Long-term results of scaphoid nonunion treated by intercalated bone grafting and Herbert's screw fixation—a study of 49 patients for at least five years

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Abstract The objective of this article is to report our clinical experience in the treatment of patients with scaphoid nonunion using intercalated bone graft and Herbert's screw and the long-term postoperative results with a minimum of five years of follow-up. We retrospectively reviewed 49 patients treated with carved intercalated bone graft and Herbert's screw fixation from September 1987 to June 2001. Preoperative clinical manifestations and postoperative results were assessed by radiography, and functional results, including grip force, range of motion of the wrist joint, and Cooney's scoring chart, were evaluated. The union rate was 93.9%. The average grip power, as well as wrist flexion and extension were significantly improved. Using Cooney's scoring system, 29 patients were rated excellent and 17 good. For successful union, anatomical reduction with carved intercalated bone grafting and Herbert's screw fixation is definitely a reliable option. This method leads to a satisfactory long-term functional outcome.

Résumé L'objectif de cette étude est de rapporter le résultat clinique du traitement des pseudarthroses du scaphoïde traitées par greffe intercalaire et vis de Herbert. Les résultats ont été évalués à long terme avec un minimum

de recul à 5 ans. Matériel et méthode: il s'agit d'une étude rétrospective de 49 patients traités selon cette technique de septembre 1987 à juin 2001. L'évaluation pré et post-opératoire a porté sur les signes cliniques, la radiographie, les signes fonctionnels en incluant la force de préhension et la mobilité du poignet ainsi que le score de Cooney. Résultats: le taux de consolidation a été de 93,9%. La force de préhension et la mobilité du poignet en flexion et en extension ont été améliorées de façon significative. Le score de Cooney était côté sur 29 patients excellents et bons chez 17 patients. Conclusion: Cette technique est une technique parfaitement fiable du traitement des pseudarthroses et permet d'obtenir des résultats satisfaisants à long terme tant sur le plan fonctionnel que sur le plan anatomique.

Introduction

Scaphoid fractures are the most common fracture of the carpal bones and account for 60% carpal injuries [1, 19]. Due to anatomical properties including tenuous vascular supply, joint fluid dilution, and the inability to form callus, as well as biomechanical properties, such as high shear stress and displacement of fragments, delayed unions and nonunions are not uncommon. Delayed treatment and an inadequate period of fixation are also responsible for scaphoid nonunion [9, 10]. It is known that the nonunion rate of scaphoid fracture is 5–10% with non-surgical treatment [5, 8, 13]. Established nonunion, if left untreated, will progress to osteoarthritis and impair the function of the wrist joint [9, 13, 18]. Therefore, in most instances, nonunions of the scaphoid are managed by surgery. However, the treatment of scaphoid nonunions is trouble-

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some, with reported failure rates between 25% and 45% [1, 21]. The key points of successful surgery for scaphoid nonunions include achieving union of the fracture, correcting the deformities, restoring anatomical alignment, and recovering the function of the wrist [6].

There are many strategies to deal with established scaphoid nonunions. Rüsse's bone grafting method was reported to achieve union in 69 of 77 patients, but joint stiffness and under-correction of the inter-scaphoid angulation were also noted [8, 20]. Herbert and Fischer reported on first treatment with Herbert's screw fixation only and recommended that bone graft should be used [7]. Christodoulou et al. reported that fixation with K-wires provided less stable fixation than screw fixation, with only 55% achieving union [22]. Barton and Warren-Smith used Herbert's screw fixation and bone graft, which yielded satisfying results with better functional results than those obtained with bone graft alone [2]. Several types of vascularised bone grafts have been reported to increase the union rate, with claimed union rates often higher than 90%. The most popular is the 1,2 intercompartmental supraretrinacular artery introduced in 1991 by Zaidenberg et al. [24]. In order to correct deformities, reach solid union, and gain good functional results, we performed thorough curettage of sclerotic bone and the unstable fibrous tissue, used healthy cancellous bone chips for impaction and an intercalated carved cortex-containing bone graft held by rigid fixation with compression by a Herbert's screw. The purpose of this study was to evaluate long-term outcomes with a minimum of five years of follow-up.

