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Long-term Results of the Treatment of Scapholunate Instability with Dynamic Extensor Carpi Radialis Brevis Tenodesis

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Background: Scapholunate dissociation is the most common form of carpal instability. This retrospective case series aimed to assess long-term results obtained by treating scapholunate instability with dynamic tenodesis using the entire extensor carpi radialis brevis tendon, which is detached from the base of the third metacarpal, rerouted in the third extensor compartment, and fixed at the distal portion of the scaphoid to maintain reduced rotatory subluxation.

Methods: Nine patients with scapholunate instability were treated. We reviewed eight patients with a mean follow-up of 12 years. One subgroup of four patients was affected by static scapholunate instability, and the other by dynamic scapholunate instability. Disability of the Arm, Shoulder, and Hand score, Patient Rated Wrist Evaluation score, modified Mayo score, and radiographs were used to determine functional and anatomical outcomes.

Results: Excellent functional results did not correlate with radiological outcome in patients with static scapholunate instability. In this subgroup, scapholunate angle and gap and radiolunate angle improved in average but remained in the pathologic range. In only one of these patients, osteoarthritis was observed. In the subgroup of patients affected by dynamic instability, very good functional outcomes correlate with radiological results, except in one patient who developed arthritic changes.

Conclusions: Dynamic tethering of the scaphoid with the extensor carpi radialis brevis tendon might be indicated in the treatment not only in patients affected by dynamic scapholunate instability but also in patients with static instability. Prospective studies with a larger number of patients are required to evaluate this method.
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INTRODUCTION

Scapholunate (SL) dissociation is the most common form of carpal instability. Most authors agree that ligament reconstruction techniques may be indicated in cases of chronic dynamic and static SL instability, where the SL ligament is not repairable but the carpal malalignment is easily reducible and the cartilage is acceptably normal, which corresponds to stage 3 and 4 in the classification published by Garcia-Elias.[1–3] Tenodesis techniques aim to correct rotatory subluxation of the scaphoid, scapholunate diastasis, and dorsal intercalated scaphoid instability. Pedicled or free tendon grafts have been used to obtain a static stabilization of the scapholunate complex, with the goal being to reduce pain, achieve a maximum of motion, and prevent carpal collapse and osteoarthritic joint disease. Static tenodesis techniques mostly reduce wrist flexion.[2,4–7] In an attempt to overcome this problem, dynamic tenodesis techniques were developed.[8–12] In the present study, we present our experiences with the dynamic tenodesis technique described by Francesco Brunelli, son of Giorgio Brunelli.[9] In this technique, the entire extensor carpi radialis brevis (ECRB) tendon is detached from the base of the third metacarpal, rerouted in the third extensor compartment, and fixed at the distal portion of

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the scaphoid to maintain a reduced rotatory subluxation of the scaphoid (Fig. 1). The uplifting moment of the ECRB tendon along the long axis of the scaphoid allows for narrowing of the SL gap without formal repair of SL ligament. The aim of our study was to examine the long-term results of this technique.

PATIENTS AND METHODS

In this retrospective study between 2005 and 2014 nine patients with SL instability underwent the dynamic tenodesis procedure. Patients with irreducible SL instability and/or arthritis were excluded from this study. Written consent was obtained from all individuals before surgery. All patients complained of wrist pain and weakness before surgery. Other clinical data were not available. The local ethics committee approved this study.

The mean period from the injury to surgical treatment was 11 months (range: 3–36). Before surgery, posteroanterior, lateral, and clinched fist radiographs were performed. At final follow-up, the clinched fist views were substituted by pencil views. An occupational therapist (E.V.) reviewed eight patients with a mean follow-up of 12 years (range: 5–14) in our clinic. One patient could not be reviewed because he moved elsewhere and could not come to our clinic for follow-up. Range of motion; grip strength; functional outcomes according to the Mayo wrist score[13] modified by Krimmer[14]; the average Disability of the Arm, Shoulder, and Hand score (DASH)[15]; and the Patient Rated Wrist Evaluation (PRWE)[16] were assessed. The first author and a radiologist performed radiological assessment. The first cases we treated with this procedure were affected by static SL instability, and we obtained encouraging clinical results. For this reason, we also started to treat patients with dynamic SL instability. Finally, four of our patients were affected by dynamic SL instability and four by static instability according to the classification of Kuo and Wolfe.[17] There was no case of ulnar translocation of the lunate (Taleisnik type II[18]). Because of the limited number of patients, no statistical methods were applied.

