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Article

The "Double-Row Shoelace" Capsulodesis: A Novel Technique for the Repair and Reconstruction of the Scapholunate Ligament of the Wrist

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Abstract

Introduction: The scapholunate interosseus ligament (SLIL) is critical for wrist stability, with injuries causing carpal instability and potential scapholunate advanced collapse (SLAC). This technical note presents a novel ligament-sparing surgical technique for treating SLIL tears ranging from grade 2 to 4 of the Garcia-Elias classification. Materials and Methods: A retrospective study was performed on ten patients treated with this novel technique. The technique involves a dorsal approach to the wrist through a 5–7 cm incision ulnar to Lister's tubercle. After exposing the scapholunate joint, reduction is performed using Kirschner wires (K-wires) as joysticks, followed by stabilisation with three K-wires through the scapholunate, scapho-capitate, and radio-lunate joints. Two 2.3 mm suture anchors with double sutures are placed where the reduction K-wires were removed. One pair of sutures connects the anchors and any remaining SLIL tissue, while the second pair create a shoelace-like capsulodesis. Post-operative care includes staged K-wire removal at one and two months, with progressive rehabilitation before returning to weight-bearing activities at six months. Results: All patients improved in pain and function. The technique addresses SLIL injuries by restoring both coronal alignment through ligament repair and sagittal alignment via dorsal capsulodesis. The use of suture anchors and direct repair preserves the native tissue while reinforcing the dorsal capsule–scapholunate septum complex, avoiding the need for tendon grafts or extensive bone tunnelling. Conclusions: This ligament-sparing technique offers several advantages, including absence of donor site morbidity, minimal damage to carpal cartilage and vascularity, and preservation of surgical options should revision be necessary. The procedure effectively addresses both components of scapholunate instability while maintaining a relatively straightforward surgical approach.

Keywords: SLIL; capsulodesis; wrist

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1. Introduction

The scapholunate interosseus ligament (SLIL) is one of the most important stabilisers among the intrinsics ligaments of the wrist [1]. Complete or partial lesions of the SLIL are among the most common cause of alteration in the kinematics of the wrist, leading to carpal instability, mainly in the form of dorsal intercalated segment instability (DISI), and wrist arthrosis as the final step of the clinical condition known as scapholunate advanced collapse (SLAC) [2]. The pivotal role of the SLIL for a correct kinematic of the wrist has been demonstrated by numerous cadaveric studies that reported how selective sectioning of the SLIL produced both kinematic and static instability of the wrist, possibly leading to the development of DISI [3,4]. This manifests with a flexion rotary subluxation of the scaphoid with dorsal translation of its proximal pole and the extension of the lunate secondary to its attachment to the triquetrum trough the lunotriquetral ligament. These modifications are responsible for the typical radiological aspects of the DISI deformity, with a wider gap in the scapholunate joint (>3 mm) and an increased scapholunate angle (>60°) [5]. As time passes, the rotary subluxation, generating a mismatch between the articular surfaces of the radius, scaphoid, and lunate, is also responsible for the development of the arthritic degeneration of the SLAC deformity secondary to the uneven distribution of loads across the articular surfaces [6]. The importance of the SLIL is also documented by numerous attempts reported in the literature to classify the various stages of injury, of which the most used is the classification proposed by Garcia-Elias et al., since it presents the advantage of guiding clinicians in choosing the optimal treatment for each stage of injury [7]. Since an SLIL injury can be diagnosed in different moments of its physiopathological evolution, surgeons have developed and designed different surgical techniques to address patients' needs and symptoms and to restore, when possible, the correct carpal alignment and kinematic [7–10]. Unfortunately, as reported by recent reviews in the literature, the results obtained are not as satisfactory as hoped, and the treatment of choice is yet to be identified [11–13]. The purpose of this article is to present the simple and ligament sparring surgical technique developed by the senior author R. De Vitis to address SLIL tears raging from grade 2 to grade 4 of the Garcia-Elias classification.

2. Materials and Methods

2.1. Study Design

A short-term retrospective study was conducted on 10 patients who underwent surgical treatment using the innovative "double-row shoelace" capsulodesis technique for the repair and reconstruction of the scapholunate ligament (SLL) of the wrist. All patients were treated at our orthopedic unit between January 2023 and September 2024. The study was conducted in compliance with the principles outlined in the Declaration of Helsinki as part of a thesis dissertation at Catholic University in Rome. Informed consent was obtained from all participants.

