Scaphoid specific volar locking plate and non-vascularised iliac crest bone graft in scaphoid non-union. A comparative cohort study

Adrian J. Talia^{a,*}, Andrew Fraval^a, Liam Halliday^a, Gabrielle McKie^a, Joseph Paiva^b,
Duy M. Thai^a

^a Department of Orthopaedics, Level 1 South, Western Health, Gordon Street Footscray, VIC 3011, Australia

^b Department of Radiology, Western Health, Gordon Street Footscray, VIC 3011, Australia

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ABSTRACT

Scaphoid non-union develops in 10% of scaphoid fractures. There is sparse literature on fixation methods other than screws. We compared union rates following fixation of scaphoid non-union using screw fixation and a novel method of plate fixation.

Retrospective study. Union rates were assessed at 3 months post-operatively by a musculoskeletal radiologist. 15 patients underwent screw fixation and 15 underwent plate fixation. 86% union rate with screw fixation and 72% plate fixation united. There was no significant difference.

Screw fixation and plate fixation in our institution both provide union rates that are consistent with the literature.

1. Background

The scaphoid is the most commonly fractured carpal bone, accounting for up to 70% of all carpal fractures.¹ Although most fractures of the scaphoid heal without surgical intervention, there is a reported non-union rate of 10%. However when displacement is recognised and adequate treatment is provided, the union rate can approach 100%.² Fracture displacement is a risk for non-union in up to 55% of cases.^{3–5}

The scaphoid is unique in that 80% of the surface of the bone is covered by articular cartilage.¹ This results in the entry points for the bloods supply to the bone being limited to the surfaces not covered in articular cartilage. Due to this limitation, the scaphoid is reliant on retrograde blood flow that largely enters the bone on the dorsal surface, and as such, fractures which disrupt this flow may place the bone at risk of avascular necrosis and non-union.⁶ Factors increasing the likelihood of non-union include delayed diagnosis or presentation, proximal pole fractures, fracture displacement, diabetes and smoking.^{7,8} Smoking is also an independent risk factor for failure after scaphoid surgery.⁹ While some non-unions may be painless, the natural history is the possibility of progression to Scaphoid Non-union Advanced collapse (SNAC) leading to functional disability.^{10–12} The demographic most commonly suffering scaphoid fractures, and subsequent non-union are young men aged 15–40 years. Prolonged immobilization is often

problematic for social and economic reasons as it may impinge on their ability to work and participate in sporting activities. This often leads to non-compliance and compromised outcomes.¹³

An intervention that allows for high union rates while enabling early return to activities such as sport or employment is appealing. Non-union of scaphoid fractures requires surgical intervention to facilitate union and prevent the development of SNAC.^{6,14} Multiple techniques have been employed towards this goal with variable success. These techniques include internal fixation with or without bone grafts, which could also be either vascularised or non vascularised.¹⁵ The techniques of internal fixation include Kirschner wires, screw fixation and plate fixation. Screw fixation is a commonly employed technique, often in conjunction with bone grafting. The most common type of screw fixation uses a variable pitch screw.^{16,17} This method has high rates of union but has been criticized by some groups for low rotational stability.^{18–20} To overcome this problem, some surgeons prefer two-screw fixation to single screw fixation.²¹ A recent cadaveric study demonstrated the biomechanical advantage of both double screw fixation and plate fixation compared with a single screw used for fixation.²⁰ Ghoneim presented a series on volar buttress plating for scaphoid non-union with wedge grafting with success.¹⁹ Leixnering et al. have shown that an anatomically contoured plate can provide good rotational stability after internal scaphoid fixation.²²

Abbreviations: CT, computed tomography; DISI, dorsal intercalated segmental instability; SNAC, scaphoid non union advanced collapse

* Corresponding author.

E-mail address: ajtalial@gmail.com (A.J. Talia).

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Herein we present our early experience with volar plate fixation of scaphoid non-union and compare it to a matched cohort of scaphoids fixed with a single screw. We believe this study will add to the sparse body of literature present on plate fixation of scaphoid non-union.

