

Treatment of Nonunion of Scaphoid Waist with Ni-Ti Shape-Memory Alloy Connector and Iliac Bone Graft

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After fracture, the unique anatomy and blood supply of the scaphoid itself predisposes to nonunion. Scaphoid nonunion presents a formidable challenge to surgeons because of the difficulties for fixation, and the high failure rate after treatment. The Ni-Ti shape-memory alloy can provide compressive stress at the nonunion site, which is the key point for bone healing. Hence, we designed a shape-memory bone connector named arched shape-memory connector (ASC). We conducted a retrospective study looking at the union rate and complications and correlating the outcome of treatment with this device. The study reviewed a cohort of six consecutive patients presenting with scaphoid waist nonunion, who were treated with ASC and iliac cancellous bone grafting at our center from August 2002 to December 2007. The patients with nonunion achieved a 100% union rate. All the patients who achieved union had good pain relief and improved function. Our study demonstrates that scaphoid waist nonunions can be successfully treated by ASC and iliac bone grafting.

Keywords arched shape-memory connector, Ni-Ti alloy, nonunion, scaphoid, shape memory

1. Introduction

The scaphoid is the most commonly prevalent fracture carpal bone, accounting for approximately 60% of the carpal fracture (Ref 1). Scaphoid fracture can escape early detection because, in many cases, they are subtle and initial symptoms are minimal. Nonunion occurs in up to 12% of patients if an occult fracture is not detected and treated (Ref 2). Nonunion can be painful and, if left untreated, often leads to osteoarthritis, weakness, and stiffness (Ref 3, 4). Cadaver studies have demonstrated that deformity of the scaphoid leads to movement decrease and particular extension (Ref 5).

Based on intensive investigations on mechanical properties of the Ni-Ti alloy, we designed a Ni-Ti shape-memory alloy device for treatment of nonunion of the scaphoid, (Chinese Patent No. ZL 01344222.8) (Ref 6). As the shape of this device looks like an arch, we call it arched shape-memory connector (ASC, Fig. 1).

From August 2002 to December 2007, six cases of scaphoid nonunion were treated with the above device, yielding a success rate of as high as 100%. In this article, we present our

experience with this device for treatments of scaphoid nonunion in six cases.

2. Material and Methods

2.1 Patients

Between August 2002 and December 2007, we treated a cohort of six consecutive patients with symptom of nonunion of the scaphoid by open reduction and internal fixation with the ASC and the cancellous bone grafting. All nonunions were diagnosed by both clinical and radiological methods, after more than 6 months from injury. Among the six patients, four were men and two were women, with a mean age of 34.6 years (range 21–55 years). The patients had their primary fractures due to fall, mostly during sports. The average time from injury to surgical treatment for nonunion was 15.5 months (range 6–48 months). The mean time interval between diagnosis and surgical fixation was 4.5 weeks (range 3 days to 12 weeks).

2.2 Surgical Procedures

A standard volar approach was used, and the fracture pseudarthrosis accompanied by the formation of sequestrum was seen. The sclerosis nonunion sites were scraped or drilled until the fresh blood was seen. Afterward, the scraped or drilled holes in the two nonunion fragments were filled with the homogenous iliac cancellous bone. The ASC was immersed in ice water, and spread shown as the dotted line in Fig. 1. Then, the two fragments were reduced, and two holes were drilled for the arm of spread ASC to insert. After being inserted into the bone, the ASC was heated with 40–50 °C warm water; the arm and waist of ASC began to revert, because the two arms of ASC were inserted into the bone hole. Therefore, the revert force was exerted on the two fragments, which was conducted to the nonunion site, producing compressive stress at the

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nonunion site which was the key point for bone healing. After operation, all the patients were immobilized in a forearm plaster for 6 weeks.

2.3 Clinical Outcome Evaluation

Rehabilitation exercise was administered in all the cases. 6 weeks after recovery from anesthesia, the patients were instructed to perform gentle flexion and extension of their carpal joints. At 1, 2, and then every 3 months after ASC implantation, respectively, union at fracture site was assessed both clinically and radiologically, and Green-O'Brien cores were used for functional recovery evaluation of the carpal joint (Ref 7).

3. Results

All the patients were included in the follow-up. All of the six patients achieved union, which was diagnosed both clinically and radiologically. A typical example is shown in Fig. 2. According to Green and O'Brien wrist scoring system, four in six wrists were rated excellent, one good and one fair.

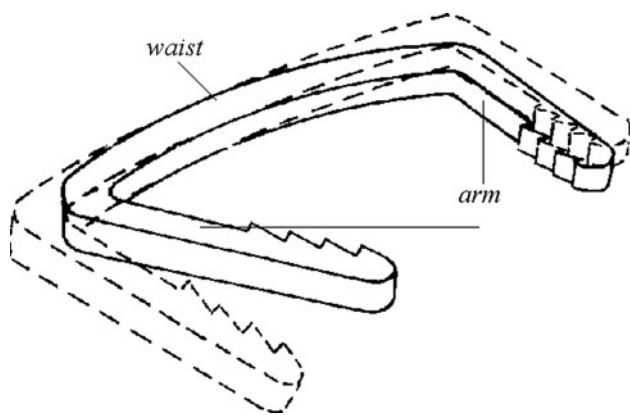


Fig. 1 Schematic diagram of arched shape-memory connector (ASC)

All the patients who achieved union had good pain relief and were able to get back to normal life. There were no cases of infection, and only one out of the six patients had to face some restriction of daily activities like carrying heavy weights and pushing heavy objects. The final clinical outcome of patients who achieved union with ASC is detailed in Table 1.

