Long-term Results After Repair and Augmentation Ligamentoplasty of Rotatory Subluxation of the Scaphoid

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Twenty-two patients had scapholunate ligament repairs combined with a new augmentation ligamentoplasty for chronic scapholunate dissociation. All were evaluated by physical and radiologic examination after a mean postoperative follow-up period of 63 months (range, 12–134 mo). According to Green and O'Brien and Johnson and Carrera scores 5/8 had excellent, 13/12 good, and 4/2 fair results. Thirteen were free of pain; 6 had mild pain and 3 had moderate pain. Nineteen returned to their original occupation. There was an average loss of 10° of flexion, 9° of extension, and 11% of grip force compared with the opposite wrist. Radiologic examination showed an average decrease of 12° of the scapholunate and 10° of the radiolunate angles compared with the levels before surgery. No signs of degenerative osteoarthritis were found in 16 (73%) cases. Five wrists showed a distinct pattern of midcarpal degeneration correlating with notable dorsal intercalated segment instability after surgery, and 2 cases had signs of radioscaphoid degeneration. (J Hand Surg 2002;27A:674–684. Copyright © 2002 by the American Society for Surgery of the Hand.)

Key words: Scapholunate dissociation, augmentation ligamentoplasty.

The importance of surgical treatment of scapholunate (SL) dissociation to reduce rotatory subluxation of the scaphoid has been well established.[1,2] Whether stabilization in longer-standing dissociations is achieved by arthrodesis[3–6] or ligament reconstruction is still debated. Until now there are only few reports about long-term results of SL ligament reconstructions.[1,7] Recently a tendency for anatomic reconstruction of the SL ligament has emerged[8,9] to obtain better functional results. The purpose of this study was to evaluate long-term results after repairs of chronic SL ligament dissociation combined with an augmentation ligamentoplasty in which the operative method is presented in detail. The procedure, in contrast to Blatt's capsulodesis,[2] was developed with the intention not to bridge the radiocarpal joint to allow better wrist motion. A similar procedure has been described by Slater et al.[10]

Materials and Methods

This study represents a retrospective follow-up analysis of 22 cases of surgically treated chronic dynamic (n = 7) or static (n = 15) SL instability at a single institution. Patients were included in the study and defined to have a chronic instability when clinical symptoms and signs were persistent or increased for at least 4 weeks or more after the trauma.

Diagnosis

The diagnosis of SL instability was based on conventional radiographs including standard neutral pos-

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teroanterior views, standard lateral views, and standard posteroanterior views in ulnar and radial deviation. An increase of the SL angle >70°, an increase of the SL gap ≥3 mm, an increase of the SL gap in forced radial deviation of the wrist,[11] and the "signet ring sign" of the scaphoid were assessed.[6,12] Dynamic instabilities were diagnosed by the presence of characteristic symptoms including dorsal wrist pain; clunking, clicking, and giving way during various activities; and a positive scaphoid shift test.[3,4,13,14] When the diagnosis was in doubt, a dynamic examination with an image intensifier was used. Abnormal movement of the scaphoid during ulnar and radial deviation and an increase of the SL gap during axial compression were used to diagnose SL dissociation. Arthrography was used to show a connection between the midcarpal and the radiocarpal joint as a sign of SL ligament disruption. The diagnosis and indication for surgery was based on conventional x-ray films in 5 cases; 12 cases had an additional arthrography and 5 had a dynamic examination with an image intensifier. Three cases had additional injuries: 1 intra-articular distal radius fracture (4 months before surgery), 1 nondisplaced fracture of the styloid process of the radius (4 weeks before surgery), and 1 nondisplaced scaphoid fracture (9 weeks before surgery). Eleven patients with isolated SL dissociation and the one with the scaphoid fracture had arthroscopy immediately before the SL ligament reconstruction was performed.