2.2. Patient Selection

Inclusion criteria were as follows:

- Clinical and radiographic (X-rays and MRI) diagnosis of chronic or subacute scapholunate instability (≥3 months from the initial injury).
- Age between 18 and 65 years.
- Absence of advanced rheumatic or degenerative wrist conditions (SLAC stage < II).

Exclusion criteria were as follows:

- Comminuted carpal fractures.

- Advanced degenerative changes of the ligament or radiocarpal osteoarthritis (SLAC stage $\geq$ II).
- Previous failed surgical interventions on the SLL.

2.3. Surgical Technique

2.3.1. Pre-Operative Evaluation

Before proceeding with surgery, a thorough diagnostic evaluation must be performed to correctly classify the stage of the scapholunate interosseus ligament injury according to the classification of Garcia-Elias. The correct staging is obtained by the administration of the following exams to the patients: dynamic and static anteroposterior and lateral X-rays, which show an alteration to Gilula's arches, possible arthrosis, a widening of the scapholunate gap superior to 5 mm typical of the Terry–Thomas sign, a misalignment of the scaphoid producing a cortical ring sign, and a scapholunate angle greater than 70°, and T2 steady-state magnetic resonance imaging of 3 Tesla to visualise the complete rupture of the SLIL [13]. Once the imaging is completed and the dissociation is between grade 2 and 4 of the aforementioned classification, it is possible to proceed with the surgical technique as follows.

2.3.2. Surgical Procedure

The patient is positioned in a supine position in a brachial plexus block with an ischemic bracelet at the arm, which is positioned prone and abducted at 90° over a radiolucent table. A sterile field is prepared with the forearm included, and the tourniquet is inflated. A surgical incision of approximately 5 to 7 cm is executed ulnar to Lister's tubercule above the fourth compartment of the extensor's retinaculum. A blunt dissection of the subcutaneous tissues is performed, and veins that might interfere with the procedure are tied and cauterised (Figure 1). The third and fourth compartments of the extensor's retinaculum are incised, and the extensor pollicis longus and the extensor digitorum communis are retracted radially and ulnarly, respectively, exposing the wrist joint capsule (Figure 2). Then, a longitudinal full-thickness capsule incision is performed above and parallel to the scapholunate joint (Figure 3). Two 2 mm diameter Kirshner's wires (K-wires) are inserted just radial to the SLIL insertion at the scaphoid proximal pole and just ulnar to the SLIL insertion at lunate. Reduction in the scapholunate joint is then performed by both distraction of the wrist and extension and ulnar deviation of the scaphoid and flexion and radial deviation of the lunate through the K-wires used as joysticks (Figure 4). The reduction obtained and the correct centring of the lunate over its fossa is then checked under fluoroscopy and then stabilised with 3 K-wires through the scapholunate, the scapho-capitate, and the radio-lunate joints (Figures 5 and 6). The two K-wires used for the reduction are then removed, and two 2.3 mm diameter suture anchors with two suture wires each (Mini quick anchor MiteK™) are fixed in the K-wire holes (Figure 7). Two suture wires, one from each anchor, are then knotted to one another and to the SLIL if still present (Figure 8), whereas the remaining other two are used to perform a two-way continuous shoelace-like suture capsulodesis of the previously made capsulotomy (Figure 9). The third and fourth compartments of the extensor's retinaculum are closed with simple stiches of reabsorbable sutures. The skin wound is finally sutured, and a sterile dressing is applied to protect both the wound and the 3 stabilising wires that are left exposed though the skin for future removal. A neutral short arm plaster splint is then positioned.

Figure 1. Surgical incision with exposure of the extensor tendons and their retinaculum.

Figure 2. Retraction of the extensor tendons and exposure of the joint capsule.

Figure 3. Longitudinal capsulotomy with exposure of the interposition of the capitate into the dislocated scapho-lunate joint.

Figure 4. Reduction in the scapholunate joint by wrist distraction and scaphoid and lunate rotation through 2 K-wires as joysticks.

