**One year outcome of surgery versus cast immobilisation for adults with an acute undisplaced or minimally displaced scaphoid fracture-**

**A meta-analysis of randomised controlled trials**

Abstract

Aims

There has been an increasing trend for early fixation of scaphoid fractures despite uncertain evidence. We conducted a meta-analysis to evaluate up-to date evidence from randomised controlled trials (RCTs) comparing the effectiveness of non-operative and surgical treatment for acute undisplaced and minimally displaced scaphoid fractures (≤2mm displacement).

Methods

A systematic review of seven databases was performed from inception until the end of March 2021 to identify eligible RCTs. Reference lists of included studies were screened. No language restrictions were applied. The primary outcome was patient reported outcome measure of wrist function at 12 months. Meta-analysis was performed for function, pain, range of motion, grip strength and union. Complications are reported narratively.

Results

Seven RCTs were included. There was no difference in function at 12 months (Hedges’ g 0.15, 95% CI -0.02 to 0.32, p=0.08). Complication rate was higher in the operative group with more serious complications.

Conclusions

We found no difference in functional outcome at 12 months for scaphoid waist fractures (≤2mm displacement) treated with a cast or surgical fixation. Complication rate is higher with surgical fixation.

**Introduction**

The scaphoid is the most commonly fractured carpal bone1.  In a large trial over 90% of all scaphoid fractures that appeared undisplaced on plain radiographs united when treated in a cast2.  Non-union incidence increases in displaced fractures (14-50%)2-4.  Untreated non-union almost always leads to wrist arthritis, usually within 5 years of injury5.  Scaphoid fractures predominantly affect young people in their most productive working years, so untreated non-union may cause disability at a young age.  Despite uncertain evidence, there has been an increase in immediate surgical fixation over cast immobilisation6.  The perceived benefits are earlier return to normal function with the avoidance of need for prolonged immobilisation.

Several small randomised controlled trials (RCT's) could not determine whether patients who had surgical fixation of undisplaced or minimally displaced scaphoid fractures had better outcomes than patients who experienced non-operative management1, 7-11.  Some RCTs suggested surgery led to earlier return of function, but complication rates were higher than with conservative management1, 8, 10.  Union rate was comparable between early surgical fixation and non-operative treatment with fixation of any fractures that did not unite1.  Previous systematic reviews and meta-analyses of these RCTs evaluating scaphoid fracture treatment have been inconclusive12-15.  Since the previous systematic reviews, further high quality evidence has been published of the clinical effectiveness of plaster cast treatment versus early surgical fixation for undisplaced or minimally displaced scaphoid fractures16.  The aim of this meta-analysis was to evaluate the current evidence from RCTs comparing the effectiveness of non-operative and surgical treatment for acute undisplaced and minimally displaced scaphoid fractures (≤2mm displacement) up to one year follow-up.

**Methods**

The protocol was prospectively registered in PROSPERO: CRD42019147309. The Centre for Reviews and Dissemination (CRD) guidance for undertaking reviews in healthcare was followed17. Reporting is in line with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines18. Ethical approval and informed consent were not required for this research.

**Data sources**

Database searches were undertaken by an experienced information specialist. The following databases were searched using highly sensitive search strategies to identify randomised trials: MEDLINE, Cochrane CENTRAL, EMBASE, PEDro, CINAHL, EMCARE, Clinicaltrials.gov and WHO International Clinical Trials Registry.

The full search strategy developed in Ovid MEDLINE is provided in Supplementary Appendix 1. This strategy was adapted for use in searching the other databases.

Databases were accessed from inception until the end of March 2021. Searches were run initially in September 2019 and updated on 31st March 2021.

The reference lists of eligible studies were manually reviewed for further relevant studies. Literature search results were uploaded to referencing software that was used to remove duplicate publications.

**Study selection**

Studies were eligible for inclusion if they were published, in any language, and fulfilled the following criteria:

**Types of study:** RCTs. Study designs other than RCTs are at higher risk of bias when assessing treatment effectiveness and were not included in this review.

**Participants:** adult (16 years or older) patients with scaphoid fractures, of any type, of less than or equal to 2mm of displacement.

**Intervention:** surgical procedures (open reduction and internal fixation or percutaneous fixation).

**Comparator:** initial non-operative treatment (e.g. splint or cast, Colles cast, short-scaphoid cast, and long-arm scaphoid cast) with fixation of fractures that fail to unite with conservative treatment.

**Setting:** there were no restrictions by type of setting in which the study was undertaken.

**Outcomes:**

Primary outcome - patient-reported outcome measure(PROM) of wrist function at 12 months.

Secondary outcomes - pain, grip strength, range of wrist motion, complications including radiographic evidence of non-union.

