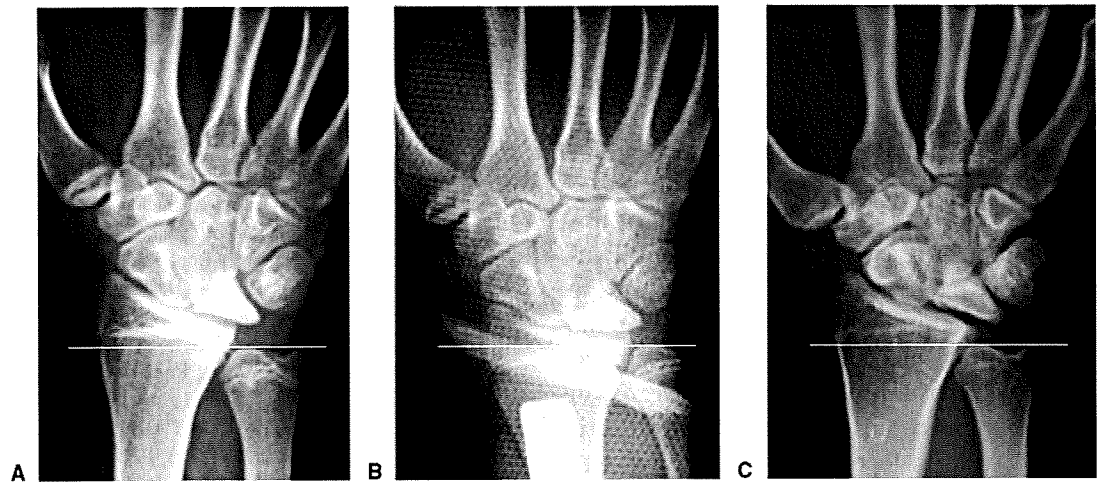

FIGURE 2: A A preoperative AP radiograph of a 13-year-old boy shows Stage IIIB Kienböck's disease in the right wrist. **B** The AP radiograph immediately after radial shortening reveals 1-mm ulna-negative variance. **C** Radial overgrowth at the affected side is found in the AP radiograph at 65 months after radial shortening. The transverse line is set on the tip of ulnar head in **A–C**.

TABLE 4. Changes in Ulnar Variance

Case	Preoperative Lichtman Stage	Age (y)	Follow-Up Period (mo)	Ulnar Negative Variance (mm) Immediately After Surgery	Ulnar Negative Variance (mm) At Follow-Up
1*	II	12	40	3	6
2	II	18	90	1	2
3*	IIIA	11	48	0	4
4*	IIIA	13	48	4	8
5	IIIB	12	113	0	2
6*	IIIB	13	65	1	5
7	IIIB	17	38	1	3
8	IIIB	18	117	0	2

*Denotes overgrowth at follow-up.

DISCUSSION

The first aim of this study was to determine the effect of radial shortening on radial growth in skeletally immature patients with Kienböck's disease. At a mean follow-up of 69 months, in standard radiographs, we recognized that 4 of the 8 patients (50%) had radial overgrowth in the affected side. There were no other findings indicating radial deformities after this surgery. To our knowledge, only 1 case report has demonstrated 8-mm overgrowth at 80 months after radial shortening for Kienböck's disease in a skeletally immature patient.[17]

Carsi et al.[24] showed that 67% of 119 pediatric patients with nonphyseal forearm fracture treated conservatively had radius overgrowth at 5 years after injury. In their study, only fractures in the proximal and middle thirds of the radius were associated with overgrowth; distal third fractures were associated with growth arrest. Our data obtained from the osteotomy cases disagree with these results. One of the reasons for this discrepancy is considered to be the stimulation of growth by surgical procedures. Bone overgrowth is thought to be caused by increased vascularity. Doria et al.[25] showed postoperative hypervascularity after femoral osteotomy in rabbits. This report did not deal with postoperative radius hypervascularity. However, this result may indicate that radial shortening induces hypervascularity of the distal radius. Therefore, we assume that the effects of the radial shortening are considered not only for mechanical decompression but also for increases in distal radius and lunate vascularity. Therefore, stimulation of growth by radial shortening is more likely the cause. Another reason seems to be the existence of microinjuries to the growth plate of the distal radius in distal third fractures. In performing radial shortening, the distal growth plate can be protected from injuries. This could arrest the growth of the radius, even though the radius responds to stimulus caused by fracture.