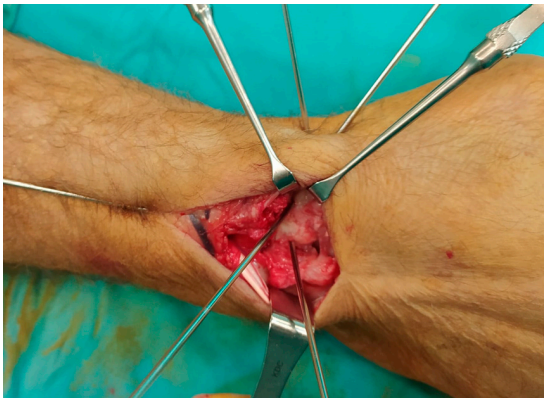

Figure 5. Stabilisation of the reduction with radio-lunate, scapho-lunate, and scapho-capitate wires.

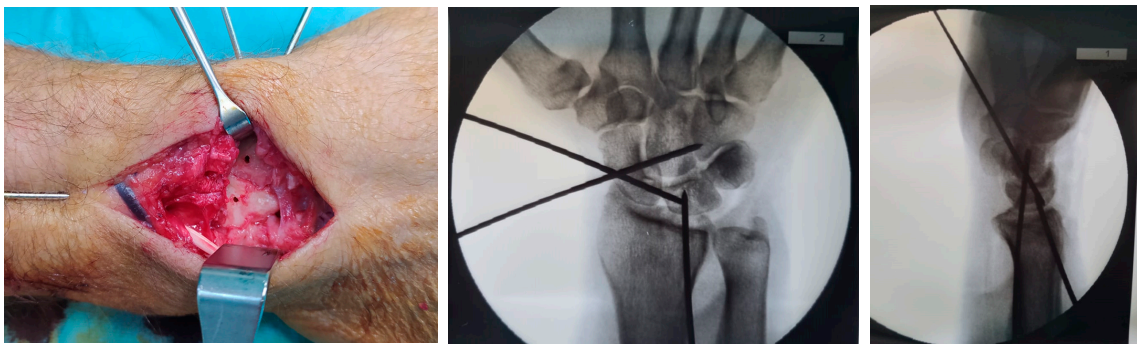

Figure 6. Removal of the reduction K-wires and AP and LL fluoroscopy control of the correct reduction and stabilisation.

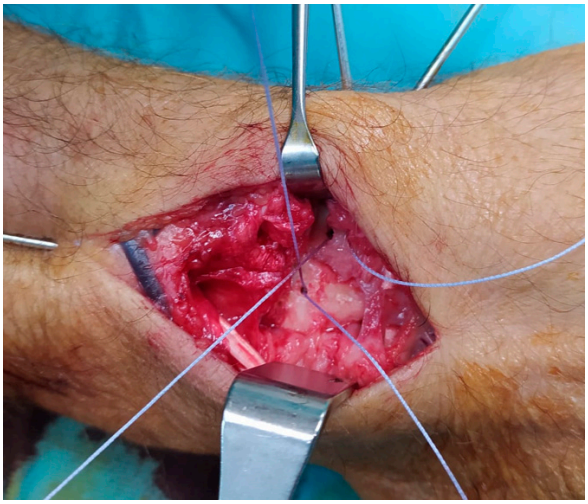

Figure 7. Two 2.3 mm diameter anchors, each with two suture wires, are fixed into holes of the K-wires used for the reduction.

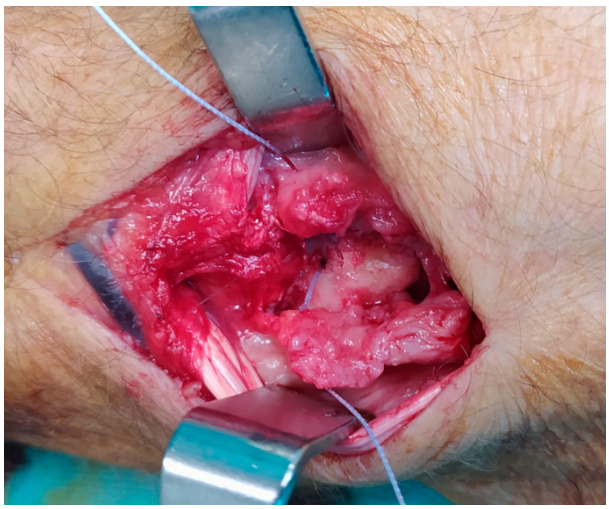

Figure 8. Two wires, one from each anchor, are wired to each other and to the remnants of the SLIL.