Outcomes were grouped according to the following time points:

1) 6 months’ follow-up or the closest assessment time point before 6 months;

2) 12 months or the closest assessment time point to 12 months between 6 and 12 months. This was chosen as the primary end-point as it would allow, as much as is feasible, that participants could complete their treatment pathways.

Titles and abstracts were independently reviewed by two reviewers (NJ, EC) for potentially relevant studies. Full text articles of potentially relevant studies were obtained and also assessed independently by two reviewers (NJ, EC) against the inclusion criteria, using a pre-defined screening form. Neither reviewer was blind to the journals or to the study authors or institutions.

Reasons for exclusion were recorded.

**Data Extraction**

Data were extracted independently by two reviewers (NJ, EC) using a piloted form. Since many of the authors were involved in the SWIFFT trial, all extraction and assessment of SWIFFT data was purposefully completed by two reviewers who were not part of the SWIFFT study group (NJ, ES). Any discrepancies regarding inclusion or data extraction were resolved by a consensus advisory group (JD, SB, NJ, EC).

The following data were extracted: study type, country, setting, study period, number of patients randomised, age, sex, follow up period, trial exclusion criteria, attrition rate, fracture characteristics (number and type, location, displacement), and outcomes.

Longer-term outcomes and return to work data were also extracted and will be reported separately.

For dichotomous outcomes, the sample size for each group and number with the outcome of interest was extracted. For continuous outcomes, the reported summary statistics were extracted (e.g. n, mean, standard deviation(SD), median, range, etc). Where data were not reported as mean and SD, standard data imputation methods were used to estimate these quantities19, 20. Where outcome measurement scales had different polarity reverse-scoring was applied so all scales had a consistent direction of effect. For the outcomes of function and pain, higher scores indicate worse outcome. Grip strength for the affected wrist is presented as a percentage of the contralateral hand, and range of motion for the injured wrist is presented as a percentage of the uninjured side; therefore, a higher value indicates less impaired grip strength/ROM, respectively, relative to the unaffected limb (Supplementary Appendix 2). Non-union was assessed by most studies at around 12 weeks. We have therefore not used the 6 month timepoint for this complication but an earlier assessment of non-union.

When clarification of data was required for any of the outcomes, authors were contacted. Two authors of included studies were contacted to see if potentially useful additional data about patient characteristics was obtainable but the data was no longer available.

Where data were presented in graph format, a computerised method was used to extract data for relevant time points21. Following data extraction a meeting was held with the advisory group and all data were reviewed and checked against included studies.

**Quality Assessment**

Quality assessment via the Cochrane Risk of Bias Tool (Version 2.0) and GRADE framework was undertaken by one reviewer (NJ) and checked by a second (ES). Risk of bias of functional outcome and union rate were each assessed against the effect of adhering to intervention (the 'per-protocol' effect) and assignment to intervention (the 'intention-to-treat' effect).

Discrepancies were again resolved by a consensus advisory group (JD, SB, NJ, ES)

**Data Synthesis**

Narrative and tabular summaries of key study characteristics, results and quality assessment are provided.

Where two or more RCTs reported the same outcome of interest for a particular time point, a quantitative synthesis was performed as per the registered protocol. Fixed effect meta-analyses were performed and forest plots are presented. Statistical heterogeneity is assessed using the chi-squared test and quantified using the I-squared statistic.

Across the studies, different PROMs were used to assess function and pain; therefore, the treatment effect for these outcomes is expressed as a standardised mean difference. A Hedges’ g effect size of 0.2 represents a small effect and 0.8 a large effect22. For other continuous outcomes evaluated using the same measurement scales, the pooled mean difference is presented. We calculated odds ratios (OR) for dichotomous outcomes. All treatment effects are presented with their associated 95% confidence interval (CI) and p-value.

Random effects meta-analyses were performed as sensitivity checks and 95% prediction intervals (PI)23 for the treatment effect are presented24. Further sensitivity analyses and a more detailed analysis plan are presented in Supplementary Appendices 3-6.

Where sufficient studies were not available for an outcome at a particular time point to conduct a meta-analysis, a narrative synthesis is presented.

Fixed effect meta-analyses of three baseline factors (age, sex, and whether dominant side injured) were undertaken to check for imbalance and heterogeneity that might suggest included RCTs suffer from insecure allocation concealment (Supplementary Appendix 7).

The potential for reporting bias is explored using funnel plots (Supplementary Appendix 8).

Analyses were conducted in Stata v1625.

**Results**

**Study selection**

The electronic searches identified 360 records after deduplication Following screening of titles and abstracts, 15 full papers were assessed for eligibility. Seven met the inclusion criteria1, 7-11, 16 (Figure 1). We did not identify any ongoing trials that met eligibility criteria.