In this study, radial overgrowth was observed in 4 of 5 patients who were less than 13 years old. A previous case report stated that overgrowth after radial shortening occurred in a 15-year-old boy.[17] Based on the radiographic distance between the distal radius and ulnar growth plates, Pritchett[26] suggested that the skeletal maturation of the forearm bones was at age 13 in girls

and 15 in boys. On the other hand, Carsi et al.[24] concluded that overgrowth after forearm fractures was not influenced by age. Although this contradicts the results mentioned earlier, the probability of radial overgrowth should be considered in doing radial shortening for Kienböck's disease in skeletally immature patients.

Another objective was to clarify the relationships between the postoperative growth changes and the clinical outcomes after radial shortening. In our study, the existence of radial overgrowth did not greatly affect the postoperative clinical outcomes. All skeletally immature patients with postoperative radial overgrowth achieved excellent clinical results. Ulnar negative variance associated with postoperative radial overgrowth seems to cause compressive force to the lunate. This biomechanical effect may lead to the progression of Kienböck's disease. However, the MRI findings obtained in this study indicate that radial shortening produces lunate revascularization and healing in skeletally immature patients with this disease. Consequently, the excessive force produced by radial overgrowth might not advance the stage of Kienböck's disease in skeletally immature patients. Radial shortening provides a positive clinical outcome for skeletally immature patients with Kienböck's disease, despite postoperative radial overgrowth. Therefore, this surgery is considered effective for Kienböck's disease in children. Regarding the surgical technique, we recommend performing a 1- or 2-mm over-shortening for skeletally immature patients, especially those who are less than 13 years old.

This study has considerable limitations. First, the analysis was based on data from a relatively small number of patients. Therefore, the statistical power might not be enough to clearly derive conclusions from this analysis. Second, we had no control group of healthy patients of the same age who did not have surgery. However, we consider that there may be no difference in the laterality of ulnar variance in skeletally immature patients. Therefore, regarding overgrowth, a difference in length of more than 2 mm was considered a discrepancy. Third, at a mean of 69 months after surgery, the radial overgrowth would not produce any radiographic changes, such as osteoarthritis of the distal radioulnar joint and related symptoms. This might not influence the clinical results the same way in the future. A longer follow-up in a large cohort population is needed to overcome these limitations.

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RADIOLUNATE FUSION WITH DISTRACTION USING CORTICOCANCELLOUS BONE GRAFT FOR MINIMIZING DECREASE OF WRIST MOTION IN RHEUMATOID WRISTS

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ABSTRACT

Radiolunate fusion is a limited carpal fusion procedure used for patients with rheumatoid arthritis. However, this procedure inevitably causes decreases in range of motion, especially wrist flexion. Linscheid and Dobyns described the possibility of minimizing the decrease in motion at the radiocarpal joint by slight distraction of the joint. We hypothesized for our modified procedure that a corticocancellous bone graft was inserted between the radius and the lunate with a small amount of over-correction could provide slight distraction of radioscaphoid joint and protect the joint from decreased range of motion after arthrodesis. Twelve wrists in ten patients with rheumatoid arthritis underwent radiolunate fusion. Mean age at operation was 53 years old and mean follow-up period was 5.7 years. Clinical evaluation and radiological assessment showed that decrease in range of motion was minimized compared with other procedures. Because our modified procedure can minimize decrease in motion, it is recommended.

Keywords: Corticocancellous Bone Graft; Distraction; Minimize; Radiolunate Fusion; Rheumatoid Wrist.

