ABSTRACT

Purpose. To compare outcomes of 3 fixation modalities for scaphoid non-union.

Methods. 27 men and 6 women aged 20 to 48 (mean, 28) years with non-union of the scaphoid involving the proximal pole (n=13), waist (n=12), and distal pole (n=8) were randomised to undergo the Herbert screw fixation (n=11), the Matti Russe bone grafting (n=9), or the Kohlman modification of vascularised muscle pedicle graft procedure (n=13). The mean duration of non-union was 10 (range, 6–30) months.

Results. The mean follow-up duration was 28 months. 30 of 33 achieved correction of both scapholunate and radiolunate angles. The mean range of motion increased from 112º to 155º. The mean grip strength increased by 30%. Functional outcomes of the 3 groups were comparable; they were excellent in 13 patients, good in 10, fair in 6, and poor in 4. There was no hardware failure or any iatrogenic fracture during pedicle dissection. One patient had a superficial infection, which was resolved after antibiotic treatment. At the 6-month follow-up, in the respective 3 groups, 8, 6 and 11 patients achieved scaphoid union after mean intervals of 17, 16, and 15 weeks.

Conclusion. The time to union was earliest in the Kohlman modification of vascularised muscle pedicle graft procedure, which is recommended for patients with old non-union (>1 year) or proximal pole fractures.

Key words: bone screws; scaphoid bone; transplants

INTRODUCTION

Five to 10% of scaphoid fractures treated nonoperatively may not achieve union,1–3 and progress to carpal collapse and eventually to radiocarpal osteoarthritis.1 Surgical fixations for scaphoid non-union have success rates of 70 to 90%.4,5 The use of Russe inlay bone grafting or iliac crest bone grafting with screw fixation results in a success rate of 90%.6

Fixation techniques for non-union of the scaphoid

PK Raju,1 Sunil Gurpur Kini2
1 Department of Orthopaedics, Bangalore Medical College and Research Institute, Karnataka, India
2 Department of Orthopaedics, Tan Tock Seng Hospital, Singapore

Address correspondence and reprint request to: Dr Sunil Gurpur Kini, Department of Orthopaedics, Tan Tock Seng Hospital, Level 4, Annex Building, 11 Jalan Tan Tock Seng, 308433, Singapore. E-mail: drsunilkini@gmail.com
Non-union is more common in proximal pole fractures, because of compromised vascularity, and conventional bone grafting may fail when it is completely avascular and there is evidence of necrotic bone and no bleeding. Vascularised bone grafting may introduce a source of angiogenic and osteogenic factors to the non-union site. Vascularised pedicled bone grafts have been used in non-union of the anterior aspect of the wrist and forearm, the pronator quadratus, and the scaphoid. Other salvage procedures include radial styloidectomy with partial scaphoid excision and/or posterior and anterior interosseous neurectomy. More complex procedures include limited intercarpal fusion, proximal row carpectomy, scaphoid excision and 4-corner fusion, and total wrist fusion. We compared outcomes of 3 fixation modalities for scaphoid non-union.

MATERIALS AND METHODS

Between 2002 and 2008, 27 men and 6 women aged 20 to 48 (mean, 28) years with non-union of the scaphoid involving the proximal pole (n=13), waist (n=12), and distal pole (n=8) were randomised to undergo the Herbert screw fixation (n=11), the Matti Russe bone grafting (n=9), or the Kohlman modification of vascularised muscle pedicle graft procedure (n=13) under general (n=19) or regional (n=14) anaesthesia (Fig. 1). Informed consent of each patient was obtained. The study was approved by the local ethics committee of the Bangalore Medical College and Research Institute.

The mean duration of non-union was 10 (range, 6–30) months. In 21 patients the right hand was involved, and in 4 the trauma had ensued more than one year earlier. The mean range of motion was 112º (80º less than the normal hand). The most affected movements were radial deviation and dorsiflexion. The arc of movements was decreased by 30%, and the grip strength by 55%. All cases were classified as D1 based on the Herbert classification.

Anteroposterior, lateral, and 30º ulnar deviation radiographs were taken. Scapholunate and radiolunate angles were measured. In 30 patients the radiolunate angles were >15º; in 31 the scapholunate angles were >45º.

For the Herbert screw fixation, a volar incision was made along the flexor carpi radialis tendon extending along the wrist crease radially over the scaphotrapezoid joint. The palmar capsule was opened, and the radiolunate and radioscapohamate ligaments dissected. The fracture fragments were reduced and the Herbert screw was inserted in a distal to proximal direction.

For the Matti Russe procedure (Fig. 2), a volar incision was made lateral to the flexor carpi radialis protecting superficial branches of the radial nerve. The fracture site was exposed and a cavity extending to adjacent fragments was created. Cancellous bone chips were taken from the iliac crest. A lozenge-shaped peg was fitted into the trough and packed with

Figure 1  Radiographs showing (a) Herbert screw fixation, (b) Matti Russe inlay bone grafting, and (c) Kohlman modification of vascularised muscle pedicle graft procedure.
bone chips and then transfixed with Kirschner wires.