**Characteristics of included studies**

All the seven included studies were two-arm, parallel-group RCTs, published between 2001 and 2020. The RCTs were conducted between 1984 and 2016 in Sweden,7, 9, 11 the UK,1, 16 and Austria,10 and the US8. Participants were recruited from hospitals (trauma/orthopaedic units) in six trials (number of sites: 1,1, 7, 9 2,10, 11 34,16) and were military personnel in the US trial8. Sample sizes at randomisation ranged from 25 to 439 (median 60) with equal randomisation to operative and non-operative treatment groups. The mean age of the participants was 30 years (range 15 to 75) and, on average, 83% were male (range 74% to 90%). Study characteristics are given in Table I. Further details are provided in Supplementary Appendix 9.

**Quality and risk of bias assessment**

Three studies were rated as high quality1, 10, 16 and four as low quality7-9, 11(Table II). One study was assessed as a high risk of bias for union and function outcomes7. This was because patients who were randomised to surgery were subsequently excluded from the trial if found to have a scapholunate ligament injury intra-operatively.

**Primary Outcome**

**Function at 12 months**

Four RCTs measured function at 12 months, each using a different PROM: DASH7, PEM1, PRWE function subscale16, and an adapted Green O’Brien score10. The pooled estimate from the fixed effect meta-analysis at 12 months favours operative treatment but is not statistically significant and the standardised mean difference is small (Hedges’ g 0.15, 95% CI -0.02 to 0.32, p=0.08, Figure 2)(Table III). There is considerable heterogeneity ( I2=74.4%, Χ2(3)=11.72, p=0.01); however, the random effects meta-analysis yielded similar, but less precise, results (Table III, Figure 2).

**Secondary Outcomes**

**Function at 6 months**

The same four RCTs measured function at 6 as well as 12 months1,7,10,16. A small, non-significant, treatment effect size favours operative treatment and considerable heterogeneity was present (Hedges’ g 0.09, 95% CI -0.09 to 0.26, p=0.35, Figure 2; I2=67.7%, Χ2(3)=9.29, p=0.03; and I2=74.4%, Χ2(3)=11.72, p=0.01). The random effects meta-analysis produced similar results (Table III, Figure 3).

**Pain**

Three RCTs measured pain at 6 and 12 months, using two different measures: visual analogue scale1, 7, and PRWE pain subscale16.

The pooled estimate from the fixed effect meta-analysis shows no significant difference at 6 (Hedges’ g -0.05, 95% CI -0.23 to 0.14, p=0.64; Supplementary Appendix 10) or 12 months (Hedges’ g 0.08, 95% CI -0.10 to 0.26, p=0.37; Supplementary Appendix 10) (Table III*).* Zero heterogeneity (I2=0.0%) was observed at both time points (Χ2(2)=0.05, p=0.98; and Χ2(2)=1.38, p=0.50, respectively). The random effects meta-analyses yielded virtually identical results (Table III, Supplementary Appendix 10).

**Grip strength**

Five RCTs measured grip strength at 6 months1, 7, 10, 11, 16 and four at 12 months1, 7, 10, 16.

The pooled estimate from the fixed effect meta-analysis at 6 and 12 months favours operative treatment. At 6 months, it is statistically significant (mean difference 8.52, 95% CI 4.91 to 12.12), p<0.001; zero heterogeneity Χ2(4)= 3.79, p=0.44) (Table III); whereas at 12 months it is not statistically significant (mean difference 2.51, 95% CI -0.76 to 5.77, p=0.13; Supplementary Appendix 10) and there is moderate heterogeneity (I2=28.4 %; Χ2(4)=4.19, p=0.24). The random effects meta-analyses yielded similar results (Table III, Supplementary Appendix 10).

**Range of motion**

Five RCTs measured range of motion (ROM) at 6 months1, 7, 10, 11, 16 and four at 12 months1, 7, 10, 16.

The pooled estimate from the fixed effect meta-analysis at 6 months favours operative treatment and is statistically significant (mean difference 5.60, 95% CI 2.74 to 8.46, p<0.001)(Table III). Considerable heterogeneity was observed (I2=80.5%; Χ2(4)=20.53, p<0.001). The random effects sensitivity meta-analysis yielded a non-significant result (2.13, 95% CI -6.51 to 10.76, p=0.63, I2=85.9%, τ2=79.85) (Table III, Supplementary Appendix 10).

The pooled estimate from the fixed effect meta-analysis at 12 months is not statistically significant (mean difference 0.61, 95% CI -1.80 to 3.01, p=0.62), and moderate heterogeneity was observed (I2=31.3%; Χ2(3)= 4.37, p=0.22). The random effects meta-analysis yielded virtually identical results (Table III, Supplementary Appendix 10).

**Complications**

Four RCTs report complications at 6 months11 or 12 months1, 10, 16. Clementson et al. reported no complications in either group at 12 months7. There were 24 (9.0%) nerve problems, infections or cases of CRPS in those treated with surgery compared to 7 (2.6%) in the non-operative group.(Table IV). Nine (3.4%) re-operations were required in the operative group and none in the non-operative group.