INTRODUCTION

For the rheumatoid wrist, several procedures are currently used for pain relief, including synovectomy. This procedure, however, cannot prevent destruction of the wrist joint secondary to rheumatoid arthritis. The Darrach procedure, or ulnar head excision, is indicated for patients with rheumatoid arthritis or patients with an incongruous or degenerative distal radioulnar joint, as this procedure can achieve satisfactory relief of pain and restoration of function. However, it causes ulnar translation and palmar subluxation of the entire carpal bones because of loss of support from the ulnar head.[1] The Sauvé-Kapandji procedure also gives good clinical results and restrains the progression of ulnar translation because it is able to support the ulnar carpal bones.[1–3] However, recent reports describe that it cannot effectively prevent the progression of ulnar translation,[4,5] even compared with the Darrach procedure.[5]

A radiolunate fusion is one of the limited carpal fusions reported by Chamay *et al.* in 1983.[6] Several reports have described good clinical results using radiolunate fusion with reduction of ulnar translation and bone fusion between the radius and the lunate. However, this procedure reduces range of wrist motion, especially flexion.[6–12] Decreased wrist motion

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causes difficulties with the activities of daily living, especially for rheumatoid patients, as rheumatoid arthritis usually affects upper extremity joints.

Linscheid and Dobyns shows that the scaphoid can rotate about the lunate more freely if the lunate is distracted slightly.[7] In addition, Hastings recommends that a bone graft inserted between the radius and the lunate can elevate the lunate from its normal position to an over-corrected height.[13] Based on these concepts, we hypothesize that a corticocancellous bone graft inserted between the radius and the lunate with a small amount of over-correction can provide slight distraction of radioscaphoid joint. This would, theoretically, protect the joint from decreased range of motion after arthrodesis. A corticocancellous bone graft, harvested from the excised ulna by the Darrach procedure, is thought to be more suitable than a cancellous bone graft because cortical bone is generally more rigid and stronger mechanically than cancellous bone. The objectives of this report are to verify that our method is effective in minimizing decrease in wrist motion compared with methods described in previous reports, and to evaluate the clinical and radiological results.

MATERIALS AND METHODS

Patients Demographics

We retrospectively reviewed 12 wrists in ten patients (four men and six women) who were diagnosed with rheumatoid arthritis and who underwent radiolunate fusion between 1995 and 2004. Two patients had bilateral procedures yielding a total of 12 wrist operations. Synovectomy and Darrach procedure accompanied radiolunate fusion. Mean age at operation was 53 years old (range, 35–75). Mean follow-up period was 5.7 years (range, 2–11) and the minimum follow-up was 24 months. The indications for radiolunate fusion included: (1) moderate to severe pain resistant to conservative treatments; (2) ulnar translation; (3) mildly affected midcarpal joint; (4) patients with a high activity level; and (5) a modified Larsen's classification[14] of between stage 2 to 4a. The modified Larsen's classification is based on the findings from X-rays:

Stage 0; No radiological alteration.
Stage 1; Swelling of soft tissues. Demineralization.
Stage 2; Marginal erosions. Initial deviation of the wrist.
Stage 3; Articular erosions. Narrowing of joint lines. Mild instability.
Stage 4a; Midcarpal ankylosis. Major radiocarpal instability.
Stage 4b; Radiocarpal ankylosis.
Stage 5a; Destruction of the carpus. Radiocarpal dislocation.
Stage 5b; Destruction of the carpus. Complete ankylosis.

Clinical and Radiological Evaluations

For clinical evaluation, range of motion and grip strength were measured. The Stanley classification was also used:[8]

Excellent; — No rest or significant activity pain.
— No functional complaints.
Good; — Minor pain not affecting function.
— Daily functions improved.
Fair; — Minor pain not significantly affecting function.
— Functionally improved or same if operation for pain or prophylaxis.
— Fused in poor position but stable.
Poor; — Significant pain.
— Daily functions same or worse.
— Poor objective function.
— Fusion failed or suspect.

Radiographically, the modified Larsen's classification was used to evaluate the radioscaphoid joint, lunocapitate joint, and scaphotrapeziotrapezoid joint.[14] The carpal height ratio (CHR) was measured according to the method of Borisch *et al.*[11] A carpal height was divided by the length of the middle finger metacarpal. The ulnar translation (UT) was also calculated according to the definition of Borisch *et al.*[11] The distance between a line parallel to the axis of the radius passing through the radial styloid process and the centre of rotation of the capitate was also divided by the length of the middle finger metacarpal. Radiographs were taken pre-operatively, at one week post-operatively, eight weeks post-operatively, and at the final follow-up visit.