Materials and methods

From May 1987 to February 2006, 116 patients with scaphoid nonunion were treated by carved intercalated tricortical autologous bone graft and Herbert's screw at Taipei Veterans General Hospital; three of the patients had bilateral scaphoid nonunions (Table 1). Among this group, 59 patients with 60 nonunions of the scaphoid were treated before June 2001. All operations were performed by the same surgeon. Patients with other associated injuries, such as scapholunate ligament injury, or scaphoid nonunion avascular collapse were excluded. We reviewed patients' charts and contacted them concerning follow-up, but only 49 were available for follow-up of at least five years.

The average age of these patients at the time of the operation was 30.6 years old (range 17–68 years). Thirty-four of the 59 patients had nonunion of the right wrist (57.6%), 24 patients had nonunion of the left wrist (40.7%), and one patient had nonunion of both wrists (1.7%). In addition, 39 of the hands were on the dominant side. The average time from initial injury to operation was 19.8 months (range 5–68 months).

Postoperatively, a short arm splint was used for two weeks, which was exchanged for a thumb spica after removal of the stitches for an additional month. Routine roentgenography including AP, true lateral, and ulnar deviation views for evaluation of the union was undertaken monthly. We assessed osseous union based on the continuity of the trabeculae on both poles of the fracture and the intercalated bone graft site in all radiographic findings.

We reviewed the radiographs, and the fracture location was identified using the Rüsse classification to proximal pole, waist, and distal pole fracture (Fig. 1). Radiographic measurements were made on posteroanterior views in both the neutral position and the deviation position and on lateral views with the forearm in neutral rotation. The radiographs were evaluated by the same orthopaedic surgeon and the scapholunate angle, the length of scaphoid in the ulnar deviation view, any sign of advancing osteoarthritis or advanced collapse, and loosening or protrusion of the screw were recorded.

A questionnaire regarding pain, joint stiffness, satisfaction with the operation, and Cooney's scoring chart (Table 2) were used. The subjective results were evaluated by physical examination and radiographs. Range of motion of dorsiflexion, palmar flexion, and ulnar deviation were recorded. The grip strength of both hands was tested three times with the Jamar dynamometer with the forearm in a neutral position and the elbow in 90-degree flexion, and the average value was recorded.

Operative technique

A volar hockey-stick approach was used just lateral to the flexor carpi radialis and medial to the radial artery. By incision of the joint capsule and the radioscaphocapitate and scaphotrapezial ligament, the nonunion site, scaphoid tubercle, and radioscaphoid joint were identified. The fibrous tissue and sclerotic bone within the site of nonunion

Table 1 Age distribution of scaphoid nonunion treated in Taipei Veterans General Hospital

Age range	10–19	20–29	30–39	40–49	50–59	60–69	70–79
Number of patients	7	38	34	17	5	14	1

Fig. 1 Rüsse classification

were debrided and curetted. The anatomical length was regained by traction and the gap between the fragments was estimated. Wedge tri-cortical bone graft was harvested within 5 cm superior to the contralateral anterior superior iliac crest. The bone graft was carved into the wedge cylinder to regain the proper length with preservation of the cortical bone, and the cancellous bone chips were gathered. Impaction of the cancellous bone graft was done before insertion of the strong, cortex-containing bone graft to avoid a gap between the osteosynthetic sites (Fig. 2). The jig hook was engaged on the dorsal aspect of the tip of the proximal pole of the scaphoid and the barrel was engaged on the radial side of the tubercle for temporary fixation and compression, and the screw length was measured by the jig itself. Additional temporary Kirschner wires were used occasionally for resistance to the rotational torque while the Herbert's screw was being inserted. Then, we removed the jig and ensured there was no gross screw protrusion (Fig. 3). Repair of the incised ligament and joint capsule was done with proper tension to avoid sequential radio-carpal or midcarpal instability and contracture-related joint stiffness. A short arm volar splint was used after operation.

Fig. 2 Harvested wedge tricortical bone graft proximal to anterior superior iliac spine; carved according to the defect size; cancellous bone chip gathered; cancellous bone graft impacted to the proximal and distal defects before being inserted into the intercalated bone graft; fixed with Herbert's screw

Results

Forty-three male patients and six female patients were followed for at least five years. Among these patients, 41 nonunions were located in the waist, three at the proximal pole, and five at the distal pole. Forty-six of 49 scaphoid nonunions had a solid union, and the union rate was 93.9%. For an example, see the case presentation in Fig. 4.

Forty-four patients were satisfied with the operation (89.8%). Five patients had mild pain of the wrist and four patients had a subjective tight sensation in the wrist joint. The average grip strength of the affected hands was 37.2 kg and the contralateral hand was 38.6 kg, or 96.3% compared with the contralateral hand.