Patients

Between 1989 and 1999, 22 patients were treated for chronic symptomatic scapholunate dissociation. Surgical intervention was indicated when clinical symptoms like pain, clunking, weakness, and giving way were persistent or increased for 4 weeks or more and when SL dissociation was diagnosed radiologically. Nineteen patients were men. The dominant wrist was involved in 13 cases. All patients recalled a preceding injury. Five reported a high-velocity accident (1 motorcycle, 3 bicycle, 1 downhill skiing accident), 6 had a fall from a height >2 m, 5 had a simple fall, 3 had a punch injury (compression injury of the wrist), and 2 reported a distraction trauma of the wrist. Average age at the operation was 46 years (range, 29–68 y). Average time between injury and surgery was 6 months (range, 4 weeks–35 months). At the time of injury 3 patients were employed doing heavy manual labor (1 metal worker, 1 stone mason, 1 farmer), 7 did moderate manual labor (5 mechanic/technician, 1 nurse, 1 cleaner), 5 did light labor (1 housewife, 2 electrician, 1 teacher, 1 dialysis nurse), and 7 were administrators.

Operative Procedure

All surgeries, except 1, were performed by a single surgeon (R.S.). A dorsal approach through the third dorsal tendon sheath was used. The dorsal articular capsule was opened, creating a transverse ulnar pedicle flap over the proximal carpal row. This flap was used to close the capsule after the ligamentoplasty. In 19 cases the SL ligament was torn at its insertion on the scaphoid and in 3 cases at the lunate. The ligament could be well exposed and was almost always sufficiently present for reinsertion. A K-wire was inserted into the lunate and was used like a joystick to bring the lunate from an extended to a neutral position. Before definitive reduction was achieved three to four 1.5-mm bore holes were made into the dorsal proximal pole of the scaphoid (or lunate; in the 3 cases that had disruption of the SL ligament from the lunate) at which the functional important part of the ligament was detached (Fig. 1). The remaining part of the SL ligament was sutured with a Goretex CV4 thread (Provas AG, Dübendorf, Switzerland). The sutures were pulled through the holes but not yet tied. After the scaphoid was brought into neutral position by applying a dorsally directed force to its tubercle from the volar side, it was transfixed to the lunate by a K-wire (Fig. 2). A second K-wire was then either drilled through the scaphoid into the capitate or through the capitate into the lunate. After correct reduction is achieved the sutures are tied. One patient had an external fixator (Hoffmann; Howmedica Inc, New York, NY) bridging the scaphoid and the lunate dorsally as temporary fixation; however, this method was used only once because of a following pin-track infection.

The idea of an augmentation ligamentoplasty at the proximal part of the scaphoid emerged because of the observation that the scaphoid was often subluxated in a way that its proximal pole was shifted dorsally, protruding between the dorsal intercarpal and radiocarpal ligament like in a button-hole deformity. The intention of surgery was to bring the proximal pole of the scaphoid back into anatomic position and reinforce the functionally most important dorsal distal part of the SL ligament.[15,16] Therefore, an ulnar pedicle flap was created from the proximal thicker part of the dorsal intercarpal ligament[17] conserving the fibers originating from the lunate. The radial pole of this flap was then shifted proximally to the proximal dorsal pole of the scaphoid and the flap was fixed by either a transosseous