Takeaways

Question: How are the long-term results in the treatment of scapholunate (SL) instability using this procedure?

Findings: This retrospective study shows excellent and good functional results in all eight patients reviewed after a mean of 12 years. Four patients were affected by dynamic SL instability and four by static SL instability. Radiological findings showed osteoarthritis in two cases.

Meaning: The extensor carpi radialis brevis tenodesis might be a less invasive method to treat dynamic and static SL instability. Larger prospective studies may be confirmatory.

The mean age of the patients was 44 years (range: 29–65) at surgery. In four patients, the trauma occurred during sports activities, and in one patient, during professional activities. In two cases, the trauma was caused by accidental fall, and in another case by a traffic accident. In one patient, SL dissociation was associated with a distal intraarticular radius fracture. The radius fracture was treated by open reduction and internal fixation. The ruptured SL ligament was repaired, and the SL joint was transfixed with pins for 6 weeks. The fracture healed uneventfully, but painful SL dissociation developed after pin removal (case 6).

Surgical Technique (Fig. 2)

A longitudinal skin incision was centered over Lister's tubercle. The dorsal sensory branches of the radial and ulnar nerves were identified and protected. The extensor retinaculum was divided along the third compartment, and the extensor pollicis longus tendon was retracted radially. The approach to the wrist capsule was performed between the third and fourth extensor compartment, retracting the retinacular flaps. The interosseus posterior

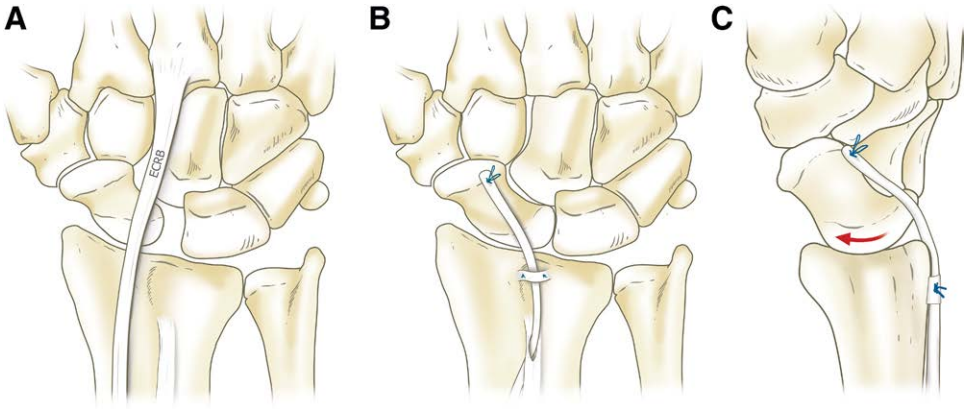

Fig. 1. Concept of ECRB tenodesis. A, Schematic illustration of scapholunate dissociation with the ECRB in situ. B, Reduction of the scapholunate dissociation. The detached ECRB tendon is passed into the third extensor compartment through the perforated fibrous septum and fixed at the distal pole of the scaphoid with a bone anchor. C, The lateral projection shows the reduction moment of the ECRB tendon to the scaphoid.