**Non-Union**

Six RCTs assessed early non-union1, 7, 9-11, 16 and five at 12 months1, 7, 9, 10, 16. Peto’s OR was used, which handles zero cell counts by excluding studies with no events in both arms (i.e. those in which all fractures united)7, 10. The pooled estimate from the fixed effect meta-analysis at both time points favour operative treatment. At the early assessment, it is statistically significant (OR of non-union 0.20, 95% CI 0.09 to 0.46, p<0.001; Figure 4) and minimal heterogeneity is observed (I2=22.0%; Χ2(4)=5.13, p=0.27) (Table III); whereas at 12 months, it is not statistically significant (OR 0.34, 95% CI 0.08 to 1.35, p=0.13, I2=31.0%; Χ2(2)= 2.90, p=0.23; Figure 5). The random effects meta-analyses yielded similar results (Table III).

**Discussion**

In this meta-analysis we evaluated RCTs comparing the effectiveness of non-operative and surgical treatment for acute undisplaced and minimally displaced scaphoid fractures in adults. We found no difference in functional outcomes at 12 months for patients treated in a cast compared to those who undergo surgical fixation.

There was no significant difference in functional outcome, measured by PROMs, between the groups at 6 or 12 months. There was no difference in pain at either time point. Grip strength significantly favoured surgical fixation at 6 months only with no difference at 12 months. Range of motion favoured surgical fixation at 6 months with the fixed effects meta-analysis only. There was no difference at 12 months or with the random effects meta-analysis at either time point. This early improved grip and range of motion may reflect the longer time spent in a cast with non-operative treatment. Non-union rate was higher at 12 months in the cast group but at low risk of occurring (2.7% vs 0.8%) and not statistically significant.

Early fixation of scaphoid fractures seems attractive and on this basis the popularity of scaphoid fracture fixation is increasing6. Numerous small, studies have compared cast and surgical treatment1, 7-11, 26, 27. Many clinicians advocate surgical treatment citing improved function, quicker return to normal activities and increased union rate based on this literature. Four meta-analyses have been performed of earlier RCTs, some have suggested improved outcome with surgical treatment but advised caution based on the limited evidence12-15. Our overall findings with a much larger pooled sample size than previous meta-analyses do not support operative fixation.

Non-union rate appears lower with operative treatment initially but there was no difference at 12 months. These data needs careful consideration. Most studies initially assessed non-union at 6 to 12 weeks then obtained CT scans and offered surgery if a non-union was identified. The data regarding initial non-union rate is from this early time point2. At this stage it would be expected that 10% of fractures treated in a cast would not have healed. In one study ten non-unions were suspected in patients treated in a cast at 12 weeks1. One fracture united with ongoing cast treatment. Seven patients underwent surgery with four fractures found to be stable suggesting at least partial union. The three definite non-unions all healed after fixation and bone grafting. Two patients refused further intervention. These were the only two non-unions present at 12 month assessment. Dias 2020 et al. reported 10 non-unions at 12 weeks16. We included these in our early analysis as no further union data is reported until the 12 month timepoint. At 12 months only four non-unions persisted. One of the four patients had undergone surgery but the fracture had still not united. The other three patients received routine cast treatment as in two cases non-union was not identified from radiographic review and the other patient did not attend for six or 12 week radiographs. This early assessment, identification and treatment of suspected non-unions prevents an accurate comparison of union rates with surgery or cast treatment alone but our findings suggest this treatment pathway is effective at preventing non-union.

Surgery was more likely to lead to other complications such as nerve injury, infection or CRPS than cast immobilisation. Most studies reported small amounts of complications. The Scaphoid Waist Internal Fixation for Fractures Trial (SWIFFT) had a low threshold for complication reporting16. This included a large number of minor, cast related complications compared to a smaller number of complications in the surgery group but more of these were potentially serious.

This meta-analysis uses the latest evidence and a robust methodology to provide useful information for clinicians treating acute scaphoid fractures. In contrast to other meta-analyses we assessed results at several pre-defined time points. All evaluation and extraction of SWIFFT data was carried out by independent reviewers who were not part of the SWIFFT study group. All but one study included scaphoid waist fractures only. The other study by Saeden et al. included all acute scaphoid fractures except those of the tuberosity9. Waist fractures still accounted for 84% of all fractures in the study. With over 400 patients included in the meta-analysis for each outcome at least 98% of fractures would be waist fractures. Our findings are therefore applicable for scaphoid waist fractures only.