Table 2 Clinical scoring chart according to Cooney et al.

Pain	Points	Functional status	Points
No pain	25	Returned to regular employment	25
Mild, occasionally	20	Restricted employment	20
Moderate, tolerable	15	Able to work, unemployed	15
Severe to intolerable	0	Unable to work because of pain	0
Range of motion	Points	Grip strength	Points
100%	25	100%	25
75–99%	15	75–99%	15
50–74%	10	50–74%	10
25–49%	5	25–49%	5
0–24%	0	0–24%	0

Cooney Scoring Chart overall results: excellent 90–100, good 80–89, satisfactory 65–79, poor <65

Fig. 3 Intraoperative photo after Herbert's screw fixation

The mean arc of dorsiflexion was 75.1 degrees compared with 55.3 degrees preoperatively, and palmar flexion was 79 degrees compared with 67.2 degrees preoperatively. Average ulnar deviation was 35.2 degrees compared with 38 degrees preoperatively.

According to Cooney's scoring of the 49 patients, 29 had excellent results (59.2%), 17 had good results (34.7%), two had satisfactory results (4.1%), and one had a poor result (2.0%). Among these patients, 34 went through at least ten years of follow-up, of which 19 had excellent results (55.8%), 14 had good results (41.2%), and one had a fair result (3%). Over the five- and ten-year follow-ups, 93.3% and 97.1% of patients had excellent and good results, respectively.

According to the roentgenographic review, the average length of intercalated carved bone graft was a mean of 4.5 mm (range 2.0–6.5 mm). The average length increased from a preoperative 25 mm to a postoperative 26.4 mm of scaphoid in the ulnar deviation view. The average scapho-lunate angle was 61.1 degrees preoperatively and 56 degrees postoperatively as a result of the correction of the humpback deformity. Forty-two of the 49 patients (85.7%) returned to their original work and seven patients (14.3%) changed to jobs with lighter loading. The average duration until a patient went back to work was 4.2 months (range 3–8 months).

There were six patients with radiographic findings of screw protrusion. Five of the screw protrusions occurred in

Fig. 4 Case presentation. *Left upper* pre-op. *Right upper* post-op one month. *Left lower* post-op three months. *Right lower* post-op five years, solid union with remodelling of bone graft. No screw protrusion into the scapho-capitate joint was seen during operation and there was no following evidence of peripheral osteolysis or arthrosis due to screw protrusion

the scapho-trapezial joint and one in the radiocarpal joint. Only two patients had clinical symptoms of impingement with pain and required surgical removal of the implant. Loosening of the screw was noted in two patients, but there were no bothersome symptoms. Union with marked remodelling of the bone graft with a nonunited scaphoid was noted. Five patients with progressive degeneration were noted in our studies. There was no complication at the donor site, including wound infection, avulsion fracture, or injury to the lateral femoral cutaneous nerve. However, many patients complained of worse pain at the donor site than at the wrist after operation.

Two of the failed cases were located in the middle third and one at the proximal pole. One underwent the same procedure again and gained union, and the other two received scaphoidectomy, fascia lata interposition, and scapho-trapezio-trapizoidal fusion.

Discussion

Delayed diagnosis or inadequate treatment may lead to nonunion of the scaphoid. Some patients with scaphoid nonunion may remain asymptomatic [15, 16], but with progression of arthrosis, bothersome symptoms may occur [9, 11, 14]. Without treatment, a predictable wrist arthrosis will develop [23], similar to scapho-lunate dissociation. Avascular necrosis of the proximal pole with or without collapse, radioscapoid, midcarpal arthrosis, and pan carpal arthritis may occur with time. Surgical treatment is the current trend for both symptomatic and asymptomatic scaphoid nonunion, avoid predictable tragedy [14]. Established nonunions of scaphoid fracture have been treated by various operative procedures. The goals of surgery for nonunion include union of the fracture, restoring alignment in rotation and length, and recovery of wrist function [6].

In our series, scaphoid nonunions occurred mostly in the dominant hand of young adult males and were usually located at the waist. The volar approach provides a clear visual field for any type of nonunion, thorough debridement of collapsed bone and fibrous tissue within the fracture site, a good and easy targeting jig application for Herbert's screw fixation, and

corrective restoration of scaphoid alignment and length. However, the volar approach may have no benefit in preserving the vascularity of the scaphoid compared with the dorsal or radial approach [12]. Therefore, careful dissection and soft tissue preservation is important. Incision of the radiocarpal and scapho-trapezial ligaments is necessary and becomes an inevitable disadvantage.