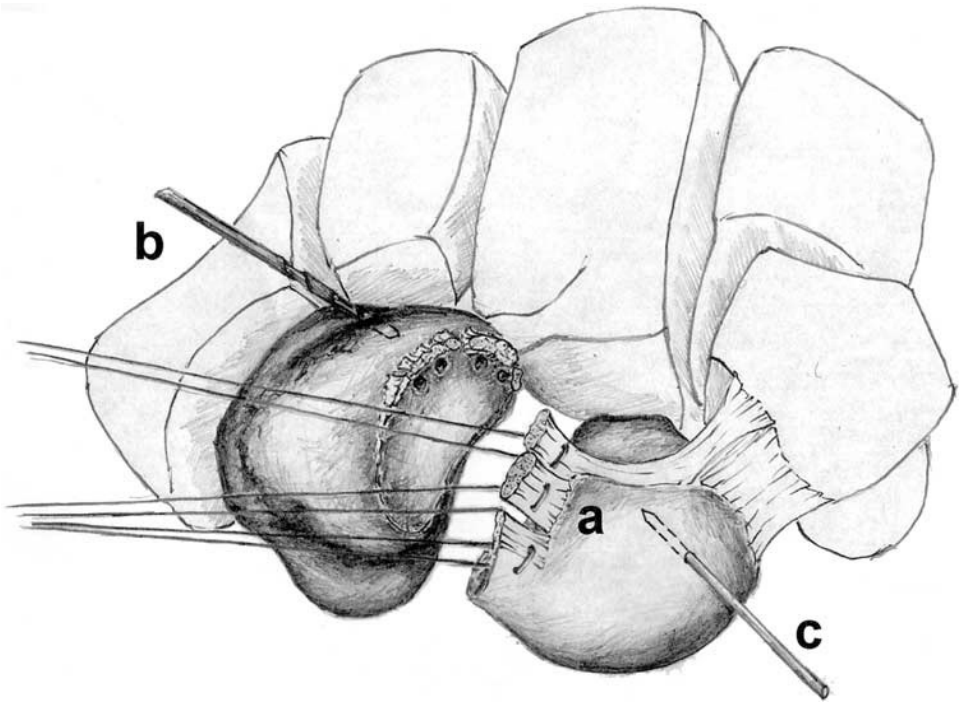

Figure 1. Surgical site; (a) the remaining most important dorsal distal part of the SL ligament is held with sutures; (b) drill holes are made in the proximal scaphoid; (c) a K-wire is inserted in the lunate and used to lever it back to the anatomic position.

suture or a 1.3-mm AO titanium screw into a ridge at the proximal dorsal aspect of the scaphoid (Fig. 3), which was made beforehand. The fibers of the flap were then running in the same direction as the original SL ligament, acting mechanically as a reinforcement of this ligament.

Postoperative treatment consisted of a short-arm thumb spica splint (wrist in 0° to 10° flexion). Flexion and extension movements of the fingers without load were encouraged immediately. Skin sutures were removed 2 weeks after surgery. From the seventh week on, the splint was removed during therapy to allow active flexion-extension movements under control of a hand therapist. Until the K-wires were removed 10 weeks after surgery no ulnar or radial deviation was allowed. Mobilization of flexion and extension was performed further under control of a hand therapist. In the first 3 months patients were advised not to force grip strength and radial or ulnar deviation because these movements unnecessarily stress the SL ligament suture and ligamentoplasty. After 6 months patients were encouraged to return to all activities.

Follow-up Evaluation

All patients were interviewed and examined by a single physician (the clinical examiner was not involved with the surgery). Radiographs were evaluated independently by the surgeon and the clinical examiner. The average postoperative follow-up period was 63 months (range, 12–134 mo; 7 cases were between 134 and 108 months, 7 cases between 107 and 24 months, and 8 cases between 23 and 12 months).

Subjective evaluation included questions about symptoms, working and sports activity level, and restrictions and satisfaction with the operation according to the score of Johnson and Carrera[18] and the modified score from Green and O'Brien[19] described by Glickel and Millender.[7] The questions included (1) pain: none, occasional mild but no interference with activity, moderate pain severe enough to decrease physical activity, severe pain or rest pain; (2) occupation and working activities: unimpaired, moderate impairment, significant difficulty or impairment, activity or occupation had to be changed; (3) sports and strenuous activities: unlimited, all activities but moderate limitations, significant limitations and cannot participate in all activities, severe limitations, participates at low level or not at all; and (4) overall satisfaction with the result of the operation: excellent, good, fair, poor, failure.