2. Methods

This retrospective, cohort-matched case series included patients who underwent surgery from June 2013 to June 2016. 30 consecutive patients were treated at our institution for scaphoid non-union. 15 patients were treated with percutaneous screw fixation and 15 were treated with a volar locking plate and non-vascularised iliac crest bone graft. Fixation method was determined by surgeon preference. We reviewed the medical record and radiology of each patient. The criterion for inclusion was internal fixation of non-united scaphoid waist fracture that had been present for longer than 3 months. None of the patients had undergone previous scaphoid surgery. Our institutional ethics committee granted ethics approval for this research and informed patient consent was obtained prior to data collection.

All patients were male, with an average age of 29.9 years ($\pm$ 9 years). The dominant hand was involved in 27 of 30 cases (90%). All fractures were the result of falling on an outstretched hand. 17 patients engaged in heavy manual work and 13 were unemployed, students or employed in office type work. The average time between injury and surgical treatment was 614 days (range 93–2173 days). Mean period of follow up was 7 months (range 15 days–39 months). 7 of 30 patients were lost to follow up at various timepoints. All patients underwent a CT scan of the fracture for pre-operative planning.

2.1. Surgical technique – plate fixation

General anesthesia was used in all patients. The patient was placed in the supine position. An inflated upper arm tourniquet was applied to the surgical extremity. The upper limb was prepared and draped using usual sterile technique. The iliac crest was also prepared and draped on the ipsilateral side to the fracture.

All patients underwent exposure through a volar incision and a capsulotomy was performed radial to the flexor carpi radialis tendon to expose the scaphoid and the edges of the fracture site were debrided back to visible bleeding bone using a small curette. The scaphoid was reduced using axial traction to the thumb with maximal ulnar deviation and extension of the wrist as described by Mathoulin and Brunelli.²³ Here the residual defect could be visualised. A wedge-shaped corticocancellous graft was obtained from the iliac crest, shaped to fit the gap, and inserted into the defect. Image intensifier was used to make sure that appropriate correction of the scaphoid deformity and the lunate rotation has been achieved after insertion of the bone graft and K-wires then used to stabilize the fracture. From the volar aspect, a three-dimensional titanium miniplate (Medartis® AG, Austringe, Basel, Switzerland) (Figs. 1–3) is fixed and secured using up to six cortical screws (Fig. 2). Finally drill wires were removed, tourniquet deflated and the wound closed. Post-operatively all patients were immobilized in a volar thumb spica backslab.

2.2. Post-operative care and radiographic assessment

For all patients undergoing both plate and screw fixation, a volar backslab was used for immobilization for the first two weeks, at which time the skin sutures were removed and a scaphoid cast applied. This was removed at 6 weeks and the patient clinically assessed with a plain radiograph. A removable splint was applied and range of motion commenced under physiotherapist supervision at this time if clinical union was present. If the patient was not clinically united at this point the cast was re-applied and the patient re-assessed fortnightly. A CT scan at 3 months was used to confirm radiologic union and reported by a musculoskeletal radiologist according to the method described by Singh et al.²⁴

Fig. 1. Industrial photograph demonstrating position of scaphoid-specific locking plate on a sawbone model. Reproduced with permission from http://www.medartis.com/uploads/Hand-02000001_e_v1.pdf.

The criteria used to establish healing were: (1) absence of pain, (2) aforementioned radiographic measures and (3) no signs of implant loosening.

2.3. Statistical methods

The primary analysis outcome was the rate of successful fracture union among the 30 patients in the study. A chi-squared test was performed to compare proportions between the two groups.

3. Results

Demographic information and surgical results comparing the two cohorts is displayed in Table 1. Patients who underwent screw and plate fixation were well matched. For the patients undergoing screw fixation, 10 of 15 underwent surgery between 3 and 6 months post injury, with the remaining 5 undergoing surgery more than 6 months post injury. For the patients undergoing plate fixation, 1 of 15 underwent surgery between 3 and 6 months post injury, with the remaining 14 undergoing surgery more than 6 months post injury. In the plate fixation cohort, 4 patients underwent surgery greater than 4 years after their injury, whereas the greatest time between injury and surgery in the screw fixation cohort was 2.6 years.