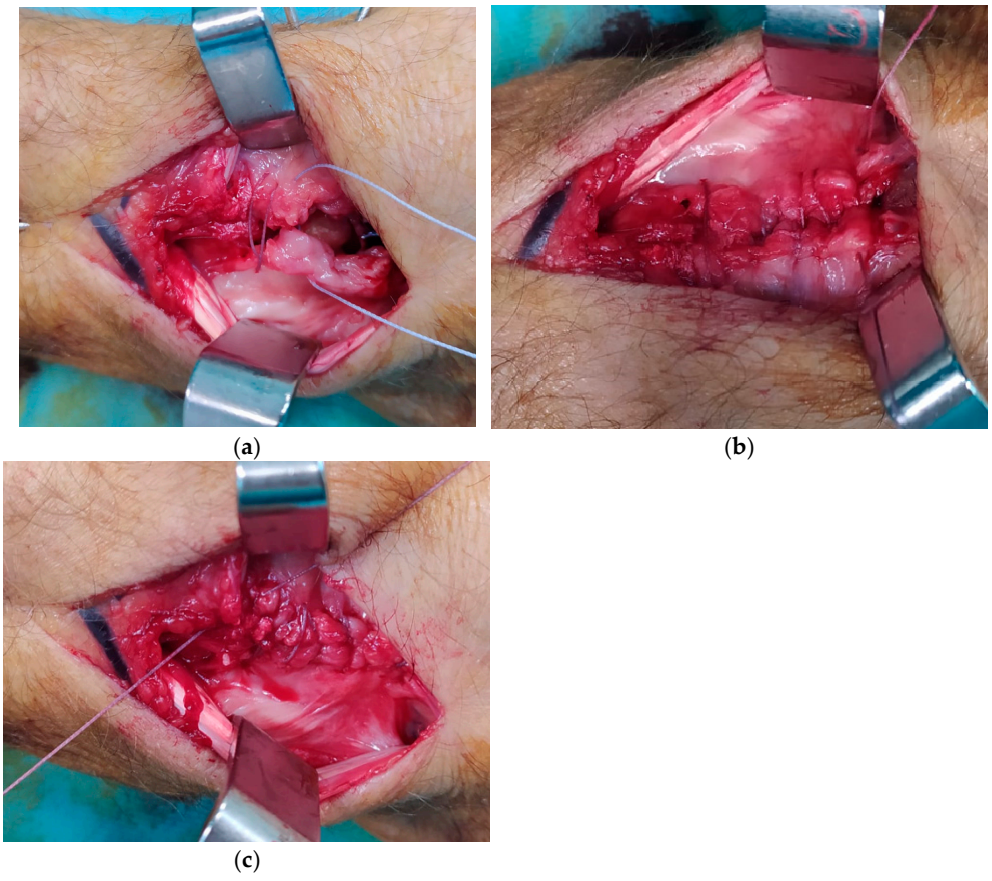

Figure 9. (**a**) First passage of the shoelace suture (left proximal; right distal); (**b**) completion of the first row of the suture with initial tensioning dorsal capsulodesis; (**c**) completion of the capsulodesis with closure of the second row of the suture.

2.3.3. Post-Operative Treatment and Rehabilitation

Post-operative X-rays are performed after surgery and at two weeks after discharge at the first clinical follow-up, where wound medication is performed (Figure 10). At one-month post-op, the radio-lunate K-wire is removed along the splint, a removable wrist brace is applied, and supervised flexion–extension rehabilitation is executed. At two months post-op, the scapho-lunate and scapho-capitate wires are removed, and the patient

is allowed to remove the brace and progress with rehabilitation. When the maximum range of motion is recovered and after six months post-op, the patient is allowed to resume weight-bearing activities.

The Michigan Hand Outcomes Questionnaire (MHQ) [14] and the VAS and qDASH [15] scales were used for pain and function evaluation at 1 year.

2.4. Data Elaboration

Data were analysed using dedicated statistical software. Pre- and post-operative outcomes were compared using the Wilcoxon signed-rank test for paired data, with a significance level of $p < 0.05$.