Operative Procedure

Operations were performed by the senior authors (A. Minami, N. Iwasaki and J. Ishikawa). A straight dorsal longitudinal incision was made, the superficial branch of the radial nerve and the dorsal branch of the ulnar nerve were identified and protected and the dorsal retinaculum was exposed. After the third, fourth, and fifth compartments were opened, synovectomy of the extensor tendons was performed. The extensor tendons were reflected and the dorsal capsule was exposed. We used primarily an H-shaped incision of the capsule and synovectomy

of the radiocarpal, midcarpal, and distal radioulnar joint was meticulously performed. The distal 1 to 1.5 cm of the ulna was cut and excised extra-periosteally using an oscillating saw, and corticocancellous bone was harvested. After the carpal bones were reduced anatomically into the lunate fossa, the proximal articular surface of the lunate, the opposite aspect of the radius, and lunate fossa were denuded and decorticated, and the cancellous bone was exposed. An approximately 5 to 10 mm height of corticocancellous bone was placed between the lunate and the radius with the wrist in the neutral position (Fig. 1).

After a K-wire was inserted through the triquetrum, the lunate, and the radius, a Herbert type screw (HBS, Kisco Medical Group, Osaka, Japan) or another K-wire was placed into the lunate, the grafted bone, and the radius (Fig. 2). In this way, the space between the scaphoid and the radius was widened and distraction was completed. The stabilization of the ulnar stump was performed with a half slip of extensor carpi ulnaris tendon using a method described previously.[15] The wrist was immobilised in a short arm splint or cast for six to eight weeks until union. The K-wire was removed after six weeks.

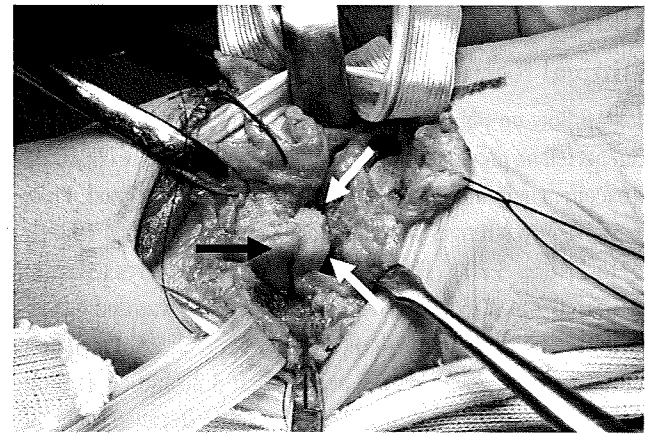
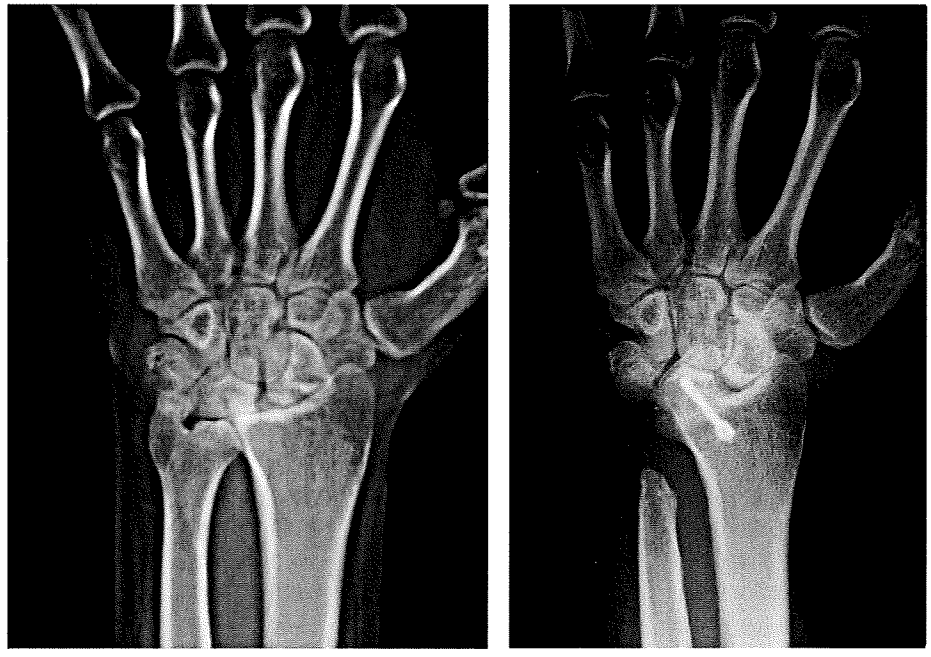


Fig. 1 Photograph during the operation. The white arrow indicates the corticocancellous bone harvested from the excised ulna. The black arrow indicates the radius near the lunate fossa.

