evidence (Braga-Silva et al., 2008; Bunker et al., 1987; Mahmoud and Koptan, 2011; Ribak et al., 2010; Ricardo, 2006). In contrast, 118 provided only level 4 or 5 evidence.

We encountered many problems when analysing the literature. Several studies used the terms 'patients' and 'fractures' interchangeably, and this created accounting errors when bilateral fractures occurred. We also found that some studies included results of fresh fractures with non-union results. When this was the case, we discussed the study and only included it if more than 70% of fractures were non-unions (Breit et al., 1985; Bunker et al., 1987; Christodoulou et al., 2001; Dos Reis et al., 1993; Ford et al., 1987; Herbert and Fisher, 1984; Hull et al., 1976; Küntscher et al., 2001; Kusunoki, 1992; Smith et al., 1991). We also encountered difficulties when splitting results into separate subgroups based on their treatment if only a single overall union rate was quoted. We were unable to create separate subgroups when this occurred and so the database entry was for the whole study and had to be excluded from certain comparisons. The analysis of PROMS was particularly difficult as there were many combinations of scoring systems and no way of standardizing the results.

In addition, relevant information, such as the patient population, the original injury, the type of operation or the outcome assessment, were not available in every study. Although age, gender and hand dominance were usually described, few studies mentioned patient occupations, mode of injury, smoking status or co-morbidities. We were unable to record the number of smokers who achieved union, particularly in larger studies. There were also few studies reporting the duration of initial immobilization or time from diagnosis to surgery.

The most commonly reported fixation device used was the Herbert screw, followed by Kirschner wires. NVBG inserted through a palmar approach was the most reported technique. We found the majority of studies used unique scoring systems for their PROM. During follow-up, it was often unclear who assessed the clinical and radiological results, such that it was impossible to assess the risk of detection bias. Only five studies reported using an independent observer for reporting clinical and radiological results (Eggli et al., 2002; Mahmoud and Koptan, 2011; Ribak et al., 2010; Saint-Cyr et al., 2011; Waitayawinyu et al., 2009). The reported union rates varied considerably. These differences may be due to patient factors (age, smoking), fracture factors (time since fracture, vascularity of the proximal fracture fragment, site of the fracture) or treatment factors (bone graft type and technique, and method of fixation). However, regardless of such factors, some of the reported union rates after bone graft surgery may appear high in comparison with personal experience. The high union rates could be a true 'finding', but could be due to a combination of the following confounding factors:

1. As with all clinical research, there is a risk of reporting bias, with surgeons and trainees keen to publish their case series only if they achieved good outcomes. Surgeons, and perhaps editors as well, are less eager to publish if the outcomes are not as good as those of clinical series that have already been published.
2. In most case series, the assessments of radiographic union after bone grafting were not made by an independent observer. In cases of uncertainty, there may have been a bias towards favouring a successful outcome.
3. Differences in the definitions of union and delayed union may also be relevant. Only 17 studies provided a definition of non-union and just seven studies defined delayed union. Some defined non-union as only occurring when the acute scaphoid fracture failed to unite after 26 weeks (6 months), whereas others defined a non-union as present once 12 weeks had elapsed since the injury (Murase et al., 2005; Schuind et al., 1999). Some acute fractures, which are not united by 12 weeks, may still have the capacity to unite given further time.
4. Many acute scaphoid fractures initially unite over only a portion of their cross-section, such that the fracture is still clearly visible (Singh et al., 2005), though united. Such partial unions usually consolidate with time. If mistaken for 'non-unions' and treated operatively, they will artificially increase the reported success rate of bone graft surgery. Also studies using CT scans to assess union often failed to describe how much bridging was required for a diagnosis of union to be made.
5. Failure of union after bone graft surgery is a diagnosis of exclusion. The harder the search for non-union, and the longer the period of follow-up after surgery, the more non-unions will be found. The standard definition of 'union' after an acute scaphoid fracture or treatment of a non-union includes the presence of bridging callus crossing the fracture (Dias, 2001). However, unless the X-ray beam on at least one radiographic image runs exactly parallel to the fracture surfaces (runs through the fracture gap), then the appearance of bridging callus may occur on all the images due to parallax. The more radiographs that are obtained, the more likely one view will clearly show a persistent non-union fracture. Thus more non-unions may be mistaken for unions on standard postero-anterior and lateral radiographs than on five view scaphoid series radiographs. Longer follow-up after surgery will allow additional features of non-union, such as bone resorption around a loose fixation device, to develop, making it easier to identify non-unions. Although we suspect that the reported union rates may be higher when relying on plain film radiographs (rather than CT) for diagnosing union, we were unable to demonstrate this in this systematic review, possibly due to the large number of other confounding factors. Moreover, comparing the combination of fixation methods, graft types, union rates and imaging modalities created over 70 permutations. The length of radiological follow-up was rarely stated in comparison with clinical follow-up and was often difficult to interpret, so was not recorded on our database.

