Original article

Non-structural cancellous bone graft and headless compression screw fixation for treatment of scaphoid waist non-union

S.H. Han*, H.J. Lee, I.T. Hong, U. Kim, S.J. Lee

Department of orthopaedic surgery, CHA Bundang medical center, school of medicine, CHA university, 463-712 Seong-nam, Republic of Korea

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ABSTRACT

Purpose: Scaphoid fracture commonly occurs around the mid-third of the scaphoid, and non-union of this fracture has several treatment options. The authors performed autologous cancellous bone graft from the iliac crest and headless compression screw fixation for the treatment of Mack-Lichtman type II scaphoid waist non-union. The purpose of this study was to determine whether this procedure was effective in achieving bony union and restoration of alignment.

Methods: Medical records and radiographs of 30 patients who underwent cancellous bone graft and headless compression screw fixation for non-union of scaphoid waist fracture were retrospectively reviewed. There were 28 men and 2 women, with a mean age of 32.8 years (range: 21–63). The mean time to surgery was 10 months (range: 3–25) and mean follow-up was 37.5 months (range: 15–52). The authors analyzed bony union, lateral intrascaphoid angle, scapholunate angle, radiolunate angle and scaphoid length on radiographs and evaluated the Modified Mayo wrist score (MMWS) as a functional outcome.

Results: Bony union was achieved in all cases. The lateral intrascaphoid angle improved from 40° to 32° (P < 0.001). The scapholunate angle also improved from 61° to 56° (P = 0.009). The radiolunate angle decreased from 8° to 4° (P = 0.048) and scaphoid length increased from 22 mm to 26 mm (P < 0.001) post-operatively. Wrist motion and MMWS improved significantly at last follow-up. However, there were no significant differences between scaphoid deformity correction angle and pre- to post-operative difference in MMWS.

Conclusions: Non-structural autologous cancellous bone graft from the iliac crest and headless screw fixation provided reliable results and can be one of the effective treatment options for patients with symptomatic Mack-Lichtman type II non-union in the mid-third of the scaphoid.

Level of evidence: Level III.

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1. Introduction

Various surgical methods have been reported for scaphoid non-union, but the ideal treatment remains uncertain [1,2]. Despite controversies, there is a general consensus that a corticocancellous bone graft is necessary for large defects, a cancellous bone-chip graft for small defects, a wedge bone graft for correction of humpback deformity and a vascularized bone graft (VBG) for avascular necrosis (AVN) of the proximal fragment. However, few studies have been carried out regarding the use of a cancellous bone graft and screw fixation for scaphoid non-union [3–5].

The authors applied an autologous iliac cancellous bone graft and headless compression screw (HCS) fixation in unstable non-union of scaphoid waist fracture. This technique involves a markedly simplified surgical procedure with no need to shape the graft, regardless of defect size or humpback deformity, and faster incorporation of cancellous as opposed to cortical bone.

The purpose of this study was to present the authors’ surgical technique, and to evaluate the surgical outcome and efficacy of the procedure.

2. Material and methods

A retrospective review of patients who underwent surgical treatment for symptomatic unstable non-union in the mid-third of the scaphoid between January 2009 and May 2014 was performed after Institutional Review Board approval.

Plain radiographs, including standard posteroanterior, lateral and billiard views (partially supinated posteroanterior with ulnar deviation) of the wrist were used to assess the scaphoid fracture...
and non-union [6]. The contralateral uninjured wrist was evaluated for comparison. Non-union was defined as at least 3 months’ post-traumatic permanent fracture, with bone resorption or sclerotic changes on plain radiograph.

Non-unions were graded according to the Mack-Lichtman classification on preoperative radiographs, and patient inclusion was limited to type-II non-union: i.e., unstable non-union with significant displacement but without degenerative changes [7]. Cases with avascular necrosis of the proximal fragment on magnetic resonance imaging were excluded (Fig. 1).