Statistical Analysis

All data were represented as mean ± standard error. Pre- and post-operative results were compared using the paired t test. The level of significance was set at a probability value less than 0.05.



(A) **(B)**

Fig. 2 Radiographs of Case 1 using the Herbert type screw. **(A)** Pre-operative radiograph shows ulnar translation and a symptomatic radiocarpal and distal radioulnar joint. **(B)** Post-operative radiograph at the final follow-up shows that ulnar translation is reduced. UT is decreased from 0.353 to 0.300. The space between the scaphoid and the radius is slightly widened and distracted. CHR is increased from 0.490 to 0.517. Slightly arthritic changes occur at the lunocapitate joint and the scaphotrapeziotrapezoidal joint.

RESULTS

Clinical Results

Mean follow-up period was 5.7 years (range, 2–11 years). All patients felt no pain or only minor pain; six wrists were classified as excellent and the remaining six were estimated as good. Post-operative grip strength was significantly improved from 12.0 ± 1.9 to 17.8 ± 3.2 kg. Flexion was significantly decreased from 42.1° ± 6.2 to 27.5° ± 3.5, whereas extension was decreased, but not significantly, from 46.3° ± 4.0 to 40.0° ± 5.5. Pronation decreased from 77.5° ± 8.9 to 75.4° ± 3.2, and supination increased from 77.1° ± 7.3 to 80.8° ± 3.6. Because range of motion was dependent on the operative position itself, the total arc of flexion-extension was also evaluated; this value decreased from 88.4° to 67.5°.

No breakage of any screw or K-wire was seen in any of the ten patients. Furthermore, neither infection nor nerve injury were reported. One patient, who was being treated for bilateral radiolunate fusions, complained of bilateral ulnar wrist pain at the distal ulnar stump. Extensor carpi ulnaris and flexor carpi ulnaris tenodesis was carried out for bilateral unstable distal ulnas, as described by Breen and Jupiter.[16]

Radiological Results

Pre-operatively, using radiographs and the modified Larsen's classification, the disease involvement at the radioscaphoid joint, lunocapitate joint, and scaphotrapeziotrapezoid joint in all 12 wrists was classified as stage 2 in two wrists (17%), stage 3 in eight (67%), and stage 4a in two (17%). At the final follow-up, the classification was stage 2 in one wrist (8%), stage 3 in nine (75%), stage 4a in one (8%), and stage 5a in one (8%). Radiographs of Case 1 show slightly arthritic changes at the lunocapitate joint and the scaphotrapeziotrapezoidal joint, and the stage was classified between 2 and 3 (Fig. 2). Case 6 reveals collapse of the carpal bones, and is classified between stage 4a and 5a.

Figure 3 shows that CHR was increased and UT was significantly decreased. The increase in CHR means that the space between the scaphoid and the radius was widened and adequate distraction was obtained. The decrease in UT indicates that the ulnar translation was effectively reduced. Figure 4 shows that CHR was significantly increased at the post-operative week 1 and slightly decreased at week 8 for ten wrists. The CHR was not decreased until the final follow-up. These results suggest that the distraction between the radius and the scaphoid was maintained until the final follow-up.

DISCUSSION

While it cannot prevent consequent wrist destruction, synovectomy is a recommended procedure for the pain relief of rheumatoid wrists. The Darrach procedure (excision of the distal ulnar head) is a reliable operation that can achieve satisfactory pain relief and restoration of function for symptomatic distal radioulnar joint and rheumatoid arthritis; however, it causes ulnar translation of the entire carpal bones.[1]

Table 1 Case Series.