For the Kohlmann vascularised muscle pedicle grafting (Fig. 3),11 a volar incision was made over the scaphoid and distal radius. Sclerotic bone was excised, and an oval trough of 15 to 20 mm was made parallel to the axis of scaphoid. The pronator quadratus was dissected off the radius subperiosteally with the bone and its volar carpal artery along the distal margin. The pedicle was freed (4–5 cm); the graft (20-mm long and 15-mm thick) was then snugly fitted into the fossa after traction and transfixed with Kirschner wires.

Postoperatively, the wrist was immobilised in a thumb spica cast for 6 weeks. Kirschner wires were then removed, and wrist mobilisation initiated. Patient outcomes were assessed using the modified scaphoid outcome scoring system (Table 1).

RESULTS

The mean follow-up duration was 28 months. 30 of 33 patients achieved correction of both scapholunate and radiolunate angles. The mean range of motion increased from 112° to 155°, and the mean grip strength by 30%. Functional outcomes of the 3 groups were comparable; they were excellent in 13 patients, good in 10, fair in 6, and poor in 4. There was no hardware failure and no iatrogenic fracture ensued during pedicle dissection. One patient had a superficial infection, which was resolved after antibiotic treatment.

At the 6-month follow-up, respectively in the Herbert screw fixation, Matti Russe bone grafting, and Kohlman modification of vascularised muscle pedicle graft procedure, 8, 6 and 11 patients had achieved scaphoid union after mean intervals of 17, 16, and 15 weeks (Table 2), whereas 3, 3, and 2 patients had persistent non-union.

Of the 3 patients with persistent non-union after Herbert screw fixation, one underwent excision for a small fragment in the distal pole. The other 2 had proximal pole non-union. One of them underwent revision with the vascularised pedicle graft procedure and achieved union after 15 weeks. The other declined further surgical intervention citing improvement in pain.

Of the 3 patients with persistent non-union after Matti Russe bone grafting, one underwent wrist arthrodesis secondary to infection. The other 2 underwent the vascularised pedicle graft procedure, one of which failed.

Of the 2 patients with persistent non-union after Kohlman modification of vascularised muscle pedicle graft procedure, one underwent excision of a fragment in the proximal pole and the other underwent proximal row carpectomy of the waist of the scaphoid.
DISCUSSION

In an early study of Herbert screw fixation, all 13 non-union cases failed to achieve union without bone grafting. Accurate placement of the Herbert screw using a free-hand technique is challenging; flexing the wrist and using the axis of the thumb as a guide may prevent malposition of the implant. However, fluoroscopic confirmation of placement of the guide-wire is not possible, because the wrist is flexed. When Herbert-screw fixation is combined with bone grafting, 25 of 26 patients with scaphoid non-union achieved union. Nonetheless, the follow-up period was short, and the definition of union was trabeculation over the fracture line on 2 of 4 radiographs. In a study of 33 scaphoid non-union treated with Herbert screws, bone grafting or both, after a mean follow-up period of 14 months, the mean palmar flexion, dorsiflexion, radial deviation, and ulnar deviation were 8°, 61°, 20°, and 35°, respectively, and the grip strength was equal to that of the uninjured hand.

The Russe inlay bone grafting procedure is a reliable treatment for symptomatic non-union of the scaphoid. The volar approach minimises damage to the blood supply and facilitates correction of any flexion deformity. Union rates have been reported to be 20/22, 21/26 (in 7 to 18 years), 147/151 (in one to 10 years), and 38/44 (in 12 to 163 months).

Vascularised bone grafts can preserve the normal anatomy of the carpus, which maximises anatomic motion and decreases the risk of degenerative change and collapse. The grafts can be obtained through one incision, and thus morbidity is minimal. The volar carpal artery originates from the radial artery at the level of radial styloid and runs along the volar aspect of the radius following the distal edge of the pronator quadratus and then forms a T-shaped anastomosis. Location of this branch is consistent and visible during dissection.

In a study of 11 patients with longstanding (5 months to 11 years) symptomatic scaphoid non-union, 5 patients had undiagnosed fractures and 5 had failed previous Matti Russe bone grafting. The vascularised bone graft was obtained from the radial aspect of the distal radius, and the vascular pedicle was based on the recurrent branch of the radial artery. Union was achieved in all 11 patients in 5 to 8 weeks. In a series of 8 symptomatic non-union persisting for 4 months to 12 years, union was achieved in all patients within 7 to 10 weeks, but the criteria for union and details of preoperative evaluation of vascularity were not included. In a study of 17 patients (10 had failed previous operations) managed with a vascularised bone graft with a pedicle from the volar carpal artery and a mean follow-up duration of 16 (range, 12–36) months, union was achieved in all 17 patients in a mean of 60 (range, 45–90) days. The use of a small muscular pedicle ensured continuity of the feeding vascular bundle.

