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ARTICLE

Rib osteochondral graft for scaphoid proximal pole reconstruction

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ABSTRACT

Background: An irreparable scaphoid proximal pole is challenging to treat because of the fragment size and limited blood supply. Salvage surgery, such as partial wrist fusion or proximal row carpectomy, may be performed but is not ideal for young patients. There are few reports of proximal scaphoid reconstruction using rib osteochondral grafts.

Methods: Four patients were treated with rib osteochondral graft for reconstruction of the scaphoid proximal pole. The patients had a mean postoperative follow-up of 24 months. The mean age at the time of surgery was 30 years. Outcome measurements included total active range of wrist motion arc, grip strength, and wrist function score. We also evaluated the progression of osteoarthritis and changes in carpal height.

Results: No complications occurred at the donor site. The range of motion improved from 82° to 95° before and after surgery. Grip strength improved from 22 kg to 33 kg before and after surgery. There was a remarkable improvement in the modified wrist function scores of Green and O'Brien from 40 points to 70 points before and after surgery. No progression of arthrosis was seen on the radiographs of all the patients. There was no significant difference in the carpal height ratio before and after surgery.

Conclusions: Proximal scaphoid fractures may require reconstruction of the articular surfaces of the radius, capitate, and lunate. Reconstruction with a rib osteochondral graft is flexible, easy to fabricate, and can reconstruct the three articular surfaces.

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Rib osteochondral graft; scaphoid nonunion; Preiser's Disease; scaphoid proximal pole

Introduction

The treatment of nonunion of the proximal pole of the scaphoid is challenging given the size of the fragment and its limited blood supply. The fundamental approach for maintaining the integrity of the proximal pole of the scaphoid is rigid fixation using either vascularized or non-vascularized bone grafting as long as the cartilage surface remains intact. However, this reconstructive treatment becomes impossible when the proximal pole of the scaphoid is unsalvageable due to fragmentation or necrosis. In this circumstance, salvage procedures, such as partial wrist fusion with scaphoid excision or proximal row carpectomy, are performed to prevent significant carpal collapse and progressive wrist degeneration. However, these procedures are not ideal in the absence of radiocarpal arthrosis or for young patients. We believe that rib osteochondral graft reconstruction would be a suitable option to restore the integrity of the proximal pole of the scaphoid in these cases.

Sandow [1] was the first to report a rib osteochondral autograft for proximal scaphoid fractures. There are only a few case reports [2–6] of this condition in the literature.

In this study, we present four cases of rib osteochondral graft, including a case of Preiser's disease. We also review the literature addressing the clinical results of rib osteochondral autograft.

Methods

Between 2013 and 2015, four patients were treated with rib osteochondral graft reconstruction of the proximal pole of the scaphoid. The patients had a median postoperative follow-up of 24 months (range, 12–36). The median age at the time of surgery was 30 years. There were three cases of posttraumatic scaphoid nonunion and one case of Preiser's disease. Out of four cases, two were treated at other hospitals. One of the two patients underwent screw fixation and vascularized bone grafting. Postoperatively, the scaphoid bone reunion failed, and the articular surface was fragmented. This case also had a brachial plexus injury. In the other case, the patient was treated with Kirchner wire internal fixation and non-vascularized bone grafting. However, bone reunion failed, and the articular surface was fragmented.

Surgical technique

The procedure was performed under general anesthesia with an upper arm tourniquet. We exposed the dorsal and proximal sides of the scaphoid using a dorsal approach through the third extensor compartment. While conserving the shape as much as possible, we excised the proximal part of the scaphoid (Figure 1(A)). The remaining distal scaphoid was debrided using burrs until a healthy cancellous bone was visible.

The osteochondral graft was harvested through a sub-mammary incision over the fifth rib. After identifying the osteochondral junction (Figure 1(B)), we dissected the periosteum and collected the graft. Since ossification inside the rib cartilage could not be recognized from the surface, the harvested rib cartilage was checked fluoroscopically and shaved to preserve the cartilage-rich