3. Results

A total of 10 patients (7 males and 3 females) with a mean age of 45.8 years (range: 25–65 years) were included in this study. All patients underwent the "double-row shoelace" capsulodesis technique for the repair and reconstruction of the scapholunate ligament. Post-operative outcomes were evaluated at twelve months post-surgery in terms of pain (VAS), functional parameters (qDASH and Michigan Hand Questionnaire [MHQ] scores), scapho-lunate angle, scapho-lunate gap, and complications. The results are summarised in Table 1.

Table 1. Patient demographics and pre- and post-operative measured parameters.

Patients	Sex	Age	Pre-op VAS	Post-op VAS	Pre-op qDash	Post-op qDash	Pre-op MHQ	Post-op MHQ	Pre-op SL Gap (mm)	Post-op SL Gap (mm)	Pre-op SL Angle	Post-op SL Angle	Complications
1	M	65	9.00	2.00	75.25	30.25	46.4%	83.2%	6.20	1.80	73.00	42.00	
2	M	48	8.00	2.00	61.25	23.50	39.2%	80.6%	5.50	2.90	72.00	45.00	K-wire tracts infection at 15 days post-op
3	F	59	8.00	2.00	80.50	28.50	43.6%	78.4%	6.70	3.10	84.00	58.00	
4	M	41	6.00	2.00	56.50	26.25	56.0%	81.3%	5.20	2.10	71.00	39.00	
5	M	44	6.00	2.00	47.25	22.75	59.6%	84.3%	5.30	1.00	70.00	40.00	K-wire tracts infection at 30 days post-op
6	M	39	6.00	1.00	38.25	13.25	68.3%	83.4%	4.90	2.20	74.00	36.00	
7	M	25	7.00	1.00	50.75	15.75	43.6%	85.4%	5.30	1.70	76.00	47.00	
8	F	56	7.00	1.00	55.75	19.25	46.8%	77.8%	5.10	3.20	70.00	54.00	
9	M	50	8.00	2.00	60.5	27.75	54.7%	78.8%	5.40	3.10	80.00	52.00	
10	F	30	6.00	2.00	40.2	18.50	62.4%	81.3%	5.10	1.30	69.00	41.00	
Mean	7/3	45.8	7.10	1.80	56.62	22.58	52.0%	81.4%	5.47	2.24	73.90	45.40	

3.1. Pain (VAS)

The mean pre-operative Visual Analog Scale (VAS) score was 7.10 ± 1.02, which significantly improved to 1.80 ± 0.42 post-operatively ($p < 0.001$). All patients reported a marked reduction in pain levels, with the majority achieving a post-operative VAS score of 2 or less.

3.2. Functional Outcomes

qDASH: The mean pre-operative qDASH score was 56.62 ± 13.13, which improved significantly to 22.58 ± 6.91 post-operatively ($p < 0.001$). This represents a 60.1% improvement in upper limb disability.

MHQ: The mean Michigan Hand Questionnaire (MHQ) score increased from 52.0% ± 9.4% pre-operatively to 81.4% ± 3.3% post-operatively ($p < 0.001$), reflecting a notable enhancement in hand function and patient satisfaction.

3.3. Scapho-Lunate Gap

The mean pre-operative scapholunate (SL) gap measured was 5.47 ± 0.56, which significantly improved to 2.24 ± 0.80 at twelve months post-operatively ($p < 0.001$). In the X-rays at twelve months, with the exception of patient n°3, who had an SL gap of 3.1 mm, all patients obtained a reduction in the scapho-lunate gap minor to 3 mm, which is considered the usual value in healthy patients.

3.4. Scapho-Lunate Angle

The mean pre-operative scapho-lunate (SL) angle was 73.90 ± 4.84, which improved to 45.40 ± 7.21 post-operatively ($p < 0.001$). This shows that a mean reduction of almost 30° of the scapho-lunate (SL) angle was obtained, and as is reported in Table 1, the scapho-lunate angle at the one-year follow-up was below 60° in all patients.

3.5. Complications

Two patients experienced minor complications during the post-operative period:

A 48-year-old male (Patient 2) developed a K-wire tract infection at 15 days post-operatively, which was immediately treated with debridement, cultural exam, and double antibiotic therapy with cefepime and daptomycin until the results of the cultural exam. After the results of the cultural exams, daptomycin was suspended, and suppressive antibiotic therapy was carried out for two more weeks after the last removal of the Kirshner's wires.