The Rüsse method of bone grafting led to a 90% union rate and 88% satisfaction [20], but inevitable joint stiffness occurred due to prolonged immobilisation for about four to six months and inadequate correction of the inter-scaphoid angulation [8, 22]. Jiranek et al. reported similar results [10]. Herbert and Fisher found that none of the nonunions healed with Herbert's screw fixation alone in their early cases [7]. Warren-Smith and Barton reported better results with the wedge bone graft and screw technique compared with Matti-Rüsse's inlay bone grafting [1, 22]. Currently, it is well known that for successful bone union, reestablishment of local perfusion, replacement of sclerotic tissue with osteoconductive and osteoinductive matrix, and rigid fixation are imperative. Filan and Herbert reported 431 patients with scaphoid fracture or nonunion with bone grafting and Herbert's screw fixation with a better functional outcome than with the standard Rüsse method and a reduction of progression of arthritis [4]. Daly et al. reported 26 patients with established nonunion treated with Herbert's screw and bone grafting with a 96% union rate [3]. Owing to the impaction of the autologous cancellous bone graft and the cortex-containing carved bone graft to fit the defect, using both osteoconductive and osteoinductive materials, we can decrease the osteosynthesis gap and successfully correct the deformity and maintain anatomical reduction. Due to the promising outcome of our early cases, we were encouraged to continue using this method with our patients with scaphoid nonunions.

Several types of vascularised bone graft have been introduced in recent years. Although they have a superior union rate, we believe there are limitations, including inadequate size, problems with fixation, and incorporation difficulty with scaphoid morphology. We think that the vascularised bone graft plays a possible role in established avascular necrosis of the proximal pole as an additional viable bone with blood supply, not mainly as bone graft.

Table 3 Distribution of age with Cooney score

Age	<19	20–29	30–39	40–49	50–59	60–69	70–79
Excellent	5	28	14	10	0	0	0
Good	2	10	12	7	3	3	0
Fair	0	0	8	0	2	9	0
Poor	0	0	0	0	0	2	1

Likelihood ratio chi-square $p < 0.001$

As to the range of motion, the carved cortex-containing bone graft and rigid Herbert's screw fixation provided good strength and stability for correction of humpback deformity, which led to a confident early range of motion and decrease in postoperative stiffness. The bone grafts were carved to rebuild the anatomical morphology of the scaphoid and avoid possible bony impingement. The incised extrinsic ligament and joint capsule were repaired with proper tension to avoid contracture. All of the above contributed to the excellent improvement in wrist motion.

Regarding the roentgenographic findings, the discrepancy between the intercalated bone graft and the average increase in scaphoid length in the ulnar-deviation view was due to curettage of the condensed bone around the nonunion site. Correction of the humpback deformity by decreasing the scapholunate angle was achieved due to the wedged shape of the bone graft. Remodelling of the bone graft was noted in most cases, with a tendency to fit the contour of the original bone fragment. Delicate dissection and repair of the incised ligament and use of carved bone graft are helpful in decreasing the sequential carpal instability and follow-on arthritic change. The delusion of screw protrusion was due to the thick cartilage coverage of the scaphoid.

It seems that a higher incidence of failure is associated with proximal pole fracture. A higher ratio of avascular necrosis of the proximal pole has been reported [17], which leads to failure with intercalated carved bone graft and Herbert's screw fixation. There are other disadvantages to this procedure in treating scaphoid nonunion including postoperative short-term donor site morbidity, time consumption, and the technical demands of the carved graft.

Excellent and good results, according to the Cooney scoring chart, with over five years of follow-up, and even more than ten years of follow-up, show that this procedure provides good long-term results. Regarding the relationship between age distribution and Cooney score, a better prognosis was seen in young patients than in older patients (Table 3).

In summary, a combination of thorough curettage of unhealthy bone, impaction of cancellous bone chip graft, shaped cortical-containing bone grafting, and internal rigid fixation with Herbert's screw provides a good option for treatment of scaphoid nonunion. This procedure provides sustained rebuilding of scaphoid length, correction of humpback deformity, avoidance of further collapse, and leads to promising bony union.

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