Limitations include the relatively short term 12 month outcome assessment. Important problems like arthritis may develop later and we plan to report long term results separately. Databases searched were slightly different to our protocol but still more thorough than recommended.28 One study included patients aged 15 years.11 Mean age from the total group was 31 so we did not exclude this study as it is unlikely that a very small number of slightly younger patients would influence the overall findings. We initially planned to carry out fixed effects meta-analysis of the pooled data. Reviewing the studies identified clinical heterogeneity with differences in surgical approach, fracture location and pattern, fixation method, cast type and radiographic assessment of displacement and non-union. We have therefore presented fixed and random effects meta-analysis for all outcomes. The analysis revealed significant heterogeneity (function, range of motion) for some outcomes but minimal for others (pain, grip, union). Our main findings were essentially the same regardless of which analysis was undertaken with the only difference being range of motion at six months significantly favouring operative treatment with the fixed effects meta-analysis but there was no difference with random effects. One large study dominates the meta-analysis. It could be questioned whether then pooling data with lower quality, heterogenous trials is worthwhile. However the additional data more than doubles the number of some rarer outcomes such as non-union. Complications reporting is varied and often vague. Not all studies report results at six months so we have sometimes used earlier results for the meta analysis at this time point. This could influence results from non operative treatment when patients may only recently have had their cast removed. Due to inconsistencies and inadequacies in reporting of findings within component trials, there was a lot of imputation and estimation of data required, e.g. SD from range.

This comprehensive meta-analysis demonstrates no difference in functional outcome at twelve months for undisplaced or minimally displaced scaphoid waist fractures treated with a cast or surgical fixation. Whereas non-union is higher with plaster cast, it is low risk of occurring at one year, and complication rate is higher with surgical fixation. This study suggests that initial cast immobilisation with early identification and fixation of non-union is the optimal treatment for undisplaced or minimally displaced scaphoid waist fractures.