Clinical evaluation included palpation for painful areas, scaphoid shift test, range of motion of the wrist

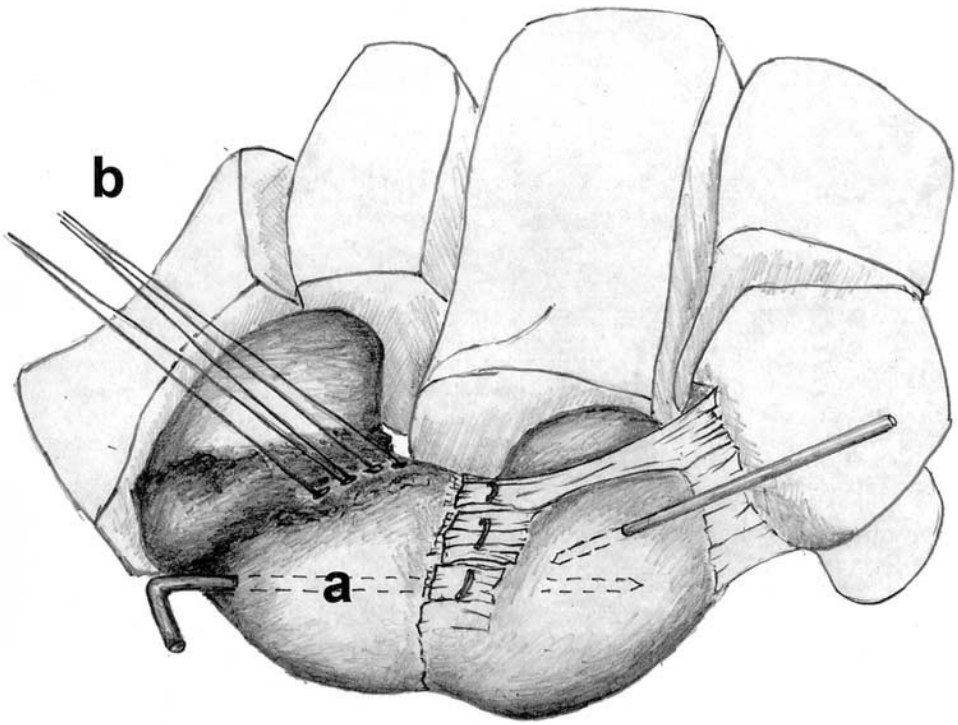

Figure 2. Surgical reduction of the scaphoid is achieved by pushing it dorsally against its distal volar pole; (a) insertion of a scapholunate and a scaphocapitate (not drawn) K-wire for temporary arthrodesis; (b) tying of the SL ligament suture.

(extension, flexion, radial and ulnar deviation, prosupination), power grip strength (Jamar dynamometer; J.A. Preston Corp, Jackson MI), and pinch and key pinch strength (Pinch gauge; B&L Engineering, Santa Fe Springs, CA). Both wrists in all patients were examined.

Radiologic evaluation of the wrist was performed at the time of the physical examination (standard posteroanterior, standard lateral, posteroanterior views in ulnar and radial deviation). Final follow-up x-rays were compared with preoperative and postoperative x-rays. The SL angle, radiolunate angle, capitolunate angle, and SL gap were evaluated using a computer-assisted device (digitalized radiographs, measurement of angles with a protractor on a personal computer). Radiographs were evaluated further in detail for degenerative changes.

Data Analysis

Statistical analysis of comparing means of preoperative and postoperative radiologic and clinical parametric data of the operated and the nonoperated wrist and subgroup analysis was performed by the Student's *t*-test. Comparison of nonparametric data of the operated and nonoperated wrist and subgroup analysis was evaluated by the Mann-Whitney U test (independent groups) and the Wilcoxon signed rank test (dependent groups). A chi-square test was used for nominal measures. p values were 2 tailed and were considered to be significant if $<.05$. Quantitative variables were written as means and standard deviations.

Results

Subjective Findings

Patients' subjective ratings of pain were as follows: 13 reported no pain, clicking, or aching, and 6 had occasional mild symptoms like dorsal wrist pain after or during strenuous activities but without limitation of their working ability or daily activities. Three patients had moderate pain with certain functional limitations. No patient reported notable or severe pain.

Occupation and working activities: 16 patients were unimpaired, 3 had moderate impairment, and 3 had to change their activity to lighter work (1 mechanic became a computer technician, 1 gardener became a technician, 1 stone mason reduced working time to 50%).