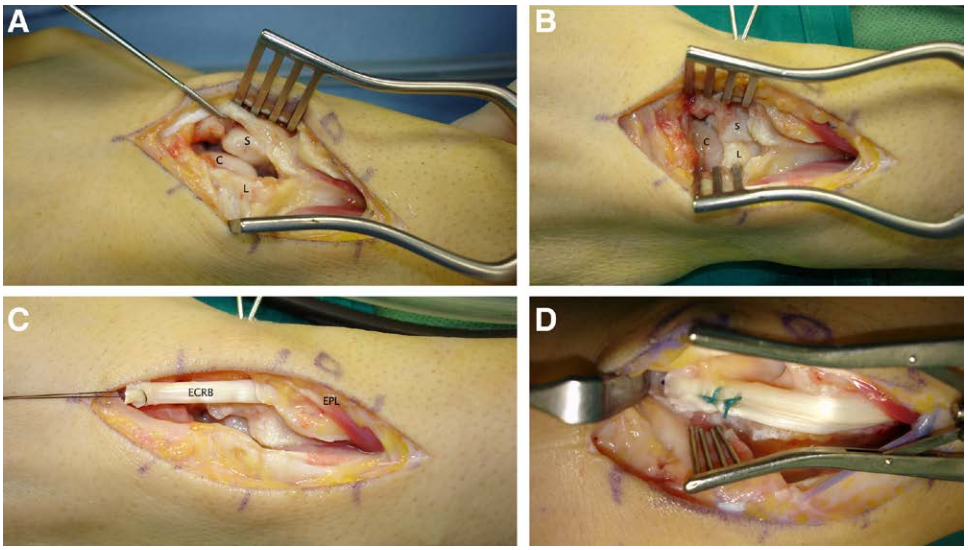

Fig. 2. Surgical technique. A, Case of chronic static scapholunate dissociation with no remnants of the scapholunate ligament. S, scaphoid; L, lunate; C, capitate. B, Anatomic reduction of the scapholunate gap and percutaneous pinning. S, scaphoid; L, lunate; C, capitate. C, Detachment of the ECRB tendon. ECRB, Extensor carpi radialis; EPL, Extensor pollicis longus. D, The ECRB tendon has been passed from the second into the third extensor compartment through the perforated fibrous septum proximal to the Lister tubercle, shortened, and fixed to the scaphoid by two bone anchors.

nerve was identified and resected. A V-shaped capsulotomy according to Berger and Bishop[19] was performed, and the SL space identified. The SL dissociation was reduced using two 1.2-mm K-wires as joysticks. The reduction was stabilized in six cases with two K-wires across the scaphocapitate and scapholunate joints under fluoroscopic control. In two cases, no stabilization with pins was performed because the reduction procedure succeeded with a minimum of effort. The ECRB tendon was detached from the base of the third metacarpal. To align the tendon along the axis of the scaphoid, the fibrous septum proximal from Lister's tubercle was perforated to create a new pulley, where the tendon was passed through from the second to the third extensor compartment. The distal dorsal portion of the scaphoid was roughened with a rongeur. The ECRB tendon was shortened by 10 mm to increase tension and fixed there with one or two bone anchors (GII Depuy Synthes, Leeds, UK). The capsule was closed, and the extensor retinaculum reconstructed, leaving the EPL tendon subcutaneously. After closure, a short thumb spica cast in neutral position of the wrist was maintained for 6 weeks. At this time, K-wires were removed and active assisted motion exercises were started. Patients were not allowed to return to sports activities or heavy work for 3 months after the operation.

RESULTS

Eight of nine patients were evaluated at an average follow-up period of 12 years (range: 5–14) (Table 1). Five patients were pain free, two patients had mild occasional pain, and one patient had moderate pain.

The functional outcome according to the Mayo wrist score[13] modified by Krimmer[14] was excellent in seven patients and good in one patient; it averaged 88 of 100 points (range: 75–98). At final follow-up, average extension-flexion was 82% (range: 62–91), and grip strength was 83% (range: 67–93) of the uninjured controlateral extremity. The average DASH[15] score was 5.4 on a scale of 100 (range: 1–24). The PRWE[16] score averaged

Table 1. Patient Data (Postoperative)

Patient	Age (y)	Injured Side	Follow-up Time (y)	Time from Injury (mo)	Extension Flexion Right (degrees)	Extension Flexion Left (degrees)	Radial-Ulnar Dev. Right (degrees)	Radial-Ulnar Dev. Left (degrees)
1	62	Right	12	7	55-0-32	75-0-65	10-0-20	10-0-30
2	33	Left	5	11	90-0-80	72-0-62	22-0-30	15-0-30
3	36	Left	12	3	75-0-80	50-0-70	20-0-24	20-0-18
4	43	Left	13	14	60-0-72	55-0-65	25-0-25	20-0-25
5	45	Left	12	5	68-0-55	60-0-50	20-0-25	20-0-30
6	65	Left	13	6	60-0-70	60-0-55	10-0-25	18-0-22
7	35	Left	14	6	80-0-70	70-0-60	22-0-32	12-0-22
8	29	Right	13	36	65-0-40	80-0-55	12-0-20	25-0-30

Dev., deviation.

Table 2. Additional Patient Data (Postoperative)

Patient	Type of SL Instability	Injured Side	Grip Strength Right (kg)	Grip Strength Left (kg)	Grip Strength (%)	Modified Mayo Score	DASH Score	PRWE Score
1	Dynamic	Right	24	26	92	75	24	29
2	Dynamic	Left	36	28	78	88	1	4.5
3	Dynamic	Left	42	36	86	98	1	9
4	Dynamic	Left	48	32	67	83	4	18.5
5	Static	Left	50	45	90	83	4	8.5
6	Static	Left	28	30	93	98	0	0
7	Static	Left	58	44	76	97	2	8
8	Static	Right	20	24	83	82	7	15

DASH, Disability of the Arm, Shoulder, and Hand score; SL, scapholunate.