Table I Summary of included study characteristics

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Author (year)**  **Country**  **# sites**  **Study period** | **Inclusion/exclusion criteria** | **Patient descriptors** | **Fracture classification/**  **mechanism of injury** | **Non-operative treatment** | **Fixation type** | **Time from injury to surgery (days)**  **Post-op regime**  **(surgery group only)** | **Outcomes** | **Follow-up time points** |
| Adolfsson *et al*, 200111  Sweden  **Sites:** 2  **Study period:** 1996-1998 | **Inclusion:**  Recent (<14 days old) undisplaced fracture of the scaphoid waist  **Exclusion:**  Not reported | **Screened:** Not reported  **Randomised:** 53  **Age (years):** mean 31, range 15–75  **Gender:** 39M:14F | All were transverse or oblique, and were similar to undisplaced types B1 or B2 of the Herbert and Fisher classification (1984). All had resulted from a fall on an outstretched hand. | Immobilisation in a below elbow plaster cast for 10 weeks, discontinued if both the clinical and X-ray examinations indicated union otherwise cast immobilisation continued for another 6 weeks. All the wrists were X-rayed after 16 weeks and if these did not clearly show union, a CT-scan was performed. If non-union on CT, fracture was immobilised for up to a further 8 weeks, until X-rays and a CT-scan demonstrated definite union. | Percutaneous Acutrak screw fixation | **Time from injury to surgery (days):**  Not reported  **Post-op regime:** Thumb to elbow’ plaster splint worn  postoperatively for 3 weeks, then removable plastic splint for a further 3 weeks during sports or strenuous activities. Unrestricted use of the hand allowed after 6 weeks. | Range of motion, grip strength, union **Primary:** Not specified  **Secondary:** Not specified | 10W, 16W  **Primary:** Not specified  **Secondary:** Not specified |
| Bond *et al*, 20018  USA  **Sites:** 1  **Study period:** 1997-1998 | **Inclusion:**  Full-time military personnel, acute nondisplaced fracture of the scaphoid waist  **Exclusion:**  Not evaluated within two weeks of injury, history of an untreated wrist injury, fracture with >1 mm of displacement that did not involve the waist of the scaphoid or that was associated with a scapholunate angle of >60° | **Screened:** 62  **Randomised:** 25  **Age (years):** mean 24, range 18-34  **Sex:** 22M:3F | Result of a fall on the outstretched hand (n=16), due to an axial load (n=8), twisting injury (n=1) | Long-arm thumb-spica cast for 6 weeks, then short-arm (below elbow) thumb-spica until fracture united. | Percutaneous internal fixation with a cannulated Acutrak screw. | **Time from injury to surgery (days):** Not reported  **Post-op regime:** postoperative dressing maintained for 7-10 days, then a removable custom-fabricated Orthoplast short-arm thumb-spica splint was worn except during bathing or during the early active range-of-motion protocol and strength-maintenance program, until fracture united. | Range of motion, grip strength, union, return to work, complications, satisfaction **Primary:** Not specified  **Secondary:** Not specified | 2Y (evaluated fortnightly for union, and every three months for range of motion)  **Primary:** Not specified  **Secondary:** Not specified |
| Clementson *et al*, 20157  Sweden  **Sites:** 1  **Study period:** 2004-2007 | **Inclusion:**  Wrist injury sustained  within the last 14 days, aged 18-65 years,  pain on the radial side of the wrist with tenderness when palpating the anatomical snuffbox or the  scaphoid tubercle or when pushing the thumb longitudinally, non- or minimally displaced scaphoid waist fracture (displacement <1 mm and/or volar  angulation <15°) on CT  **Exclusion:**  Not reported | **Screened:** 292  **Randomised:** 45  **Age (years):** median 29, range 18-62  **Sex:** 38M:7F | B1/T/+C (n=5), B1/T/-C (n=5), B2/T/+C (n=6), B2/T/-C (n=22), not reported (n=7) | Below-elbow thumb-spica cast until signs of radiological union. | Percutaneous internal fixation with  a cannulated compression screw | **Time from injury to surgery (days):** median 10, range 4-17  **Post-op regime:** Immobilized in a cast for 2 weeks, after which physiotherapy was initiated. Patients instructed to avoid heavy loading of the  hand and wrist for 6 weeks. | Range of motion, grip strength, function, union, pain, satisfaction **Primary:** Not specified  **Secondary:** Not specified | 6W, 10W, 14W, 26W, 52W, extended follow-up (median 6 years, range 4-8)  **Primary:** Not specified  **Secondary:** Not specified |
| Dias *et al*, 20051  UK  **Sites:** 1  **Study period:** 1996-1999 | **Inclusion:**  Of working age with a clear bicortical fracture of the scaphoid waist, seen within a week of injury  **Exclusion:**  Preexisting symptoms in the upper limb, associated injuries, or unicortical or tuberosity fractures, trans-scaphoid perilunate dislocation | **Screened:** 205  **Randomised:** 88  **Age (years):** mean 29.5, range 16-61  **Sex:** 79M:9F | Mechanism of injury: fall (n=64), wrenching (n=11), punch (n=7), motor-vehicle accident (n=5), unsure (n=1) | Immobilization in  a below-the-elbow cast with the thumb left free and the wrist held in slight dorsiflexion for 8 weeks, then allowed to mobilize the hand and the wrist | Open reduction and internal fixation with a Herbert screw. | **Time from injury to surgery (days):** mean 9.2  **Post-op regime:** Bulky  bandage for 2 weeks then allowed to move  wrist and hand. For two patients, the bandage was supplemented with a plaster volar splint for 6 weeks because of concerns about the security of fixation. | Range of motion, grip strength, function, union, pain, return to work, complications  **Primary:** Not specified  **Secondary:** Not specified | 2W, 8W, 12W, 16W, 52W  **Primary:** Not specified  **Secondary:** Not specified |
| McQueen *et al*, 200710  UK and Austria  **Sites:** 2  **Study period:** Not reported | **Inclusion:**  Aged 17-65 years, Herbert type B1 or B2 fracture of the scaphoid  **Exclusion:**  Previous ipsilateral fracture of the scaphoid, additional injuries to the ipsilateral upper extremity, a pathological condition of bone, a terminal disease, evidence of substance abuse, polytrauma, unwilling or unable to co-operate with follow up | **Screened:** Not reported  **Randomised:** 60  **Age (years):** mean 29.4, range 17-65  **Sex:** 50M:10F | B2 fracture (n=59), B1 fracture (n=1). Undisplaced (n=53) | Colles cast with the thumb free for 8 weeks. If clinical or radiological examination suggested  delayed union, a further cast was applied for up to 4 weeks. | Percutaneous fixation of the scaphoid using a standard Acutrak screw | **Time from injury to surgery (days):** “within 14 days”  **Post-op regime:** Wrist not immobilised,  patients encouraged to mobilise within the limits of comfort. Physiotherapy prescribed if clinically indicated. | Range of motion, grip strength, function, union, return to work, complications  **Primary:** Not specified  **Secondary:** Not specified | 8W, 12W, 16W, 52W  **Primary:** Not specified  **Secondary:** Not specified |
| Saedén *et al*, 20019  Sweden  **Sites:** 1  **Study period:** 1984-1986 | **Inclusion:**  Acute fractures of the scaphoid  **Exclusion:**  Fracture through the tuberosity of the scaphoid and those with  radiological signs of delayed union or pseudarthrosis | **Screened:** Not reported  **Randomised:** 61  **Age (years):** mean 33, SD 17  **Sex:** 49M:13F | N=62 as one participant had 2 fractures: 24-C2.1 (n=3), 24-C2.2 (n=52), 24-C2.3 (n=3), 24-C3 (n=4). Fall (n=28), accident (n=22), other (n=12) | Short-arm below elbow cast until the fracture  showed radiological signs of union. | Open reduction internal fixation using a Herbert screw. | **Time from injury to surgery (days):** mean 12, SD 5  **Post-op regime:** Plaster cast for 2 weeks | Range of motion, grip strength, function, union, return to work, complications  **Primary:** Not specified  **Secondary:** Not specified | Followed-up until fracture united, then at long-term (mean 11.7 years, range 10.2-12.8)  **Primary:** Not specified  **Secondary:** Not specified |
| Dias *et al*, 202016  UK  **Sites:** 34  **Study period:** 2013-2016 | **Inclusion:**  Skeletally mature, aged 16 years or older, presenting within 2 weeks of injury, clear, unequivocal minimally displaced (≤2mm) bicortical fracture of the scaphoid waist that did not involve the proximal pole  **Exclusion:**  Concurrent wrist fracture in the opposite limb, trans-scaphoid perilunate dislocation, multiple injuries in the same limb, lack mental capacity to comply with treatment or data collection, pregnant, out of area of a participating site | **Screened:** 1047  **Randomised:** 439  **Age (years):** mean 32.9, SD 12.7  **Sex:** 363M:76F | Mechanism of injury: fall (n=318), hit on palm of hand (n=70), punch (n=16), motor-vehicle accident (n=17), other (n=16), missing (n=2) | Immobilisation in a below-elbow cast for 6–10 weeks, with or without inclusion of the thumb, and urgent surgical fixation when non-union was confirmed, plus standardised written physiotherapy advice | Percutaneous/open surgical fixation with a headless compression screws | **Time from injury to surgery (days):** mean 10.2, range 3-20  **Post-op regime:** Post-surgery cast/splint, plus standardised written physiotherapy advice | **Primary:** Function  **Secondary:** Range of motion, grip strength, union, return to work, complications | **Primary:** 52W  **Secondary:** 6W, 12W, 26W |