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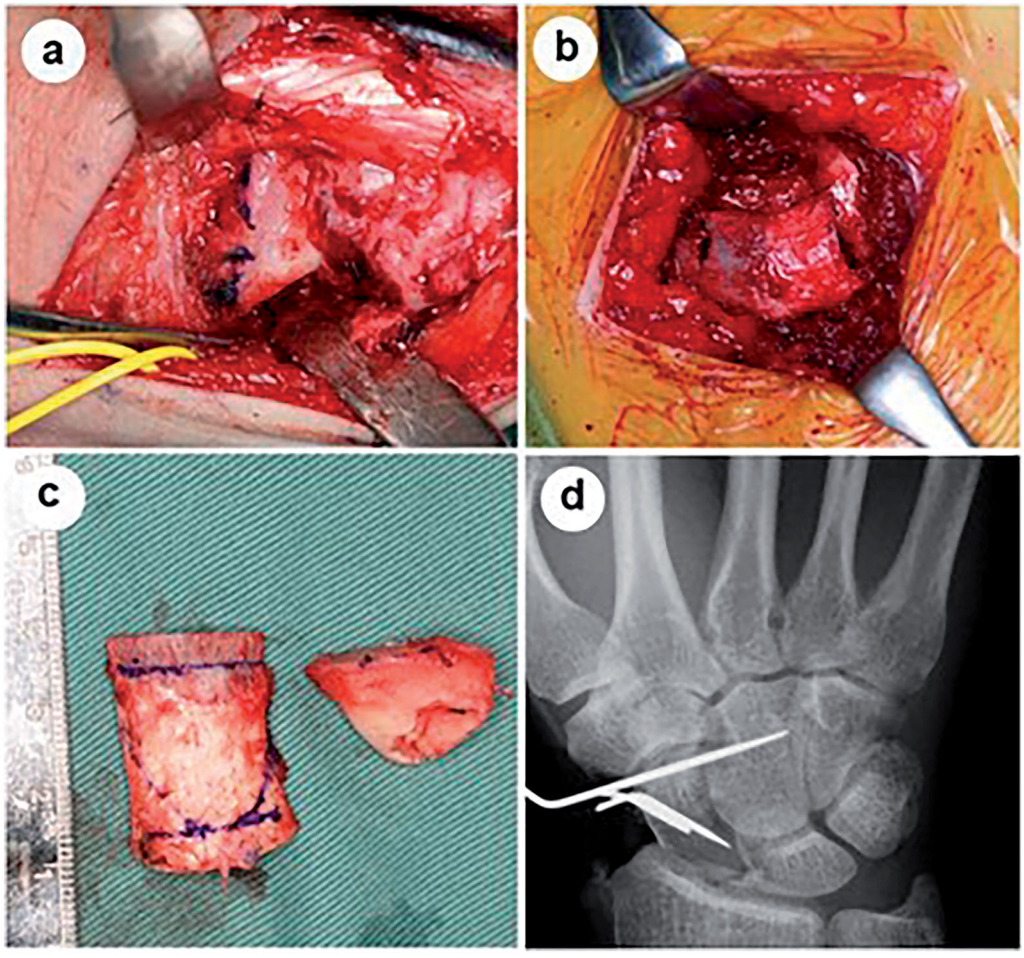

Figure 1. The proximal part of the scaphoid was resected while maintaining its shape (A). The fifth rib cartilage was harvested (B). The rib osteochondral graft was trimmed to the shape of the resected scaphoid (C, left: rib osteochondral graft, right: resected scaphoid bone). The rib osteochondral graft was fixed with Kirschner wires (D).

areas. The graft was trimmed to match the original shape of the excised part of the scaphoid and was compared to the excised bone fragment (Figure 1(C)). After maximizing the space in the scaphoid, we checked the size several times until the costal cartilage was a tight fit. Then, we placed the graft into that space and connected the graft with the remaining distal scaphoid using two or three 1.5 mm Kirchner wires (Figure 1(D)). The wires were shortened under the skin. A postoperative forearm cast was performed for six weeks, and the wires were removed after confirming bone fusion on CT.

Outcome measures

Measurements of the outcome were the total active range of wrist motion arc for flexion/extension, grip strength, and the modified wrist function score of Green and O'Brien [7].

We also evaluated changes in the carpal height and the progression of osteoarthritis.

Statistical methods

All statistical analyses were performed using EZR Version 1.37 (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [8] Wilcoxon signed-rank test was used for pre- and postoperative comparisons.

Results

The mean operative time was 191 (182–210) min. The average length of the rib osteochondral graft was 18.5 (18–20) mm. The pain was relieved in all the patients. No complications occurred at the donor site. The median preoperative and postoperative total range of wrist motion was 82° and 95°, respectively, indicating an improvement in the range of motion ($p = 0.09$). Grip strength improved from 22 kg before surgery to 32 kg after surgery ($p = 0.09$). The ratio of grip strength on the injured side to the contralateral side improved from 46% before surgery to 70% after surgery ($p = 0.125$). The postoperative modified wrist function scores of Green and O'Brien were excellent in one case, good in one case, fair in one case, and poor in one case. There was a remarkable improvement from 40 points before surgery and to 70 points after surgery ($p = 0.09$) (Table 1). The poor case in this study was complicated by brachial nerve injury. The median preoperative and postoperative carpal height ratio was 0.511 and 0.511, respectively ($p = 1$). No progression of arthrosis was observed on radiography in any of the patients.