					Pre-Operation			Final Follow-Up			8 Weeks		Pre-Operation			Final Follow-Up			
Case	Age	Sex	Side	F-U (Yrs)	Larsen	CHR	UT	Larsen	CHR	UT	CHR	UT	Ext/Flex	Pro/Sup	GS	Stanley	Ext/Flex	Pro/Sup	GS
1	44	M	L	10.9	2	0.490	0.353	3	0.517	0.300	0.396	0.302	40/25	75/90	14	Excellent	60/40	90/90	25
	45	M	R	10.2	2	0.490	0.451	2	0.475	0.393	0.519	0.442	50/60	60/90	15	Excellent	60/40	45/70	35
2	51	F	R	2.8	3	0.447	0.316	3	0.483	0.310	—	—	35/35	65/75	6	Good	10/10	80/70	—
3	43	M	R	9.1	3	0.475	0.322	3	0.500	0.324	0.509	0.356	40/60	70/80	26	Excellent	25/25	80/90	33
4	58	M	L	7.3	3	0.508	0.347	3	0.393	0.262	—	—	55/70	80/80	5	Good	65/50	70/50	3.3
5	59	F	R	7.3	3	0.457	0.304	3	0.577	0.308	0.519	0.327	60/20	90/90	8	Excellent	20/20	80/90	7
6	74	M	R	5.7	3	0.569	0.400	3	0.619	0.349	0.563	0.375	50/60	80/70	16	Good	30/25	80/80	12
	75	M	L	4.8	4a	0.369	0.400	5a	0.369	0.415	0.524	0.413	20/45	90/90	10	Good	25/30	70/90	10
7	36	F	R	3.8	3	0.455	0.391	3	0.483	0.333	0.458	0.322	35/20	80/0	7	Excellent	55/30	80/80	24
8	56	F	R	2.1	3	0.435	0.331	3	0.436	0.290	0.444	0.302	60/30	80/80	18	Good	60/10	80/90	18
9	35	F	L	2.0	4a	0.344	0.377	4a	0.431	0.379	0.424	0.322	40/10	80/90	7	Good	30/20	80/90	12
10	62	F	R	2.0	3	0.459	0.328	3	0.492	0.279	0.548	0.274	70/70	80/90	6	Excellent	40/30	80/80	14

F-U: Follow-up period, CHR: carpal height ratio, UT: ulnar translation, GS: grip strength (kg).

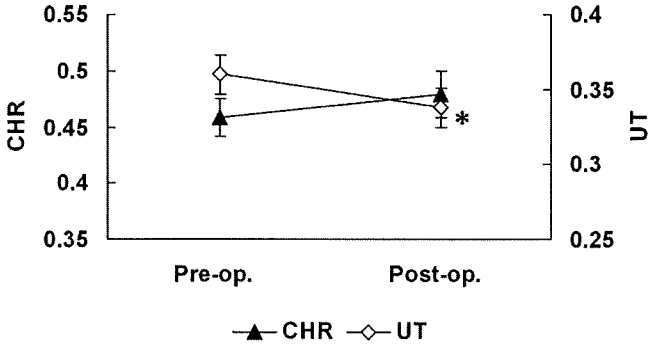


Fig. 3 CHR and UT pre-operatively and at the final follow-up. CHR is increased and UT is significantly decreased ($*p < 0.05$ vs. pre-operatively).

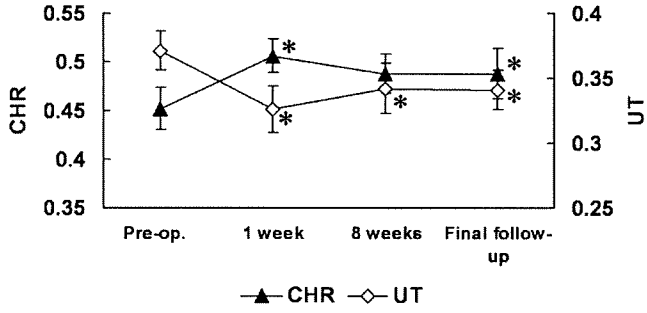


Fig. 4 CHR and UT of the ten wrists pre-operatively, at one week post-operative, eight weeks post-operative, and at the final follow-up. CHR is increased after operative procedures. After slight decrease, the heights are maintained. UT is also decreased and stable after a slight increase ($*p < 0.05$ vs. pre-operatively).