12 (range: 0–29; Table 2). Six of eight patients were manual workers. All patients were satisfied with the result and would have the operation again, and subsequently returned to their former activities.

Radiological outcome: the average preoperative SL gap in the four cases of static SL instability was 6.5 mm (range: 5–9), and measured 4.5 mm (range: 4–6) at final follow-up. The SL angle decreased from a mean preoperative value of 86 degrees (range: 75–95) to 78 degrees (range: 76–90) at the time of final review. The radiolunate angle increased from a mean value of 25 degrees to 28 degrees (range: 12–33) at final follow-up. In the other subgroup of cases with dynamic instability, the average preoperative SL gap was 2 mm (range: 1.5–2.5) and measured 1.5 mm (range: 1–2) at final follow-up. The SL angle increased from a mean preoperative value of 61 degrees (range: 55–80) to 68 degrees (range: 55–82) at final review. Two cases in the group of dynamic instability had a Viegas type II lunate[20] with an additional facet to the hamate; all the others had a type I lunate. No ulnar translocation of the lunate was noted. Posttraumatic arthritis was observed in two of eight patients, one patient in the subgroup of static instability and one patient in the other group. This patient had a Viegas type II lunate (Table 3). Both patients developed arthritis of the radiocarpal and midcarpal joint. In the patient affected by dynamic SL instability (case 3), we suppose that too much tension was put on the ECRB tendon, and this may have contributed to the development of arthritis (Fig. 3). In the other patient (case 8), probably too much effort must be applied to reduce the SL dissociation. Thus, loss of reduction and arthritis were predictable (Fig. 4).

DISCUSSION

The management of chronic SL instability without arthritis is challenging and remains controversial. To address this multiplanar form of instability, including scapholunate gapping, rotatory subluxation and pronation of the scaphoid, DISI, and ulnar drift of the lunate, more complex procedures have been developed.[21–26]

These newer techniques achieve promising short- and midterm results in limited cohorts of patients. However, up to now, there are no long-term results that prove that the correction obtained is permanent and will prevent osteoarthritis. Furthermore, these techniques are technically more demanding and have a higher risk of complications like avascular necrosis of carpal bones,[27–29] especially in techniques where drill holes up to 3 mm and more were performed in the proximal part of the scaphoid and in the lunate. The idea was that simpler and less invasive methods like dynamic tenodesis procedures might achieve satisfying long-term results.

In 2004, the concept of dynamic tenodesis was introduced: an active wrist extensor tendon transferred to the distal pole of the scaphoid would enhance the extensor

Table 3. Radiologic Data

Patient	Type of SL Instability	SL Interval Preoperative (mm)	SL Interval Follow-up (mm)	SL Angle Preoperative (degrees)	SL Angle Follow-up (degrees)	RL Angle Preoperative (degrees)	RL Angle Follow-up (degrees)	Arthritis
1	Dynamic	1.5	1	55	55	0	0	No
2	Dynamic	2.5	2	80*	82	10	11	No
3	Dynamic	2	2	55	76	21	20	Yes SLAC III
4	Dynamic	2	1	55	57	2	1	No
Mean		2	1.5	61	68	8	8	1/4 patients
5	Static	9	6	75	76	12	23	No
6	Static	5	4	85	80	25	35	No
7	Static	7	4	88	64	33	22	No
8	Static	5	4	95	90	30	30	Yes SLAC III
Mean		6.5	4.5	86	78	25	28	1/4 patients
								Total 2/8 patients

RL, radiolunate; SLAC, scapholunate advanced collapse; SL, scapholunat.
*The same value on the healthy contralateral side.

Fig. 3. Dynamic SL instability treated by ECRB tenodesis. Radiograph at 12-years follow-up shows mild midcarpal and radiocarpal arthritis.

Fig. 4. Static SL instability treated by ECRB tenodesis. Radiograph at 14-years follow-up shows midcarpal and radiocarpal arthritis. The bone anchor in the lunate was used to fix a remnant of the SL ligament.

forces throughout the entire range of motion, maintaining its rotatory subluxation corrected. In a case report, Brunelli et al[9] used the entire wrist ECRB tendon in a 22-year-old man with static SL instability. Eight months after the operation, the patient obtained a painless wrist with satisfactory motion and a very good reduction of the SL joint.