Table II Quality and risk of bias assessment of included studies

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **Risk of Bias** | | | |
|  |  | **Function** | | **Union** | |
| **Author** | **Quality** | adhering to intervention | assignment to intervention | adhering to intervention | assignment to intervention |
| Adolfsson, 200111 | Low | n/a | n/a | Some concerns | Some concerns |
| Bond, 20018 | Low | Low | Low | Low | Low |
| Clementson, 20157 | Low | High | High | High | High |
| Dias, 20051 | High | Low | Low | Low | Low |
| McQueen, 200810 | High | Low | Low | Low | Low |
| Saedén, 20019 | Low | Some concerns | Some concerns | High | High |
| Dias, 202016 | High | Low | Low | Low | Low |

Table III Results of the fixed and random effects meta-analyses for each outcome and time point

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Outcome** | **Time point**  **(months)** | **Number of studies (participants)** | **Fixed effect meta-analysis** | | **Random effects meta-analysis** | | | |
| **Hedges’ g (95% CI)** | **I2 (%)** | **Hedges’ g (95% CI)** | **95% PIa** | **I2 (%)** | **τ2** |
| Function | 6 | 4 (482) | 0.09 (-0.09, 0.26) | 67.7 | 0.14 (-0.28, 0.56) | (-1.20, 1.47)  (-1.67, 1.94) | 73.8 | 0.13 |
|  | 12 | 4 (537) | 0.15 (-0.02, 0.32) | 74.4 | 0.11 (-0.42, 0.64) | (-1.66, 1.88)  (-2.28, 2.50) | 83.9 | 0.24 |
| Pain | 6 | 3 (426) | -0.05 (-0.23, 0.14) | 0.0 | -0.05 (-0.23, 0.14) | (-0.46, 0.37)  (-1.27, 1.18) | 0.0 | 0.00 |
|  | 12 | 3 (482) | 0.08 (-0.10, 0.26) | 0.0 | 0.08 (-0.10, 0.26) | (-0.34, 0.50)  (-1.16, 1.32) | 1.8 | 0.00 |
|  |  |  | **Mean difference (95% CI)** |  | **Mean difference (95% CI)** |  |  |  |
| Grip strength | 6 | 5 (558) | 8.52 (4.91, 12.12) | 0.0 | 8.52 (4.91, 12.12) | (3.41, 13.62)  (2.67, 14.37 ) | 0.0 | 0.00 |
|  | 12 | 4 (479) | 2.51 (-0.76, 5.77) | 28.4 | 3.26 (-1.49, 8.01) | (-8.52, 15.05)  (-12.67, 19.20) | 32.9 | 7.85 |
| Range of motion | 6 | 5 (555) | 5.60 (2.74, 8.46) | 80.5 | 2.13 (-6.51, 10.76) | (-25.53, 29.79)  (-29.58, 33.83) | 85.9 | 79.85 |
|  | 12 | 4 (479) | 0.61 (-1.80, 3.01) | 31.3 | 0.61 (-1.80, 3.01) | (-3.30, 4.52)  (-4.68, 5.89) | 0.0 | 0.00 |
|  |  |  | **OR (95% CI)** |  | **OR (95% CI)** |  |  |  |
| Non-Union | 6 | 5 (585) | 0.20 (0.09, 0.46) | 22.0 | 0.20 (0.09, 0.46) | (0.06, 0.65)  (0.05, 0.77) | 0.0 | 0.00 |
|  | 12 | 3 (458) | 0.34 (0.08, 1.35) | 31.0 | 0.34 (0.08, 1.35) | (0.02, 7.17)  (0.00, 2835.66) | 0.0 | 0.00 |
| a 95% prediction intervals are presented in two forms, using degrees of freedom of both *k*-1 and *k*-2, where *k* is the number of component studies in the meta-analysis | | | | | | | | |