The Sauvé-Kapandji procedure, another candidate, can obtain a stable painless wrist and retain enough mobility for function.[17] This procedure is also reported that it got satisfactory clinical results and restrained the progression of ulnar translation by supporting the ulnar carpal bones.[1–3] Recently, however, Momohara *et al.* report that the ulnar deviation of the proximal carpal row cannot be completely controlled by the Sauvé-Kapandji procedure although it may stabilize the carpal bones of the rheumatoid wrist, maintain a functionally important range of motion, and relieve pain.[4] Kobayashi *et al.* also describe that there is no statistical difference between post-operative ulnar translation of the carpal bones after the Darrach procedure compared to after the Sauvé-Kapandji procedure.[5]

Chamay *et al.* was the first to report the radiolunate fusion procedure for the rheumatoid wrist.[6] Currently, radiolunate fusion has been applied for early- to medium-stage rheumatoid wrists and good clinical results have been reported.[8,10,18] Stanley and Boot reported the results of 16 wrists which underwent radiolunate fusion for rheumatoid wrists. The Stanley's classification revealed that 56.3% was estimated as Excellent, 18.8% as Good, 6.3% as Fair, and 18.8% as Poor, respectively. They also reported that pre-operative factors related to the fair or poor results were rapid disease, excessive pre-operative translocation, significant proximal row destruction (scaphoid involvement), bowstring of the extensor tendons, and severe stiffness.[8]

Of the 12 wrists in our study, we had six excellent and six good results. Grip strength was significantly improved from 12.0 to 17.8 kg ($p < 0.05$). Ishikawa *et al.* also reported significant improvement in grip strength, from 104 to 143 mmHg ($p < 0.05$)[12] despite complications including wound problems, fractures and displacements, malplacement of materials, and screw crossing or protruding into the midcarpal joint.[9,10] A complication rate as high as 8% has been reported with this procedure.[10]

One of the most undesirable aspects of radiolunate fusion is the resultant decrease in range of motion at the wrist joint. Borisch and Haussmann and and Ishikawa *et al.* reported that wrist motion was decreased, especially for flexion and radial deviation.[10,12] Because the range of extension and flexion is dependent on positioning at the time of surgery, we estimated the decrease in motion for our patients by percentage of total arc of flexion-extension. In the current report, total arc of flexion-extension was decreased from 88° to 68° (77%). However, this value is the highest of four reports and is therefore desirable (Table 2). Originally, Linscheid and Dobyns described 17 rheumatoid patients and five patients with traumatic arthritis.[7] We calculate the values of range of motion of only rheumatoid patients in this paper. Our results support the hypothesis that our modified method using corticocancellous bone graft can provide distraction and minimize post-operative decrease in wrist motion in rheumatoid patients.

Conversely, Meyerdierks *et al.* reported that radiolunate fusion caused a 47% decrease in flexion-extension in a cadaveric study using external fixators.[19] This discrepancy may be due to the midcarpal joint, which may compensate for the fused radiocarpal joint. In addition, the ligaments between the carpal bones are affected and weakened by rheumatoid arthritis. Meyerdierks *et al.* also reported that radioscapholunate fusion caused a 64% decrease in total arc of extension-flexion, whereas radiolunate fusion caused a 47% decrease.[19] Ishikawa *et al.* reported that, because radioscapholunate fusion caused a more severe decrease in range of motion, this method was avoided.[12]

Table 2 Range of Motion Pre-Operatively and at the Final Follow-Up About Previous Reports and the Current Report.

					Pre-Operation		Final Follow-Up		
	Year	*n*	Age	F-U (Yrs)	Ext/Flex	Arc‡	Ext/Flex	Arc‡	Percentage of Arc‡ (%)
Linscheid *et al.*§	1985	17	—	2.3	53/49	102	32*/36*	68	67
Borisch *et al.*	2002	42	53	5.0	35/39	74	28†/18†	46	62
Ishikawa *et al.*	2005	16	—	> 10	30/27	57	25/14*	39	68
Current Report	2009	12	53	5.7	46/42	88	40/28†	68	77

*$p < 0.01$ vs. pre-operation.

†$p < 0.05$ vs. pre-operation.

‡Arc = Ext + Flex.