4. Discussion

Internal fixation of the scaphoid is recommended for acute fractures that are displaced and for those with established nonunion. A variety of suitable implants for treating nonunion of the scaphoid are available, such as AO scaphoid screw, Heune scaphoid screw, absorbable screw, and Richards's navicular screw. Although these implants have been reported with a high success rate of achieving union (Ref 8-10), continuous interfragmentary compressive capability is achieved to a lesser extent than that achieved with ASC. Further more, the success of screw fixation relies on the quality of the bone, whereas after scraping or drilling the sclerosis nonunion site, the bone of scaphoid became very thin, which may cause the failure of the screw fixation.

We have not found in the literature clinical studies on ASC fixation for scaphoid nonunion. In our series, union rate was high in all the patients treated with ASC and autogenous cancellous bone grafting within 48 months from injury. The high union rate may be closely related to the compressive pressure at the nonunion site produced by shape-memory effect of nitinol alloy which possesses excellent properties of wear and corrosion resistance and good biocompatibility. As of now shape-memory alloys have been widely used for manufacturing new instruments and devices which find applications in clinical practices (Ref 11, 12).

Owing to the characteristics of shape-memory alloys, the manipulation and implantation of ASC must be implemented with the following precautions. Before implantation, the ASC is to be immersed in ice water, and after reduction of the fracture, the ASC is to be implanted and warmed with 40-50 °C water. It is important that, when scraping or drilling at the nonunion sites, one should be careful not to smash the sclerosis nonunion

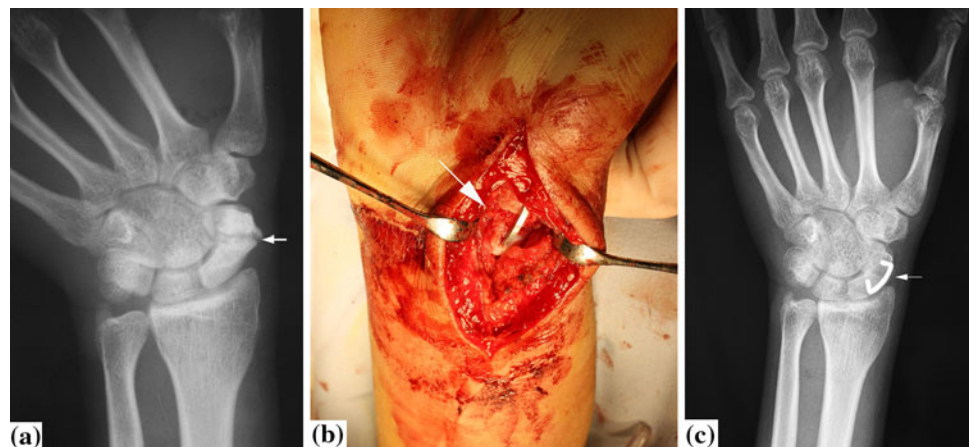


Fig. 2 (a) A 21-year-old male patient with scaphoid nonunion occurred 2 years after conservative treatment. (b) The nonunion was treated with ASC and cancellous bone grafting. (c) 2.5 months after operation, the nonunion has healed very well

Table 1 Clinical details of patients

Number	Age/sex	Mechanism of injury	Diagnosis of nonunion after index fracture (months)	Functional outcome	Green and O'Brien scoring
1	21/male	Sports	48	Normal	Excellent
2	37/female	Sports	7	Normal	Excellent
3	55/male	Traffic accidents	6	Some restriction of daily activities	Fair
4	47/male	Falling	15	Normal	Excellent
5	25/male	Sports	9	Normal	Good
6	23/female	Sports	8	Normal	Excellent

fragments, which may result in the failure of the operation. Fixation of the nonunion of scaphoid with ASC should be performed in a single attempt, because, after scraping or drilling at the nonunion end, the two nonunion fragments of the scaphoid become a hollow one, and repeated manipulation may therefore smash them.

However, it is likely as well that there were other factors which could have contributed to the result, namely, the surgical technique and the cancellous bone grafting. In the pseudoarthrosis cases, bilateral bone chips are completely mobile and unstable, while the bone surface shows sclerosis. The surgery is aimed at not only when one gets a solid bone fusion, but also when one needs to correct the accompanying wrist deformity. Therefore, we can use a small scraper and a small grinder to remove bone hardening surface, so that the facets perpendicular will face up to the scaphoid axis, and the bone implanted chips will become very stable.

Using the ASC, we have achieved high rate of bone healing with a low incidence of complication. Accelerated healing of the nonunion promotes the functional recovery of the compromised arm. The advantages of ASC in the treatment of scaphoid nonunion, as we presume, lie mainly in the continuous compression of the fracture, and stable biomechanical environment. Based on the encouraging results of our clinical trials, we believe that ASC can serve as an effective means for management of scaphoid nonunion.

5. Conclusions

The arched shape-memory connector (ASC), which can provide compressive stress at the nonunion site and is safe and easy to use, is an efficacious device for the treatment of the scaphoid nonunion.

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