Sports and strenuous activities: 15 patients returned to their original sport (5 bicycling, 2 hobby gardener, 2 horse riding, 2 swimming, 2 skiing, 1

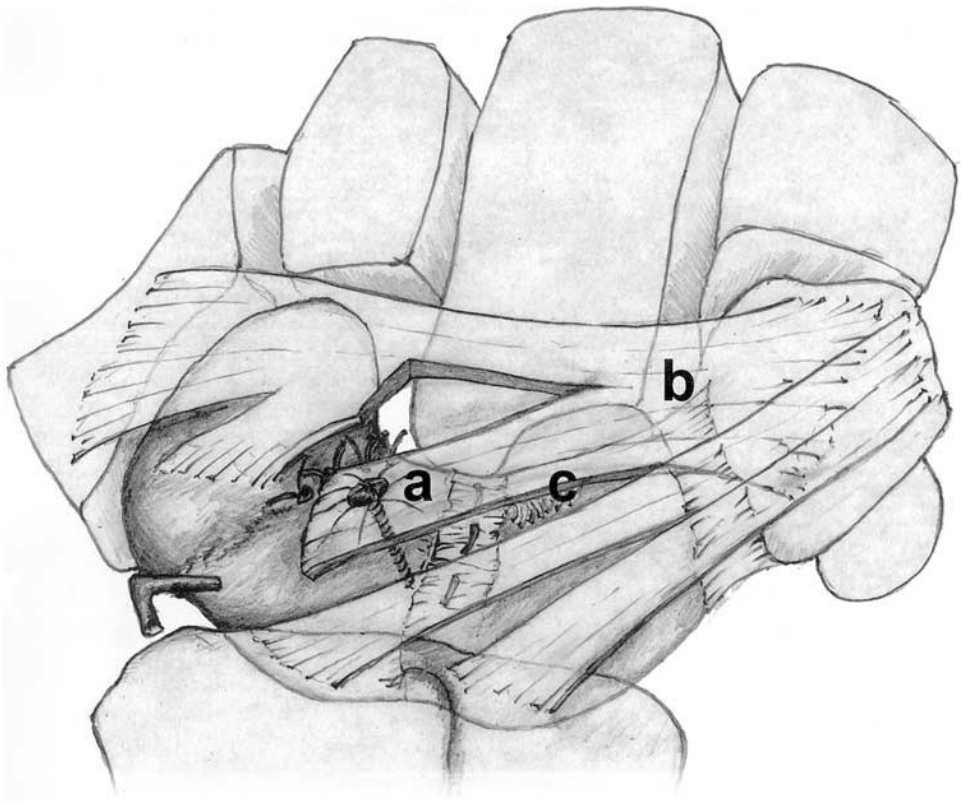

Figure 3. Augmentation ligamentoplasty; (a) an ulnar pedicle flap from the proximal half of the (b) dorsal intercarpal ligament is prepared and shifted over the proximal dorsal pole of the scaphoid and fixed to it by a 1.3-mm AO screw and/or a transosseous suture. (c) Fibers originating from the lunate are preserved.

karate at high level, 1 volleyball). Six patients did not perform sports but had no limitations in their daily living. One patient had marked limitations and therefore did not return to his recreational bicycling.

Overall satisfaction with the results: Fourteen patients rated their overall satisfaction as excellent, 7 as good, and 1 as poor.

Clinical Findings

On palpation 15 wrists were free of pain, 3 had mild pain, and 2 had moderate discomfort over the dorsal radiocarpal aspect of the wrist and 2 over the ulnocarpal area. The scaphoid shift test was negative in all patients. Average loss of range of motion of the operated compared with the nonoperated wrist was 9° extension and 10° flexion, 3° radial deviation, 6° ulnar deviation, 3° supination, and none for pronation (Table 1). Differences of pronation and supination were not statistically different. Average loss of grip strength of the operated compared with the nonoperated wrist was 5 kg (11%), loss of key pinch strength was 0.5 kg (4.7%), and loss of pinch strength was 0.4 kg (4.3%), with the last 2 values being statistically not different. There was no loss of sensibility, and all patients had full finger motion.