A 44-year-old male (Patient 5) developed a K-wire tract infection at 30 days post-operatively, which was managed until the second and last K-wire removal surgery with the administration of 875 + 125 mg of amoxicillin–clavulanic acid three times a day.

No other significant complications, including reoperation, stiffness, or recurrent instability, were reported during the follow-up period.

3.6. Individual Outcomes

The highest improvement in MHQ score was observed in Patient 7 (+41.8%), while the lowest improvement was observed in Patient 8 (+31.0%).

Patient 6 demonstrated the greatest reduction in qDASH score (−25.00 points) and scapholunate angle correction (38°), aligning with the highest improvement in both pain and hand function.

Finally, the greatest reduction in the scapho-lunate gap (4.3 mm) was obtained in Patient 1.

3.7. Summary of Findings

On average, the patients demonstrated the following:

A 74.6% reduction in VAS pain scores.

A 60.1% improvement in qDASH scores.

A 29.4% improvement in MHQ scores.

A 59.0% improvement in scapholunate gap.

A 38.6% improvement in scapholunate angle.

Despite minor complications in two cases, the overall clinical and functional outcomes were highly satisfactory, with significant improvements in pain, function, anatomical parameters, and patient satisfaction.

3.8. Statistical Analysis

The Wilcoxon signed-rank test revealed a statistically significant reduction in VAS scores after surgery ($p < 0.001$), indicating a significant improvement in pain levels.

The Wilcoxon signed-rank test demonstrated a statistically significant improvement in qDASH scores post-operatively ($p < 0.001$), reflecting reduced upper limb disability.

The Wilcoxon signed-rank test showed a statistically significant increase in MHQ scores ($p < 0.001$), indicating a substantial improvement in hand function and patient satisfaction.

4. Discussion

The technique described in this article was elaborated by the senior Author R. De Vitis, bearing in mind the main objectives that must be persecuted when repairing an SLIL according to Wolfe, which focus on restoring a coronal alignment through an SLIL repair and the obtainment of a correct sagittal alignment through a retentive caspulodesis [16]. Each of these objectives are obtained through one of the steps in the procedure; in particular, the coronal alignment is obtained by the reduction in the scapholunate dislocation stabilised by the scapho-capitate and scapholunate wires, allowing for a direct suture between two of the four wires from the two anchors with the remnants of the SLIL. The sagittal alignment is obtained through the double-row shoelace dorsal capsulodesis that enhances the mechanical stability of both the dorsal intercarpal ligament and the dorsal capsule–scapholunate septum (DCSS), by which, as has been shown by different cadaveric studies, must be involved with some degree of damage to develop a scapholunate instability [17–19]. Finally, the role of the K-wires is first to maintain the carpal row bones in the correct position until soft tissues are fully healed. We believe that the strength of this technique lies in several factors, such as the absence of donor site damage secondary to graft harvest and the minimal damage to carpal bone cartilage and vascularisation, given the lack of tunnelling and bone fusion, which are all features of the most established and widely performed procedures, such as the reduction in and association of the scaphoid and lunate (RAST), three-ligament tenodesis, and the Brunelli procedure [7–10]. Furthermore, in case of failure, it is still possible to proceed with the more validated techniques of reconstruction [7–10,20,21] or salvage procedures [22–24]. Finally, as shown in Table 1, we report the preliminary results at 12 months of follow up of a cohort of 10 patients evaluated for pain with the Visual Analog Scale (VAS) and two functional scores, the quick Disability of the Arm Shoulder and Hand (qDASH) and the Michigan Hand Questionnaire (MHQ), in terms of the scapholunate angle and scapholunate gap. The population is divided as follows, with most patients (70%) being male with an average age of 45.8 years, ranging from 25 to 66. The pre-operative mean value of the VAS was 7.1 m and, at the 12-month follow-up, improved by more than 5 points, reaching a mean value of 1.8. Moreover, a significant improvement in both the qDASH and MHQ scores was registered at the last follow-up. The qDASH mean score increased by more than 30 points from 56.52 to 22.58, reaching the margin of the highest quartile. Also, the MHQ score increased from 52.0% to 81.4%, showing an increase of almost 30 percentage points, growing from a fair functionality of the hand to a good functionality. Given the wide range of age between patients, we performed a stratified analysis of the outcomes, dividing the patients into three groups: less than or equal to 30 years, between 30 and 50 years, and above 50 years (Table 2). Although there were not any statistically significant differences between the three groups, a few considerations can be made: first of all, the group aged less than or equal to 30 years reached the best post-operative values, with the exception of the SL angle, for which the best result was achieved in the 30 to 50 age range. Furthermore, the best improvements in the VAS and qDASH scores and SL gap were achieved in the group aged above 50 years, whereas the best improvements in the MHQ score and SL angle were reached in the less than or equal to 30 years group and the group aged between 30 and 50 years, respectively. These outcomes could be explained by the longer period of time and the subsequent chronification of the clinical state between lesion and treatment in older patients, causing a worse absolute result along with a higher relative improvement. As per the post-operative complications, only