In the same year, Seradge et al[11] described a dynamic tenodesis technique where they used two strips of the extensor carpi radialis longus (ECRL) tendon that are passed through an osseous tunnel in the distal pole of the scaphoid and wound around the FCR tendon. An estimated 102 patients affected exclusively by dynamic SL instability were treated by this technique. They reported a high percentage of good and excellent functional results, maintaining carpal alignment after a follow-up of 5 years. In a recent article, Seradge et al[30] presented functional and radiological results in 20 patients with a 20-year follow-up period. In total, 81% of good and excellent results were achieved, and no radiocarpal arthritis was observed.

In 2008, Bleuler et al[8] described another dynamic ECRL tenodesis technique. The tendon was freed, retracted radially, and fixed at the distal pole of the scaphoid with a cancellous screw and a special washer once the rotatory subluxation of the scaphoid had been corrected. Twenty wrists of 19 patients with static SL instability underwent this procedure. The authors reported very good pain relief but did not mention other clinical or radiological outcomes.

In a case study, Peterson and Freeland[10] reported a technique where the entire ECRL tendon is detached from the metacarpal base and fixed to the distal scaphoid pole through a blind tunnel. Fixation is performed with transosseous sutures in the scaphoid tubercle, using a limited palmar approach. A 44-year-old man was treated with this technique: he had a distal nondisplaced intraarticular radius fracture associated with a static SL lesion. The radius fracture was pinned, the SL lesion was repaired, and the ECRL tendon was transferred to the distal scaphoid. Six months later, the patient had minimal activity-related pain and 80% grip strength. SL interval and angle were restored.

In 2017, Soleman et al[12] reported another modification of the Bleuler technique. In this technique, no hardware such as screws, bone anchors, or pins are used. The distal part of the scaphoid is wrapped around with a palmaris longustendon graft: one part is passed through a bone tunnel, and the other part along the radial side of the scaphoid. Both parts are woven together on the dorsal side. A radial-side strip of the ECRL tendon is then detached distally. After extension of the wrist, the palmaris longus loop is woven into the ECRL tendon strip, using the Pulvertaft technique. Eight patients with static instability underwent this procedure. After a follow-up of 18 months, all patients reported pain relief, and there were very good clinical and radiological results.

The results of this study are contradictory. Very good clinical outcomes are in contrast with radiological