In the screw cohort, one patient had a superficial iliac crest infection after their initial operation and was treated with oral antibiotics, and their scaphoid fracture was united at 3 months. Two patients in this cohort had unplanned return to theatre. One patient required removal of screw after loss of fixation and screw backing out 6 months post-operatively. This patient was lost to follow up after their second operation. Another patient required 3 revision operations, and has since been managed with plate fixation. This patient has been followed up for 1234 days and their scaphoid fracture remained un-united.

In the plate cohort, two patients experienced painful impingement and returned to theatre for removal of plate. Both patients have since confirmed radiographic union. A third patient has required a four corner fusion, after initially achieving union and subsequently sustaining a fall onto their wrist post surgery, breaking the plate and re-fracturing the scaphoid.

Fig. 2. (a) Intraoperative photograph from our patient cohort demonstrating the surgical approach and final positioning of the scaphoid specific locking plate after fracture reduction, debridement and interposition of tricortical wedge graft. (b) Final positioning of scaphoid specific plate on intraoperative fluoroscopic images.

Successful radiographic union was achieved in 16 of 30 cases. A further 2 cases were assessed as clinically united based on radiographic appearance and an absence of clinical symptoms at follow up. The screw group had a union rate of 86% and the plate group 72% if assessing the patients who were not lost to follow up for the 3-month CT scans. The chi-square statistic is 1.7836. The *p*-value is 0.18. This result is *not* significant at $p < 0.05$.

5 patients in the screw cohort and 2 patients in the plate cohort were lost to follow up prior to the three month CT scan and hence union was not able to be assessed. All patients were contacted in an attempt to be rescheduled into outpatients but were never seen again by the Orthopaedic team.

4. Discussion

The humpback deformity which occurs with scaphoid fractures was described by Nakamura et al.²⁵ This occurs over time as the volar and radial cortices erode, creating a defect with respect to the normal dimensions of the scaphoid (Fig. 4).^{26,27} The volar collapse occurring with this type of deformity can be overcome by insertion of a wedge shaped bone graft of appropriate size obtained from the iliac crest. Restoration of this true scaphoid anatomy also corrects dorsal intercalated segmental instability (DISI).²⁵ The tricortical wedge graft also provides a large surface area, across which bony union can occur. This fracture pattern is known to be unstable often leading to ischaemia of the proximal pole which can increase the risk for progression to non-union. In recent times, authors have described an off-label use for metacarpal plates used as a volar buttress to keep the wedge graft from extruding out of the fracture site with success.¹⁹ Leixnering et al. describe the first reported series using an anatomically contoured scaphoid specific locking plate for fixation of scaphoid non-union with wedge shaped

Table 1
Demographic information and Surgical results.

	Screw (n = 15)	Plate (n = 15)
Demographics		
Age mean (std dev)	30.1 years (10.3 years)	29.9 years (8.7 years)
BMI mean (std dev)	25.9 (5.9)	27.5 (5.9)
Smokers n (%)	5 (33.3%)	4 (26.7%)
Diabetes n (%)	0 (0.0%)	1 (6.7%)
Injury to dominant hand n (%)	7 (46.7%)	5 (33.3%)
Manual labour n (%)	9 (60.0%)	8 (53.3%)
Office work/student n (%)	6 (40.0%)	2 (13.3%)
Unemployed n (%)	0 (0.0%)	5 (33.3%)
Surgical information		
Time to surgery median (IQR)	155 days (127–393 days)	754 days (534–1249 days)
Period of follow up median (IQR)	99 days (55–187 days)	221 days (179–327 days)
Loss to follow up* n (%)	5 (33.3%)	2 (13.3%)
^Not united n (%)	2 (13.3%)	3 (20.0%)
United** n (%)	8 (53.3%)	10 (66.7%)
Radiologically united** n (%)	6 (40.0%)	10 (66.7%)
Clinically united** n (%)	2 (13.3%)	0 (0.0%)

*Loss to follow up indicates post-operative follow up of less than 3 months.

** Clinically united indicates union assessed at 3/12 by orthopaedic consultant, with radiological evidence of union on plain Xray and no ongoing symptoms or limitations.