two patients developed minor complication; in both cases, it was a superficial infection of the tracts of the scapho-lunate and scapho-capitate K-wires. In the first patient, the infection developed at 30 days post-surgery and was managed with an empiric antibiotic therapy for 20 days until the K-wires were removed. The second patient developed an infection at 15 days post-surgery; they underwent surgical exploration of the tracts and cultural exams of the tampons, and they were treated with suppressive specific antibiotic therapy until the K-wires were removed, and this was achieved without further problems and with a full recovery at the last follow-up. These two cases led to high percentage of superficial infection of the K-wire tracts; nevertheless, the authors believe that the cause did not reside in the choice to leave the K-wires exposed, since at our institution, all procedures involving the use of K-wires are performed with the K-wires left exposed, and the rates of infection are within the percentages described by the literature. We believe that a plausible cause for the development of the two infections could be that both procedure were performed during summer and that the first wound medication was executed at 15 days post-op, thus exposing the patients to a high risk of wound contamination through sweat, which is why we are considering performing an additional check-up of the wound at 7 days post-op, especially in the hottest months of the year. Although our study involved a small population and needs a longer follow-up for further validation, the results obtained, if confirmed at later follow-ups, could be compared to those obtained with standard procedures. In particular, pain relief, which we believe is the main objective, was obtained in all patients, and as is reported by Garcia-Elias et al.'s review at 46 months where only 2 patients out of 38 examined showed pain in most activities of daily life [7]. Garcia-Elias et al. also reported on two cases of asymptomatic recurrence of carpal collapse (5%) and nine cases of mildly symptomatic osteoarthritis (23%) at the last follow-up. These are results that we hope to match as we progress in the follow-ups of our patients. Our results are also comparable to those obtained by Brunelli and Brunelli [10], where they first described their technique on eleven patients reporting restoration of carpal alignment, the absence of a loss of scaphoid reduction, and the complete satisfaction of every patient at last follow-up. Our results are similar to another study by White et al. [25], which showed similar outcomes at the last follow-up, with a reduction in and association of the scaphoid and lunate (RASL) technique, reporting a final mean DASH of 17 points, a mean scapho-lunate gap of 2.1 mm, and a mean scapho-lunate angle of 55°. With the exception of the study by Brunelli, both of the previously cited studies report on a much longer follow-up than ours, with 46 months for the study by Garcia-Elias and 6.2 years for the study by White et al., thus making a direct comparison between our work and these two could be misleading; nevertheless, the above treatments are among the most established and must be regarded as the standard to reach.

Table 2. Patient results stratified by age range.

Groups	Patients	Pre-op VAS	Post-op VAS	Pre-op qDash	Post-op qDash	Pre-op MHQ	Post-op MHQ	Pre-op SL Gap (mm)	Post-op SL Gap (mm)	Pre-op SL Angle	Post-op SL Angle
>50 Y	1	9.00	2.00	75.25	30.25	46.4%	83.2%	6.20	1.80	73.00	42.00
	3	8.00	2.00	80.50	28.50	43.6%	78.4%	6.70	3.10	84.00	58.00
	8	7.00	1.00	55.75	19.25	46.8%	77.8%	5.10	3.20	70.00	54.00
	9	8.00	2.00	60.5	27.75	54.7%	78.8%	5.40	3.10	80.00	52.00
	Mean	7.75	2.00	64.11	26.25	51.8%	80.4%	5.85	2.33	76.50	48.25
<30 Y	7	7.00	1.00	50.75	15.75	43.6%	85.4%	5.30	1.70	76.00	47.00
	10	6.00	2.00	40.2	18.50	62.4%	81.3%	5.10	1.30	69.00	41.00
	Mean	6.50	1.50	45.48	17.13	53.0%	83.3%	5.20	1.50	72.50	44.00
30 > Y < 50	2	8.00	2.00	61.25	23.50	39.2%	80.6%	5.50	2.90	72.00	45.00
	4	6.00	2.00	56.50	26.25	56.0%	81.3%	5.20	2.10	71.00	39.00
	5	6.00	2.00	47.25	22.75	59.6%	84.3%	5.30	1.00	70.00	40.00
	6	6.00	1.00	38.25	13.25	68.3%	83.4%	4.90	2.20	74.00	36.00
	Mean	6.50	1.75	50.81	21.44	55.8%	82.4%	5.23	2.05	71.75	40.00