Case report

Patient 1, a 21-year-old male who played rugby in college, had persistent left wrist pain. The preoperative function of the wrist was 50° in flexion, 60° in extension, grip strength was 31 kg, and the modified wrist function score of Green and O'Brien was 50

Table 1. Patient summary.

Patients	Age	Sex	Etiology	Wrist motion arc extension/flexion			Grip strength (kg)			Grip strength as % of injured vs contralateral			Wrist function score			Carpal height			Follow-up period (mo)
				pre-op	post-op	*p* value	pre-op	post-op	*p* value	pre-op	post-op	*p* value	pre-op	post-op	*p* value	pre-op	post-op	*p* value	
1	21	M	Nonunion	50/60	60/65		31	40		67.4	87		50	90		0.511	0.53		24
2	28	M	Nonunion, brachial nerve injury	15/50	25/55		12	22		24.5	44.9		10	50		0.511	0.51		12
3	32	M	Preiser's disease	40/40	50/45		32	41		66.7	91.1		45	80		0.5	0.51		24
4	38	M	Nonunion	30/22	40/45		12	26		21.4	53.1		35	60		0.522	0.48		36
Median	30			37/45	45/50	0.09	22	33	0.09	46	70	0.125	40	70	0.09	0.511	0.51	1	24

points. Preoperative radiographs and CT scans showed nonunion and atrophy of the proximal pole (Figure 2(A)) of the scaphoid bone. The cartilage on the proximal surface had degenerated. Therefore, an osteotomy was performed at the scaphoid waist region to remove the proximal bone fragments. The rib osteochondral graft was inserted into the proximal part of the scaphoid and fixed with Kirschner wires (Figure 2(B)). Two years post-operation, there was no progression to osteoarthritis, and the carpal bone alignment was maintained (Figure 2(C)). The wrist function was 60° in flexion, 65° in extension, grip strength was 40 kg, and the modified wrist function score of Green and O'Brien was 90 points. He now works in the transportation industry and teaches rugby.

Discussion

Irreparable scaphoid proximal pole due to nonunion or idiopathic osteonecrosis, such as Preiser's disease, are difficult to treat, especially in young patients. To reconstruct the proximal scaphoid, articular reconstructions of the radius, capitate, and lunate, and ligament reconstruction must be considered.

For articular reconstruction, a rib osteochondral graft, vascularized medial femoral trochlea flap [9,10] and proximal hamate autograft [11] have been reported as methods for autologous joint reconstruction. The clinical report only included the rib osteochondral graft and medial femoral trochlea flap, as the proximal hamate autograft remains in the experimental stage.

We summarize the reports [1–6] of proximal scaphoid reconstruction with rib osteochondral graft. All the results were stable over 24 months. Of the 94 cases including ours, three had complications at the site of harvest (3.2%), one did not have bony union (1.1%), and one case underwent salvage surgery (1.1%) (Table 2). Overall, the results were good, and there were few complications. In one of our cases, although the pain improved, the functional score was low because the patient had a brachial plexus injury, and the grip strength did not recover.

The medial femoral trochlea flap has also been reported to have good results. However, this flap is commonly used to reconstruct one plane of the radiocarpal joint of the scaphoid [9]. Therefore, the indication for this is a reconstruction of small bone fragments of only one articular surface. In comparison, a rib osteochondral graft can reconstruct three articular surfaces.

Next, preservation or reconstruction of the scapholunate ligament is common. However, this still depends on the extent of osteonecrosis. There is no unified view on whether reconstruction should be performed. Using a cadaver model, Capito [12] reported that after complete dissection of the scapholunate ligament, the extension of the scaphoid with a 4-mm spacer restored alignment without ligament repair. This suggests that if the scaphoid can be reconstructed slightly longer, ligament reconstruction may not be necessary. Although it is possible to maintain the carpal alignment by reconstructing the scaphoid slightly longer, the progression of osteoarthritis due to the increased load remains a concern. However, in our cases, the alignments were maintained, and none had progression to osteoarthritis. Because of the thickness of the rib cartilage, shaving may not be a problem. Reconstruction of the scaphoid using rib osteochondral autografts may be a solution without ligament reconstruction.