Bony union was assessed from the serial radiographs taken at each follow-up visit, and defined as consolidation of the non-union gap (as shown by a bridging bone on at least two views), absence of loosening of the internal fixation, and no further displacement of the fragment [8]. At the time of confirmation of union on plain radiographs, computed tomography scans were performed. Preoperative radiographic determination of union and measurements were evaluated by experienced observers (two surgeons and one radiologist) blinded to all other study data, who also confirmed the clinical and radiographic follow-up findings.

The presence of deformity was assessed from lateral intraoscalphoid angle (LISA: lines are drawn perpendicular to the proximal and distal articular surfaces and the resulting angle is measured), scapholunate angle (SLA: the angle between the axis of the lunate and the axis of the scaphoid), radiolunate angle (RLA: the angle between the lateral longitudinal axis of the radius and the central axis of the lunate), and scapholunate length on plain radiographs (billiard view) (Fig. 2) [9]. Postoperative LISA, SLA, RLA and scapholunate length were compared with the preoperative condition, and differences were analyzed.

To assess functional outcome, wrist joint range of motion (including dorsiflexion [DF], volar flexion [VF], radial deviation [RD] and ulnar deviation [UD]) was assessed clinically using a goniometer at each follow-up visit. The Modified Mayo Wrist Score (MMWS) was checked at 6 weeks, 3 months, 6 months and annual follow-up visits [10]. The postoperative measurements and the functional outcomes taken at the last follow-up were analyzed.

There were 28 males and 2 females, with a mean age of 32.8 years (range: 21–63). Twenty-two patients were injured on the right wrist and 8 patients on the left. Twenty-four injuries (80%) involved the dominant wrist. The mean time between injury and surgery was 10 months (range: 3–25) and the mean follow-up period was 37.5 months (range: 15–52).

2.1. Statistical analysis

Two clinical results were statistically analyzed. The primary analysis compared postoperative LISA, SLA, RLA, and scapholunate length with the preoperative condition, to determine whether alignment improved. Preoperative and postoperative radiographic measures were compared on paired t-tests. A secondary analysis used Pearson’s product-moment correlation to examine a correlation between the corrected angle of deformity and recovery of function. In detail, we compared pre- to postoperative difference in LISA, SLA, RLA and scapholunate length with pre- to postoperative difference in MMWS. Statistical significance was defined as a P-value <0.05. The statistical software R (v 3.1.0, Comprehensive R Archive Network, GNU General Public License) was used for all statistical analyses.

2.2. Surgical procedure

The non-union site was approached by a longitudinal incision along the radial border of the flexor carpi radialis in all patients (Fig. 3). The sclerotic border of the non-union was exposed through longitudinal capsulotomy, after removal of the surrounding scar tissue. We created a biconcave cavity until the healthy well-vascularized cancellous bone was exposed, using a burr and curette to insert the bone graft, leaving enough bone stock for fixation. After scapholunate shape and length were restored by the joystick maneuver with wrist extension, the guide-pin of an HCS was inserted from the distal fragment and passed through the cavity to the proximal fragment under direct vision. At this point, we inserted an additional K-wire to prevent rotation of the fragments. The cancellous bone was harvested from the iliac crest through a cortical window of approximately 2 cm. Harvested cancellous bone was prepared as chips and packed into the prepared cavity around the guide-pin. The dorsal aspect of the scapholunate defect was filled first, extending across the non-union, and the Synthes 2.4 mm HCS (DePuy Synthes, Bettlach, Switzerland) was inserted to stabilize the scapholunate under image-intensifier guidance. The leading part of the screw was positioned in the center on the proximal pole, with the threads completely crossing the bone graft. After fixation, the position of the screw was confirmed and additional tight packing with cancellous bone into the surrounding defect was carried out. The capsule and skin were closed and immobilized with a short arm-thumb spica splint, replaced by a thumb spica cast after stitch removal.
Removal of cast and gentle progressive range of motion exercises were permitted from 6 weeks postoperatively. Return to normal daily activities was recommended after confirmation of union on plain radiographs and CT scan during follow-up visits.