** Radiologically united indicates union as assessed by consultant radiologist.

^ For the purposes of this study, union was assessed at 3 months post-surgery.

iliac crest bone graft for failed screw fixation.²² This study was a prospective case series of 11 patients and the reported union rate is 100%. The plate used in this cohort, as with our study is a variable angle scaphoid locking plate (Figs. 1–3), this plate is anatomically contoured

Fig. 3. Computed tomography slices demonstrating final positioning and union of scaphoid non-union treated with a volar plate and iliac crest bone graft. (a) Coronal slice, (b–c) sagittal slices demonstrating plate positioning and union after interposition of tricortical iliac crest bone graft.

Fig. 4. Sagittal computed tomography slice demonstrating the flexed type, “humpback” deformity that occurs in scaphoid non-union. This particular fracture type lends itself to volar plate fixation with bone grafting as described in this paper.

to the scaphoid and allows the surgeon to overcome the aforementioned humpback, flexed deformity and is designed in such a way to prevent extrusion of the bone graft.

For many authors, intramedullary screw fixation of the scaphoid is the treatment of choice. This can be a single screw technique,^{16,17,28} or double screw technique,^{21,29} which has been demonstrated to have certain biomechanical advantages. All patients undergoing screw fixation in our cohort underwent fixation with a single cannulated, headless compression screw (Fig. 5).

This report contains the largest known cohort of scaphoid non-union patients who underwent fixation using this plate method (15 patients) and presents our early experience using this device. We have compared them to an equivalent cohort who underwent screw fixation. Plate fixation has been adopted in our institution for fixation of scaphoid waist non-union, which demonstrate this humpback-type deformity. The theoretical advantage of the plate is rotational stability, hence the potential for early immobilization of patients following internal fixation with this device. However for this cohort, all patients in the two surgical groups maintained constant post-operative immobilization. Despite the patients in our cohort having more chronic injuries (14 of 15 patients having surgery greater than 6 months after injury), plate fixation in our specific patient population has been demonstrated to achieve similar union rates to the current standard of practice, screw fixation, without significant increase in complications. It also provides the anatomic advantage of being able to reliably interpose cortical wedge graft to prevent graft extrusion and to overcome humpback deformity. There is a theoretical biomechanical advantage of rotational stability and potential for early mobilization.²⁰ The lower union rate of 72% in the plate group in this cohort may be owing to the greater chronicity of injury or poor proximal pole vascular supply in the humpback-type deformity that was more likely to be present in the plate group.

5. Conclusions

This paper adds to the sparse literature on scaphoid non-union, and the single paper on plate fixation using this device. However this study has significant limitations, namely that it is retrospective, shorter follow-up times and the sample size is small. In a cohort this small, all patients should be followed up to completion but that was not possible for various reasons. Patients are sent appointment reminder letters and automatically rescheduled into appointments when they fail to attend, however 7 patients in this study were lost to follow up. Further study is needed to demonstrate the safety and efficacy of this plate device and elucidate whether the rotational stability of the construct allows for early mobilization in line with modern fixation principles.

Declarations

Ethics approval and consent to participate

This study was granted written institutional ethics approval via the Western Health Human Research Ethics Committee prior to recruitment and contact of patients.

Consent for publication

Not applicable

Availability of data and materials

All data supporting our findings are contained within the manuscript.

Competing interests

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Authors' contributions

- AJT – lead author and corresponding author. Responsible for study design, collection and synthesis of data, write up and critical appraisal.
- AF – data collection, synthesis, critical review, study design.
- LH - data collection, synthesis.
- GM - data collection, synthesis.
- JP – critical review and radiological opinion regarding union.
- DT – senior author, study design and oversight. Treating surgeon in all cases.

All authors read and approved the final version of the manuscript.

Fig. 5. Case example from our cohort of scaphoid non-union, which underwent screw fixation. Day 1 post-operative radiographs shown (a) Anteroposterior projection, (b) scaphoid projection, (c) lateral projection. The headless compression screw is demonstrated bridging the fracture site. This patient went on to union at the 3 month post-operative CT scan.

Department of Health disclaimer

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jor.2019.03.005>.

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