Fewer non-unions will be missed on CT or MRI scans, which are free of parallax, but image distortion due to a cannulated screw or other implant within the scaphoid may cause uncertainty (Ganapathi et al., 2001). Our belief is that, as a minimum requirement for research studies, union after non-union surgery should always be assessed using scaphoid series radiographs obtained a minimum of 6 months after bone graft surgery. In our opinion, standard wrist radiographs (postero-anterior and lateral) are inadequate. Ideally union

Table 5. Our recommended minimum dataset for future scaphoid non-union studies.

Definitions	Patient details	Fracture details	Details of non-union diagnosis and treatment	Details of outcome assessment
Union Delayed union Non-union Proximal pole/ waist fractures Avascular necrosis DISI deformity	Age Gender Occupation Smoking Mechanism of injury Numbers of patients identified, recruited and followed-up	Initial treatment Duration of initial acute immobilization DISI deformity measurement AVN present Displacement of fracture on each imaging modality used Bilateral fractures Method of diagnosing non-union Time since initial injury to primary or secondary surgery	Implants used Approach used Donor site for bone graft Vascularized or non-vascularized bone graft Post-operative immobilization duration	PROM Scaphoid views with definition of positioning for each view Radiography/imaging used to assess outcome (union/non-union) Independent assessment of clinical outcome Independent assessment of radiographic outcome Time of clinical outcome assessment Time of radiographic assessment of union

AVN: avascular necrosis; DISI: dorsal intercalated segment instability; PROM: patient reported outcome measures.

would be determined using a CT or MRI scan in every instance in a research study (Dias, 2001), but this may not be feasible. We would suggest the requirement that all scaphoid non-unions that appear united on scaphoid series radiographs but remain painful, undergo a CT scan to confirm union. Thus a clinical evaluation of the outcome is essential, and this is what will determine the patient's opinion of the value of their treatment in the short-term. However, a painless non-union may cause painful osteoarthritis in the future, such that accurate determination of whether a non-union unites or persists is as important an outcome measure as a PROM.

About half the studies that we encountered gave definitions for the proximal, waist and distal poles of the scaphoid. Most used the 'thirds' definition, which probably explains the high number of proximal pole fractures and may have resulted in an optimistic reported rate of union for these fractures. Most studies that gave a breakdown of the number of proximal, waist and distal fractures did not report union rates for each, probably because the numbers in each group would have been too small. Some studies specifically excluded proximal pole fractures (Saint-Cyr et al., 2011; Trezies et al., 2000), whereas others included them (Kirkeby and Hansen, 2006; Sotereanos et al., 2006; Wilhelm and Wilhelm, 1999). The variability in methods for identifying, assessing and managing proximal pole fractures made them difficult to analyse in any great detail.

The methods used to diagnose AVN included observing punctate bleeding (Green, 1985), increased sclerosis on radiographs (Bertelli et al., 2004) and lack of signal on MRI scans (Henry, 2007). One study claimed that the MRI appearances of AVN could be reversed by using VBG (Dailiana et al., 2004). The mean union rates when using VBG and NVBG were 84% and 80%, respectively. When avascular necrosis of the scaphoid proximal pole was identified, the mean rate was 74% with VBG, compared with 62% with NVBG. There was a lack of specific demographic, preoperative and postoperative treatment data that increased the risk of selection bias when comparing these groups.

Non-unions after non-operative treatment of the acute fracture in a plaster cast had a lower union rate than when primary fixation had failed and was revised. This may be a significant finding, especially if the plaster cast treatment selects non-unions that are more likely to fail or have AVN. This may also be a biased finding if these cases are referred to more experienced hand surgeons with greater success rates. Acute fractures that developed partial union after fixation but were misdiagnosed as non-unions, may have caused the revision surgery group to have a higher success rate, as these fractures have been shown to unite given enough time (Singh et al., 2005).

This systematic review is limited by the high volume of low level evidence that has been included. We included studies with a minimum of ten patients to capture as many studies as possible, but meta-analysis of such studies was not possible. The lack of consistency in reporting union and non-union definitions created difficulties when trying to compare union rates for various treatment methods.

We recommend that future researchers take into account the deficiencies in previous studies that we have highlighted, so that comparisons can be made more easily in the future. We also recommend that a minimum data set be used in studies of the treatment of scaphoid fracture non-unions (Table 5).

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