3. Results

Bony union was achieved in all 30 patients; mean time to union was 12.5 weeks (range: 8–32) (Fig. 4). Comparison of preoperative and postoperative follow-up radiographs demonstrated marked improvement. Average LISA improved after surgery from 40° to 32° ($P<0.001$). SLA and RLA also decreased from 61° to 56° ($P=0.009$) and from 8° to 4° ($P=0.048$), respectively. Preoperative scaphoid length was shorter than on the contralateral side in all cases, and increased 22 mm to 26 mm postoperatively ($P<0.001$) (Table 1). On preoperative evaluation, humpback deformity (apex-dorsal malalignment of the scaphoid, defined as LISA > 45°) was observed in 9 of the 30 cases. LISA improved from 49° to 38° and MMWS also showed good results, but without statistical significance. Dorsal intercalated segment instability (DISI), defined as RLA > 15° on true lateral view, was seen in 7 patients preoperatively, 6 of whom showed RLA < 15° postoperatively; however, the
remaining patient showed decreased postoperative RLA, although still greater than 15° (decrease from 27° to 18°). There were no newly developed cases of DISI.

The range of motion of the wrist at last follow-up improved compared to the preoperative condition: dorsiflexion from 63° to 73° ($P<0.001$), palmar flexion from 65° to 76° ($P<0.001$), radial deviation from 15° to 17° ($P=0.030$) and ulnar deviation from 36° to 37° ($P=0.326$). Mean Modified Mayo wrist score at last follow-up was 92.5; this also represented improvement over the mean preoperative score of 70.5 ($P<0.001$) (Table 2). Twenty-three patients were rated as “excellent (90–100)”, 5 patients as “good (80–90)” and 2 patients as “satisfactory (60–80)”. There was no significant correlation between the correction angle of scaphoid deformity and pre- to postoperative difference in MMWS (Table 3). No patients required removal of hardware, and there were no cases of surgical site infection, screw penetrating the articular surface, screw cut-off or donor-site related problems.

**4. Discussion**

In the present study, scaphoid alignment, and especially LISA and SLA, was significantly restored. Scaphoid length increased

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**Table 1**

Mean values for preoperative and postoperative radiographic measurements.

<table>
<thead>
<tr>
<th>Radiographic measurements</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LISA ($^\circ$)</td>
<td>40 [9]</td>
<td>32 [7]</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SLA ($^\circ$)</td>
<td>61 [11]</td>
<td>56 [6]</td>
<td>0.009</td>
</tr>
<tr>
<td>RLA ($^\circ$)</td>
<td>8 [10]</td>
<td>4 [9]</td>
<td>0.048</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>22 [2]</td>
<td>26 [2]</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data represent mean [SD] (paired t-test).

**Table 2**

Mean values for preoperative and postoperative functional measurements.

<table>
<thead>
<tr>
<th>Functional measurements</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DF ($^\circ$)</td>
<td>63 [11]</td>
<td>73 [13]</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VF ($^\circ$)</td>
<td>65 [16]</td>
<td>76 [20]</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MMWS</td>
<td>70.5 [10]</td>
<td>92.5 [12]</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data represent mean [SD] (paired t-test).

**Table 3**

Correlation between correction of scaphoid deformity and function.

<table>
<thead>
<tr>
<th>MMWS V.S.</th>
<th>LISA</th>
<th>SLA</th>
<th>RLA</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s correlation coefficient</td>
<td>−0.013</td>
<td>0.090</td>
<td>−0.070</td>
<td>−0.201</td>
</tr>
<tr>
<td>$P$-value</td>
<td>0.947</td>
<td>0.638</td>
<td>0.713</td>
<td>0.288</td>
</tr>
</tbody>
</table>