Table IV Total number and percentage of each complication reported in each study at 6 and 12 months. Complications are reported according to the intention to treat principle.

| **Outcome and study** | | **Operative** | **Non-operative** |
| --- | --- | --- | --- |
| *Infection, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 0 (0) | 0 (0) |
| 12 months | Dias, 2005 | 1 (2.3) | 1 (0) |
|  | Dias, 2020 | 3 (1.4) | 3 (0.9) |
|  | McQueen, 2008 | 0 (0) | 0 (0) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *Delayed wound healing, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 0 (0) | 0 (0) |
| 12 months | Dias, 2005 | 10 (22.7) | 0 (0) |
|  | Dias, 2020 | 3 (1.4) | 1 (0.5) |
|  | McQueen, 2008 | 0 (0) | 0 (0) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *Hypoesthesia, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 0 (0) | 0 (0) |
| 12 months | Dias, 2005 | 1 (2.3) | 0 (0) |
|  | Dias, 2020 | 2 (0.9) | 2 (0.9) |
|  | McQueen, 2008 | 0 (0) | 0 (0) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *Nerve, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 0 (0) | 0 (0) |
| 12 months | Dias, 2005 | 0 (0) | 0 (0) |
|  | Dias, 2020 | 10 (4.6) | 0 (0) |
|  | McQueen, 2008 | 0 (0) | 0 (0) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *Screw penetration, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 0 (0) | 0 (0) |
| 12 months | Dias, 2005 | 0 (0) | 0 (0) |
|  | Dias, 2020 | 76 (34.7) | 6 (2.7) |
|  | McQueen, 2008 | 1 (3.3) | 0 (0) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *Screw other, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 1 (4.3) | 0 (0) |
| 12 months | Dias, 2005 | 1 (2.3) | 0 (0) |
|  | Dias, 2020 | 17 (7.8) | 1 (0.5) |
|  | McQueen, 2008 | 2 (6.7) | 0 (0) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *AVN, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 0 (0) | 0 (0) |
| 12 months | Dias, 2005 | 0 (0) | 0 (0) |
|  | Dias, 2020 | 6 (2.7) | 19 (8.6) |
|  | McQueen, 2008 | 0 (0) | 2 (6.7) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *Cast, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 0 (0) | 0 (0) |
| 12 months | Dias, 2005 | 0 (0) | 0 (0) |
|  | Dias, 2020 | 6 (2.7) | 47 (21.4) |
|  | McQueen, 2008 | 0 (0) | 0 (0) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *CRPS, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 1 (4.3) | 0 (0) |
| 12 months | Dias, 2005 | 1 (2.3) | 0 (0) |
|  | Dias, 2020 | 5 (2.3) | 0 (0) |
|  | McQueen, 2008 | 0 (0) | 1 (3.3) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *Other, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 0 (0) | 1 (3.8) |
| 12 months | Dias, 2005 | 0 (0) | 0 (0) |
|  | Dias, 2020 | 0 (0) | 0 (0) |
|  | McQueen, 2008 | 0 (0) | 0 (0) |
|  | Clementson, 2015 | 0 (0) | 0 (0) |
| *Re-operation, n (%)* | |  |  |
| 6 months | Adolfsson, 2001 | 0 (0) | 0 (0) |
| 12 months | Dias, 2005 | 0 (0) | 0 (0) |
|  | Dias, 2020 | 8 (3.7) | 0 (0) |
|  | McQueen, 2008 | 1 (3.3) | 0 (0) |

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Figures

Figure 1. PRISMA flow diagram

Figure 2 A and B. Forest plot of fixed(A) and random(B) effects function outcome at 12-month time point

Figure 3 A and B. Forest plot of fixed(A) and random(B) effects function outcome at 6-month time point

Figure 4 A and B. Forest plot of fixed(A) and random(B) effects non-union outcome at early follow-up

Figure 5 A and B. Forest plot of fixed(A) and random(B) effects non-union outcome at 12-month follow-up