The advantage of rib osteochondral graft reconstruction over a vascularized cartilage flap is the greater freedom of graft placement and wire insertion without concern for the flap pedicle. It is also indicated for relatively large defects such as Preiser's disease, nonunion, and proximal articular surface defects. As mentioned

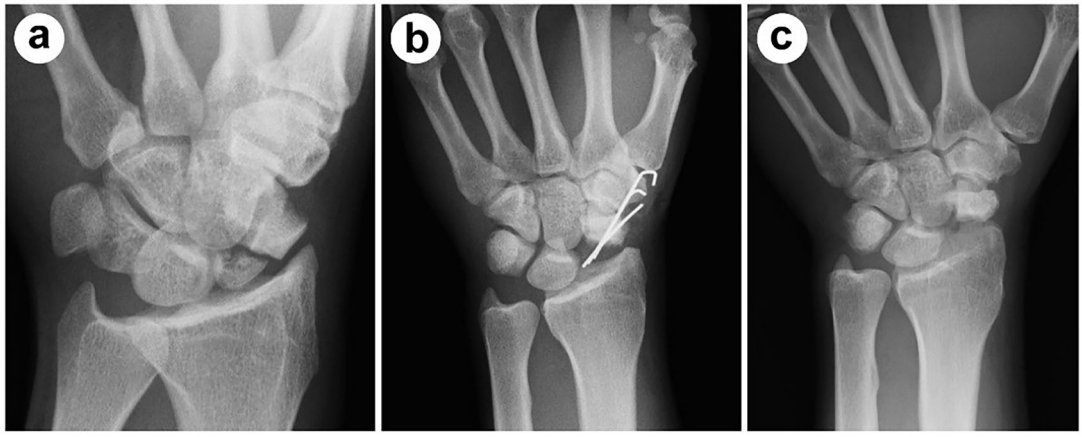

Figure 2. Preoperative (A), intraoperative (B), and two years postoperative (C) radiographs.

Table 2. Summary of the reports of proximal scaphoid reconstruction with rib osteochondral autograft.

		Cases (n)	Follow-up period (months)	Post-op grip strength (kg)	Post-op grip strength %normal	Post-op total range of wrist mortion arc (degrees)	Post-op wrist function score	Complication	Salvage surgery
Sandow	1998	22	24 (12–72)	Not described	80 (62–133)	93 (80–140)	80 (50–90	Hemothorax 1	0
Veitch	2006	14	64 (27–103)	42 (22–64)	Not described	Not described	79 (50–90)	0	0
Obert	2013	18	49 (6–120)	Not described	Not described	Not described	Excellent 5, Good 10, Fair 3	Nonunion 1	0
Yao	2013	3	50 (24–96)	37 (28–50)	84 (62–110)	117 (90–130)	Not described	0	0
Zechmann-Mueller	2020	21	29 (20–42)	Not described	85 ± 18	116 ± 21	Not described	0	0
Bain	2020	12	124 (41–211)	36 (15–48)	Not described	72	Not described	Pneumothorax 2, Infection 1	Wrist arthrodesis 1
Our case	2021	4	24 (12–36)	69 (45–91)	69 (45–91)	97 (80–125)	70 (50–90)	0	0

above, it seems to be the only donor that can reconstruct all articular surfaces of the radius, capitate, and lunate simultaneously. In addition, there was no functional loss after harvesting the rib cartilage.

The disadvantages of this technique are the risk of pneumothorax and the possibility of ossification of the rib cartilage in patients over 40 years of age. Previous reports included major complications affecting vital signs such as pneumothorax and hemothorax. However, these were technical errors due to rib cartilage harvesting. Rib cartilage harvesting is a common technique that is performed traditionally, and these complications are likely to decrease with the improvement of skills. Our average operating time under general anesthesia was 191 min, and it may be possible to perform this as day surgery in some hospitals. However, due to the possibility of complications at the donor site, we hospitalize the patient, and monitor vital signs until the next day. Another disadvantage is the problem of calcification. Calcification of the rib cartilage varies by sex and individual, and calcification is seen even in young people [13]. In people over 50 years of age, calcification is clearly depicted on X-rays [14]. Above 40 years of age, accurate assessment of ossification within a rib osteochondral graft is difficult before harvesting. However, fluoroscopy can be used to identify areas with rich cartilage content, which can be used for reconstruction. It is also not indicated for Kalainov [15] type 1 lesions involving the entire scaphoid bone. In addition, it is difficult to assess is the time of bone union using X-rays. Therefore, we assessed the bone union with CT scans when considering wire removal.

The limitations of this study are its small number of cases and the lack of the long-term outcome beyond 20 years. Because of the small number of cases, the improvement was apparent, however, the difference was not statistically significant. The results need to be validated by accumulating more case evidences in the future.

Reconstruction of an irreparable proximal scaphoid using a rib osteochondral graft was performed with good results. This may be the first-line treatment for patients under 40 years of age.

Disclosure statement

No potential conflict of interest was reported by the authors.

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