§Linscheid *et al.*[7] is originally described about 17 patients of rheumatoid arthritis and five patients of traumatic arthritis. We calculated the values of only 17 rheumatoid arthritis patients based on the results in this paper.

F-U: Follow-up period.

Table 3 CHR and UT Pre-Operatively and at the Final Follow-Up About Previous and Current Reports.

					CHR		UT	
	Year	*n*	Age	F-U (Yrs)	Pre-Op.	Final Follow-Up	Pre-Op.	Final Follow-Up
Linscheid *et al.*¶	1985	17	—	2.3	0.47	0.47	0.343	0.314
Della Santa *et al.*	1995	16	62	4.8	0.47	0.43	0.330	0.320
Borisch *et al.*	2002	53/42‡	53	5.0	0.43	0.38*	0.320	0.300*
Ishikawa *et al.*	2005	16	—	> 10	0.49	0.46	0.180§	0.175§
Current Report	2009	12	53	5.7	0.46	0.48	0.360	0.338†

*$p < 0.01$ vs. pre-operation.

†$p < 0.05$ vs. pre-operation.

‡For CHR, $n = 53$; for UT, $n = 42$.

§In this paper, the numbers are not described. Therefore, these data are estimated from the graph of the paper.[12]

¶Linscheid *et al.*[7] is originally described about 17 patients of rheumatoid arthritis and five patients of traumatic arthritis. We calculated the values of only 17 rheumatoid arthritis patients based on the results in this paper.

F-U: Follow-up period, CHR: carpal height ratio, UT: ulnar translation.

Table 3 compares results regarding CHR and UT among various surgeons. CHR was decreased at the final follow-up in all except our study (where corticocancellous bone graft was adopted) and Linscheid's report.[7] This implies that the widening and distraction of the radiocarpal joint is preserved until the final follow-up, when the corticocancellous bone graft is placed between the radius and the lunate. Borisch *et al.* used the excised ulnar head to fill subchondral cysts,[10] and Ishikawa *et al.* packed bone chips from the resected ulnar head between the lunate fossa and the lunate.[12]

The Sauvé-Kapandji procedure is also an acceptable treatment for the rheumatoid wrist, especially for painful distal radioulnar joints. Momohara *et al.* showed that this procedure stabilized the carpal bones of the rheumatoid wrist, maintained a functionally important range of motion, and relieved pain, although it could neither stop the disease process nor re-establish or maintain carpal height.[4] They also reported that CHR was decreased and UT deteriorated (increased) using the Sauvé-Kapandji procedure, whereas CHR was not changed and UT was improved (decreased) using partial arthrodesis such as radiolunate fusion, and that the Sauvé-Kapandji procedure caused loss of flexion from a pre-operative 31° to post-operatively 23°.[4] This suggests that the Sauvé-Kapandji procedure cannot prevent ulnar translation of the carpal bones or preserve the carpal height. Another limitation of the Sauvé-Kapandji procedure is the potential for non-union. Rothwell *et al.* reported that the non-union rate of the Sauvé-Kapandji procedure was 32%,[20] while that of radiolunate fusion is reported to be 5% to 8%.[10,18,21] Fujita *et al.* speculated that this relatively high non-union rate could be secondary to the

difficulty in providing sufficient osseous support for the ulnar aspect of the radius in rheumatoid patients with erosion of the distal aspect of the ulna.[22]

The principal limitation of the present study is that it is a retrospective study based on a relatively small number of patients. Based on our results, a larger prospective study may be warranted in the future.

Radiolunate fusion is an acceptable procedure for the symptomatic rheumatoid wrist because pain is reduced and grip strength is improved. The clinical and radiological results are also satisfactory if these indications are followed: early- to medium-stage rheumatoid wrist, mildly affected midcarpal joint, no collapse of carpal bones, patients with high activity levels, and a modified Larsen's classification stage of between 2 and 4a. A previous considerable drawback of radiolunate fusion was the decrease in joint motion after operation. Although wrist extension, pronation, and supination are only slightly, if at all, affected, wrist flexion is significantly decreased. Because our modified procedure with distraction of radiocarpal joint using corticocancellous bone graft can minimize this decrease in range of motion at the wrist joint, it is recommended for the rheumatoid wrist.

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