Radiologic Findings

Evaluation of preoperative, postoperative, and latest x-rays showed an average decrease of the SL angle of 19° postoperatively (65° to 45°) and of 12° (65° to 53°) at final follow-up. The average radiolunate angle decreased postoperatively by 10° (16° to 6°), which remained at final follow-up (6°). The average SL gap decreased postoperatively by 0.9 mm (3.2–2.3 mm) and in the final x-rays by 0.7 mm (3.2–2.5 mm). All differences were statistically significant (Table 2). Two preoperative radiographs were not evaluated because of incorrect exposure, and 1 radiograph was no longer available.

Degenerative changes were apparent in 6 cases, whereas 16 cases had none (Figs. 4, 5). Two had sclerosis and minimal decrease of the joint space between the radius and the scaphoid. Five cases had a specific pattern of degenerative changes between

Table 1. Clinical Evaluation of Range of Motion and Strength Expressed as Mean (SD) and p Values

	Operated Side	*Nonoperated Side*	*Difference*	*p Value*
Extension (°)	50 (13.8)	59 (10.1)	9	.01
Flexion (°)	48 (12.8)	58 (9.8)	10	.02
Radial deviation (°)	20 (10.5)	23 (12.7)	13	.21
Ulnar deviation (°)	34 (7.8)	39 (7.1)	5	.06
Pronation (°)	85 (2.2)	85 (2.1)	0	.71
Supination (°)	86 (2.8)	87 (2.5)	1	.37
Hand grip strength (kg)	43 (12.1)	49 (14.4)	6	.31
Key grip strength (kg)	10.4 (2.4)	11 (2.6)	0.6	.71
Pinch grip strength (kg)	7.8 (2.3)	8.2 (2.1)	0.4	.94

the capitate and the lunate but with a normal radioscaphoid joint (Fig. 6): 4 had only slight joint space narrowing, but 1 had complete capitolunate and capitoscaphoid joint space loss, whereas the radioscaphoid joint showed only slight degeneration.

Subgroup Analysis

To evaluate long-term results all patients were divided in 2 groups according to postoperative interval (group 1: 11 cases between 134 and 44 months; group 2: 11 cases between 34 and 12 months) and were compared with each other. There were no statistically significant differences (except better radial deviation in group 1 [26°, SD 9°] compared with group 2, [14°, SD 6°, $p < .01$]) in the 2 groups concerning symptoms, pain, activity level, working-capacity restriction, subjective evaluation, grip strength, and range of motion. The 2 groups did not differ concerning degenerative changes, radiologic angles, and the SL gap.

Patients with degenerative changes at follow-up x-ray evaluation (6 cases) had a significantly ($p = .027$) higher SL angle (52°, SD 6°) postoperatively compared with patients without degenerative changes (16 cases: 43°, SD 9°). At the time of the latest follow-up evaluation the difference in the SL angle between degenerative and nondegenerative wrists was still apparent (with degenerative signs: 61°, SD 9°; without degenerative signs: 50°, SD 10°; $p = .035$). In patients with degenerative signs an increase in the SL gap occurred between the postoperative and the late follow-up x-ray (increase of 0.9 mm, SD 0.5 mm, $p < .01$), whereas it remained the same in patients without degenerative changes. There was no difference concerning subjective or objective outcome (except in grip strength; degenerative: 32 kg, SD 10 kg; nondegenerative: 47 kg, SD 9 kg, $p < .01$). There were no differences of clinical and radiologic outcome for different time intervals between trauma and surgery (9 cases: 4–35 months, average, 12 months; 13 cases: 4 weeks to 4 months, average, 6 weeks). The subgroup analysis consisted of only 6 to 13 cases for each group and therefore did not have strong statistical power.

Scoring

The clinical results according to the Green and O'Brien[19] score were excellent in 5 (23%), good in 13 (59%), and fair in 4 (18%) cases. Results according to Johnson and Carrera[18] score were excellent in 8 (36%), good in 12 (55%) and fair in 2 (9%) cases.