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Fig. 4. Radiographs of a 27-year-old female patient before and 1 year after surgery. A. Preoperative AP view. B. Preoperative lateral view. C. Postoperative AP view. D. Postoperative lateral view.
compared to the preoperative value. There were no distractions in comparison with normal contralateral values. The range of motion of the wrist and MMWS also improved compared to the preoperative condition. However, there was no significant correlation between corrected angle of deformity and recovery of wrist function. Amadio et al., found that individuals who regained normal scaphoid alignment, defined as LISA < 35°, were more likely to have satisfactory function and less likely to develop osteoarthritis than patients with greater LISA [11]. This documents the importance of restoring normal carpal anatomy. Although our results showed no significant relationship, overall good results were good for patient satisfaction related to pain and function and for recovery of range of motion. We believe that these results were due to restoring anatomical alignment and the achievement of bony union.

Various surgical procedures have been introduced to treat scaphoid non-union. Sufficient bone grafting and rigid fracture fixation after exposing the cancellous bony surface and achieving good vascular flow by debridement of all necrotic tissue are the most important surgical principles [4,12]. Some authors have recommended that scaphoid reduction can be maintained using a corticocancellous wedge bone graft for correction of humpback deformity, but the procedure is difficult, and articular surface disruption can occur.

On the other hand, other authors suggested that scaphoid reduction could be maintained without custom-shaped corticocancellous grafts. Watson et al. described a dorsal approach with scaphoid reduction, cancellous bone graft and K-wire fixation. Union was achieved in 89% of cases, flexion and extension averaged 76% of contralateral values and grip strength 88% [13]. Nagle reported a similar technique using a volar approach, packed morcelized cancellous bone graft and K-wire fixation, which showed similar results [14]. Nagle also claimed that cancellous morcelized graft could be manipulated more easily and precisely than corticocancellous graft to fit the scaphoid defect [14]. Cohen et al. recently reported a simple surgical technique consisting in volar approach with scaphoid reduction, screw fixation and cancellous graft from the ipsilateral distal radius, which showed successful results [15].

The present authors also prefer cancellous bone grafting using autologous cancellous bone from the iliac crest, as surgical procedure is simple, graft harvesting is easy, and the cancellous graft incorporates well into the scaphoid cancellous bone, not requiring graft shaping.

A cancellous graft can be harvested easily from the distal radius or iliac crest. Although there has been controversy as to which is better, iliac crest graft retrieves more marrow and osteogenic mesenchymal stem cells [16]. In addition, Park et al. reported that pure cancellous bone harvested from the iliac crest had both the osteogenic features required for osseous integration and sufficient initial strength to resist physiological load [8]. However, lateral femoral cutaneous nerve injury and abdominal hernia associated with iliac crest bone harvesting still remain as possible complications [17].

To correct humpback deformity, the joystick maneuver with K-wires was applied with the wrist in extension in the present procedure. The bony defect was filled with cancellous bone chip after insertion of the HCS guide-pin. The procedure showed good results in patients with humpback deformity, although sample size precluded any significant correlation.

A headless self-compression screw is commonly inserted for stabilization of fragments and graft. It is buried under the articular surface and provides strong fixation. One study reported that screw fixation was superior to K-wire fixation in unstable scaphoid non-union [4]. However, Ramamurthy et al. performed a multivariate analysis showing that fracture site and patient age, rather than fixation technique, were the significant determinants of outcome [18].

The present study hypothesized that both stable fixation and graft material are important for bone union. For this reason, we chose a headless compression screw for stable fixation and cancellous bone graft for better bone healing. However, when bone stock is not enough, in cases such as distal or proximal scaphoid non-union or proximal pole avascular necrosis, another method should be considered.

The limitations of this study were that the number of patients was relatively small and the design was retrospective. Moreover, the included patients had relatively small deformity. In case of severe humpback deformity, our procedure may be not effective. In conclusion, non-structural autologous cancellous bone graft from the iliac crest and headless screw fixation provided reliable results for the treatment of scaphoid waist non-union. This method can be one of the effective treatment options for patients with symptomatic Mack-Lichtman type II non-union in the mid-third of the scaphoid.

Disclosure of interest

The authors declare that they have no competing interest.

References