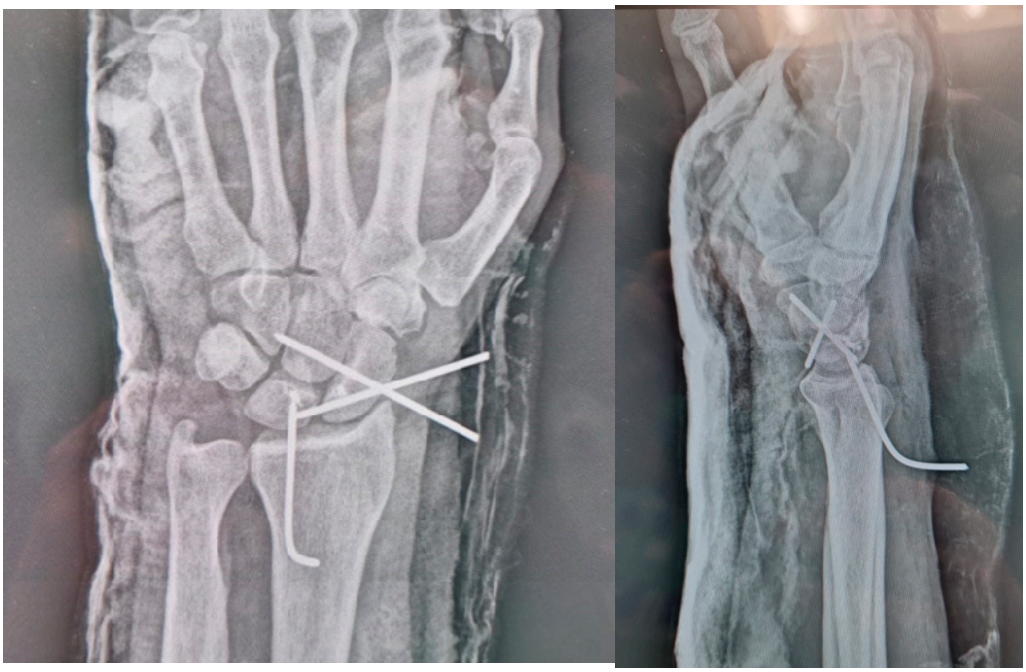

Figure 10. Post-operative AP and LL X-rays.

This study has several limitations, including its retrospective design, the lack of blinding, and a relatively small sample size. Future prospective studies and comparison studies are needed to better understand the results.

Despite these limitations, the study's strengths include the improvement in the quality of life of all patients.

5. Conclusions

In conclusion, the authors feel confident in recommending the implementation of the proposed technique, especially considering the satisfactory preliminary results obtained at the twelve-month follow-up of this first cohort of ten patients, which is part of a two-year follow-up study on a cohort of twenty patients that is being carried out and will be published as soon as all the patients complete 24 months of follow-up. Finally, the authors, being aware that further investigations are necessary to validate the procedure, are publishing this first paper with the hope of inviting other hand surgeons to participate in the design and implementation of a prospective, multicentred, and possibly randomised controlled study.

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Abbreviations

The following abbreviations are used in this manuscript:

SLIL	Scapho-Lunate Interosseus Ligament
DISI	Dorsal Intercalated Segment Instability
K-wires	Kirshner's Wires
SLAC	Scapho-Lunate Advanced Collapse
DCSS	Dorsal Capsule–Scapholunate Septum

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