Table 2. Radiologic Evaluation of Angles and Gap Expressed as Mean (SD) and p Values

	Preoperative	*Postoperative*	*Follow-up*	*Difference*	*p Value*
SL angle (°)	65 (12.6)	45 (9.2)		20	<.001
	65 (12.6)		53 (11.3)	12	<.001
RL angle (°)	16 (11.7)	6.1 (6.9)		9.9	<.001
	16 (11.7)		6.2 (11)	9.8	<.001
CL angle (°)	9 (11.4)	−5 (7.1)		−14	<.001
	9 (11.4)		1 (9)	−8	<.001
SL gap (mm)	3.2 (1.2)	2.3 (0.6)		0.9	<.001
	3.2 (1.2)		2.5 (0.8)	0.7	<.001

Differences of values are from preoperative to postoperative and from preoperative to follow-up radiographs.
RL, radiolunate; CL, capitolunate.

Figure 4. Radiographs showing a wrist with dynamic SL dissociation (A) preoperatively and (B) 11 years after SL repair and augmentation ligamentoplasty, which was performed 5 months after trauma. The patient is pain free and has full function.

Complications

After repair of the SL ligament complication resulted in the 1 patient who had an SL external fixator for temporary fixation and developed a pin-track infection 6 weeks after surgery that resolved completely after pin removal.

Discussion

Scapholunate dissociation is the most common instability pattern of the wrist and can lead, if untreated, to degenerative arthritis of the radiocarpal and later of the midcarpal joint.[4,11,20–23] The pattern of degeneration can be explained by the different

Figure 5. Radiographs showing a wrist with static SL dissociation (A) preoperatively and (B) 10 years after SL repair and augmentation ligamentoplasty, which was performed 3 months after trauma. The patient is pain free and has full function. Black lines represent the SL angle.

nonspherical surfaces of the concerned joints.[4,24–27] Therefore different classifications and indications for correction of carpal instability are reported,[6,19] and different modes of repair and/or reconstruction of the SL ligament were described.[2–6,28–32] Ligament repair was originally reserved for acute injuries because of its unsatisfactory[33] or inconsistent results in chronic instabilities. Recently repair of chronic SL