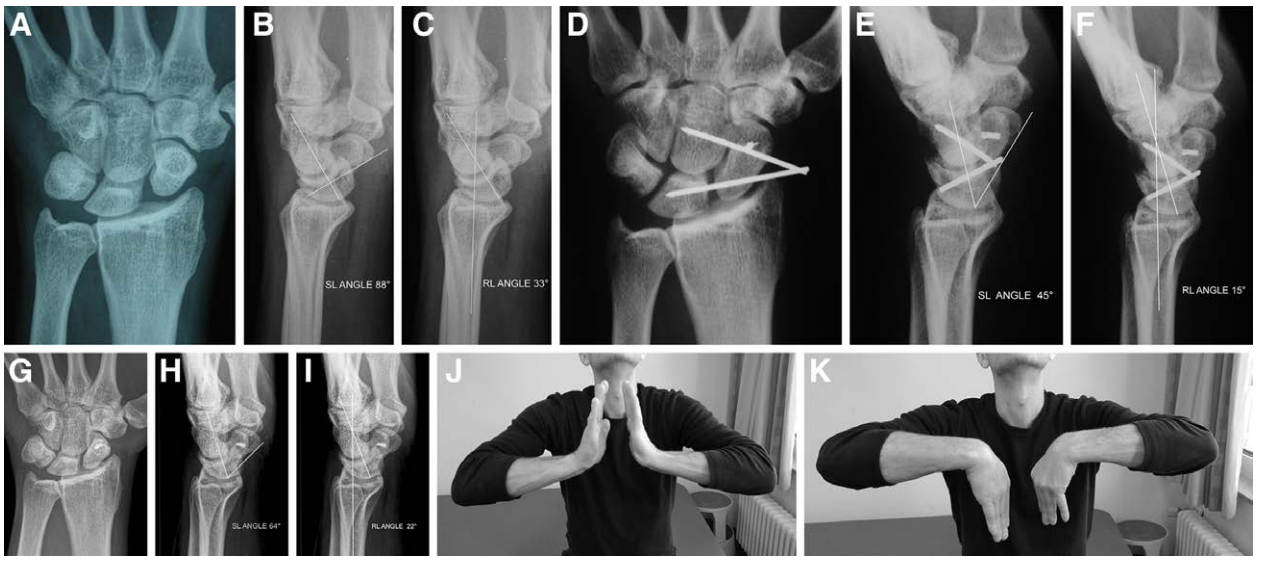

Fig. 5. Case number 7. A–C, A 35-year-old man who had a motorcycle accident with trauma of his left nondominant wrist 6 months before. Radiographs show evident signs of static scapholunate instability. D–F, Postoperative radiographs show correct carpal alignment. G–I, Radiographs at 14-years follow-up show loss of carpal alignment but no signs of degenerative osteoarthritis. J–K, Function at 14-years follow-up. No pain, 76% grip of the healthy contralateral side.

findings that show a loss of SL reduction into the pathologic range in all patients affected by static SL instability (Fig. 5). It is difficult to explain the discordance between clinical findings and radiological results. We hypothesize that the tethering of the scaphoid by the ECRB tendon may reduce the pronation malalignment of the scaphoid, preventing degenerative changes in three of four cases. 4D-CT imaging is needed to ascertain more information about wrist kinematics in these patients.[31] Regarding the radiological outcome in the subgroup of patients affected by dynamic instability, there was no meaningful change of radiographic parameters as expected.

The present study has several limitations. There is a limited cohort of patients, no preoperative clinical data were available, the study design is retrospective, and we did not perform ultrasound imaging to assess the integrity of the tenodesis.

However, to our knowledge over 10 years, results of patients with static and dynamic SL instability treated by a dynamic tenodesis technique have not been previously described (Tables 4 and 5). We suppose that dynamic tethering of the scaphoid with the ECRB tendon might be sufficient to allow for a harmonious motion of the scaphoid when secondary stabilizers of the SL complex are intact as in dynamic SL instability. When secondary stabilizers of the scapholunate complex are insufficient, as in cases of static instability, this type of tenodesis might not be able to prevent the loss of reduction. Nevertheless, only in one of those patients did osteoarthritis occur.

CONCLUSIONS

Because the number of patients is small, only a few conclusions can be made. The ECRB tenodesis is less invasive and relatively easy to perform. Dynamic traction on

Table 4. Clinical Data [Comparison with the Literature (Dynamic Tenodesis Techniques)]

Publication	No. Patients	Technique	SL Instability	Follow-up (mo)	E/F (degrees)	Grip (%)	Pain	Score
Brunelli[9]	1	ECRB	Static	8	130	—	No pain	—
Seradge et al[11]	102	ECRL	Dynamic	63	106	82	93% no pain	Green& O'Brien 85% exc. + good
Bleuler et al[8]	19	ECRL	Static	—	—	—	VAS 1—4 in 10 P	—
Peterson and Freeland[10]	1	ECRL	Static	6	—	80	Minimal	—
Soleman et al[12]	8	ECRL + PL	Static	18	119°	91	—	Green & O'Brien 91, DASH 7
Present study	8	ECRB	Dynamic 50% Static 50%	144	115°	83	2/8 patients	Mayo 88 DASH 5.3 PRWE 12

DASH, Disability of the Arm, Shoulder, and Hand score; PL, palmaris longus tendon; VAS, visual analogue scale.

Table 5. Radiologic Data [Comparison with the Literature (Dynamic Tenodesis Techniques)]

Publication	SL Interval Preoperative (mm)	SL Interval Follow-up (mm)	SL Angle Preoperative (degrees)	SL Angle Follow-up (degrees)	RL Angle Preoperative (degrees)	RL Angle Follow-up (degrees)	Arthritis
Brunelli[9]	9	2	120	50	——	—	—
Seradge et al[11]	2.3	2.2	52	49	—	—	—
Bleuler et al[8]	—	—	—	—	—	—	—
Peterson and Freeland[10]	Static instability	Static instability	Restored	Restored	Restored	Restored	—
Soleman et al[12]	—	—	74	67	—	—	0
Present study: dynamic instability	2	1.5	61	68	8	8	1/4 patients
Present study: static instability	6.5	4.5	86	82	26	29	1/4 patients

RL, radiolunate; SL, scapholunate.

the distal pole of the scaphoid is intended to correct rotational subluxation. Formal reconstruction of the SL ligament is not addressed. The present long-term results may support the conviction that this procedure is indicated not only in dynamic types of SL instability but also in static ones that are reducible easily. Larger prospective studies may be confirmatory.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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