### Table 1
Modified scaphoid outcome scoring system*

| Outcome                                      | Score |
|----------------------------------------------|-------|
| Pain                                         |       |
| No pain                                      | 3     |
| Occasional pain, no change in activity, mild | 2     |
| discomfort with strenuous use                |       |
| Moderate pain, tolerable but some limitation in activities | 1     |
| Severe pain, serious limitations in activities | 0     |
| Function                                     |       |
| Back to usual work                           | 3     |
| Back to usual work/sports with mild limitations | 2     |
| Can perform most activities of daily living, but cannot perform high-demand wrist activities | 1     |
| Chronic pain limitation/discomfort           | 0     |
| Patient’s perception of motion               |       |
| Equal to opposite side                       | 3     |
| Not equal to opposite side, but enough to perform usual activities | 2     |
| Enough motion for daily use, but some limitations in usual activities | 1     |
| Stiff, not enough motion for daily use       | 0     |
| Overall satisfaction                         |       |
| Very satisfied with surgical results         | 2     |
| Moderately satisfied with surgical results   | 1     |
| Not satisfied with surgical results          | 0     |

* Excellent, 10–11; good, 9–8; fair, 7–6; and poor, ≤5

### Table 2
Fixation outcomes of the 3 different techniques for scaphoid non-union

| Technique                                      | Mean time to union (weeks) | No. of patients (union/non-union of scaphoid) | Total (%) |
|------------------------------------------------|----------------------------|----------------------------------------------|-----------|
| Herbert screw fixation                         | 17                         | Proximal pole 1/3 5/5 Distal pole 2/3       | 8/11 (73) |
| Matti Russe inlay bone grafting                | 16                         | Proximal pole 2/4 2/3 Distal pole 2/2       | 6/9 (67)  |
| Kohlman modification of vascularised muscle pedicle graft procedure | 15                         | Proximal pole 5/6 3/4 Distal pole 3/3 | 11/13 (85) |
REFERENCES

1. Rajagopalan BM, Squire DS, Samuels LO. Results of Herbert-screw fixation with bone-grafting for the treatment of nonunion of the scaphoid. J Bone Joint Surg Am 1999;81:48–52.
2. Lindstrom G, Nystrom A. Natural history of scaphoid non-union, with special reference to “asymptomatic” cases. J Hand Surg Br 1992;17:697–700.
3. Dias JJ, Brenkel IJ, Finlay DB. Patterns of union in fractures of the waist of the scaphoid. J Bone Joint Surg Br 1989;71:307–10.
4. Filan SL, Herbert TJ. Herbert screw fixation of scaphoid fractures. J Bone Joint Surg Br 1996;78:519–29.
5. Robbins RR, Ridge O, Carter PR. Iliac crest bone grafting and Herbert screw fixation of nonunions of the scaphoid with avascular proximal poles. J Hand Surg Am 1995;20:818–31.
6. Zaidemberg C, Siebert JW, Angriagiani C. A new vascularized bone graft for scaphoid nonunion. J Hand Surg Am 1991;16:474–8.
7. Sunagawa T, Bishop AT, Muramatsu K. Role of conventional and vascularized bone grafts in scaphoid nonunion with avascular necrosis: a canine experimental study. J Hand Surg Am 2000;25:849–59.
8. Green DP. The effect of avascular necrosis on Russe bone grafting for scaphoid nonunion. J Hand Surg Am 1985;10:597–605.
9. Braun RM. Pronator pedicle bone grafting in the forearm and proximal carpal row. Orthop Trans 1983;7:35.
10. Chacha PB. Vascularised pedicular bone grafts. Int Orthop 1984;8:117–38.
11. Kawai H, Yamamoto K. Pronator quadratus pedicled bone graft for old scaphoid fractures. J Bone Joint Surg Br 1988;70:829–31.
12. Herbert TJ. The fractured scaphoid. St Louis: Quality Medical Publishing; 1990:31–3.
13. Herbert TJ, Fisher WE. Management of the fractured scaphoid using a new bone screw. J Bone Joint Surg Br 1984;66:114–23.
14. Daly K, Gill P, Magnusen PA, Simonis RB. Established nonunion of the scaphoid treated by volar wedge grafting and Herbert screw fixation. J Bone Joint Surg Br 1996;78:530–4.
15. Bunker TD, McNamee PB, Scott TD. The Herbert screw for scaphoid fractures. A multicentre study. J Bone Joint Surg Br 1987;69:631–4.
16. Russe O. Fracture of the carpal navicular. Diagnosis, non-operative treatment, and operative treatment. J Bone Joint Surg Am 1960;42:759–68.
17. Jiranek WA, Ruby LK, Millender LB, Bankoff MS, Newberg AH. Long-term results after Russe bone-grafting: the effect of malunion of the scaphoid. J Bone Joint Surg Am 1992;74:1217–28.
18. Stark HH, Rickard TA, Zemel NP, Ashworth CR. Treatment of ununited fractures of the scaphoid by iliac bone grafts and Kirschner-wire fixation. J Bone Joint Surg Am 1988;70:982–91.
19. Cooney WP 3rd, Dobyns JH, Linscheid RL. Nonunion of the scaphoid: analysis of the results from bone grafting. J Hand Surg Am 1980;5:343–54.
20. Mathoulin C, Haerle M. Vascularized bone graft from the palmar carpal artery for treatment of scaphoid nonunion. J Hand Surg Br 1998;23:318–23.