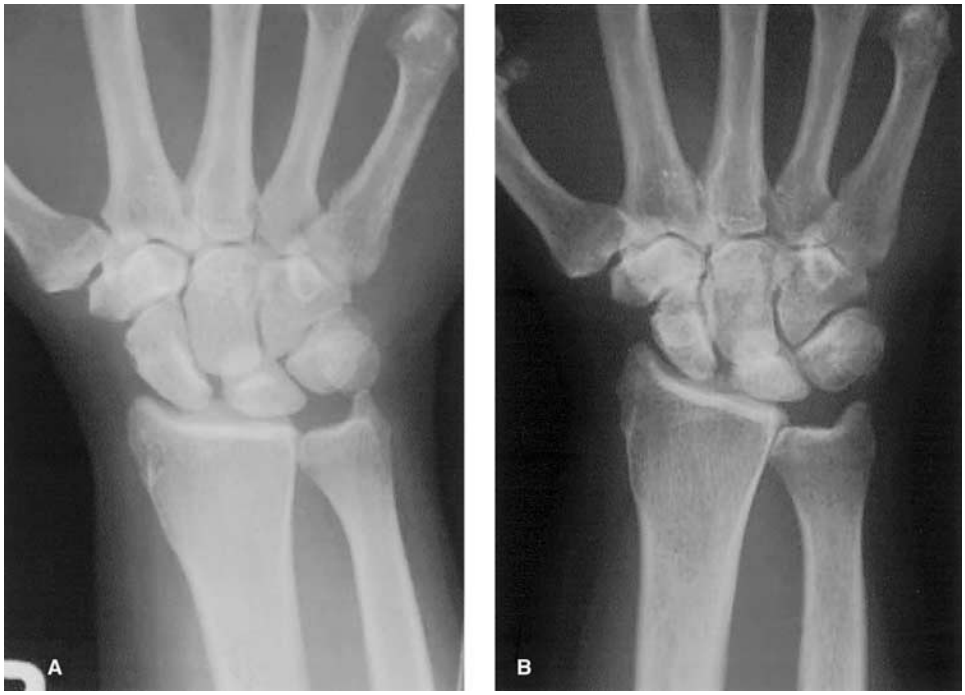

Figure 6. Radiographs showing the wrist (A) preoperatively and (B) 5 years after SL repair and augmentation ligamentoplasty, which was performed 2 months after trauma. The distinct pattern of isolated midcarpal degeneration is apparent; the patient has slight restriction with pain during heavy work.

dissociations without degenerative changes has begun to be reported[7,8,34] as well as replacement of the ligament by autograft.[35,36]

Biomechanical investigations report the SL ligament to be one of the strongest ligaments in the wrist having a failure load from 232 to 360 N.[35,37–39] If this ligament is ruptured, the 2 carpal rows may destabilize and a dorsiflexed intercalated segment instability[11] deformity develops as the scaphoid is rotated and flexed by compressing forces[40] across the wrist around the radiocapitate ligament. The lunate, however, because of its sagittal wedge shape and by the compressing force of the capitate, plus its intact ulnar ligaments, is forced in an extended position.[15,16,41] To re-establish normal wrist kinematics, the ligament has to be reconstructed as nearly anatomically as possible. The most important part of the segment is the $7 \times 7 \times 3$ mm[36,42] large dorsal distal portion.[15,16] The aim of the augmentation ligamentoplasty is to reinforce this structure to keep the proximal pole of the scaphoid in anatomic position. Our procedure does not disturb the movement of the proximal carpal row during flexion and radial deviation, which is the main advantage compared with other procedures[2,31,43,44] in which the movement of the radiocarpal joint is limited by a joint-bridging ligament reconstruction.

Another technique that includes the dorsal intercarpal ligament for SL reinforcement was described earlier by Slater et al.[10] We inserted the ligament into the proximal rather than into the distal part of the scaphoid directly over and along the original SL ligament to fix the poximal pole of the scaphoid.

Clinical outcomes of various SL ligament repair techniques show large variations. Some investigators[8,9,34] report good results, whereas others reported unsatisfactory results.[29,45] Good clinical outcomes despite unsatisfactory postoperative radiologic findings were reported by others.[7,30,46,47] Our clinical results were excellent and good according to the Green and O'Brean score in 89% and according to the Johnson and Carrera score in 94%. Nineteen patients (86%) returned to their original occupation. In contrast to others[46] the SL gap and SL angle were reduced significantly by this procedure. Average range of motion compared with the noninvolved wrist was 84%, which is similar compared with the results of Lavernia et al[8] (88%) and Saffar et al[45] (82%) and better than the results of Deshmukh et al[46] (60%), Wyrick et al[29] (60%), and Bickert et al[9]

(78%). The whole range of motion of the wrist (extension-flexion) was 109° and is similar compared with the results of Van Den Abbeele et al[30] (110°) and Glickel and Millender[7] (115°) but not as good as the results of Wintman et al[34] (128°).

A notable improvement of the SL angle and gap was achieved from the preoperative to the latest radiographs. The SL angle and gap increased after the removal of the K-wires, but lengthening of the ligamentoplasty may also play a role.

Five wrists (23%) showed a distinct pattern of only midcarpal (capitolunate) joint-space narrowing (Fig. 6), which has been described also by Glickel and Millender.[7] Only 2 patients (9%) had a radiocarpal joint-space narrowing. Degenerative radiologic signs were not influenced by the time between trauma and surgery or the time passed after surgery. The procedure described in this study changed the usual pattern of degeneration of the wrist,[20,24,27] which usually started at the radioscaphoid joint and was followed by degeneration of the capitolunate joint. We hypothesize that the pattern of degeneration observed in this study is related to the lunate, which often remains in slight dorsiflexion. A persisting incongruency in the capitolunate joint may lead to an increased incidence of observed degeneration.

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