



HAL
open science

Radioscapholunate fusion for posttraumatic osteoarthritis with consecutive excision of the distal scaphoid and the triquetrum: A comparative study

B. Degeorge, L. Dagneaux, D. Montoya-Faivre, G. Dautel, F. Dap, B. Coulet, C. Lazerges, M. Chammas

► **To cite this version:**

B. Degeorge, L. Dagneaux, D. Montoya-Faivre, G. Dautel, F. Dap, et al.. Radioscapholunate fusion for post-traumatic osteoarthritis with consecutive excision of the distal scaphoid and the triquetrum: A comparative study. *Hand Surgery and Rehabilitation*, 2020, 39, pp.375 - 382. <10.1016/j.hansur.2020.05.002>. <hal-03492001>

HAL Id: hal-03492001

<https://hal.science/hal-03492001v1>

Submitted on 14 Sep 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY-NC 4.0 - Attribution - Non-commercial use - International License

Radioscapholunate fusion for posttraumatic osteoarthritis with consecutive excision of the distal scaphoid and the triquetrum: a comparative study

Étude comparative des arthrodèses radio-scapho-lunaire post-traumatiques avec excision consécutive du pôle distal du scaphoïde distal et du triquétrum

B. Degeorge^{1,2}, L. Dagneaux¹, D. Montoya-Faivre², G. Dautel², F. Dap², B. Coulet¹, C. Lazerges¹, M. Chammas¹

1: Department of Hand and Upper Extremity Surgery, Peripheral Nerves Surgery, Lapeyronie University Hospital of Montpellier, 371, avenue du Doyen Gaston Giraud, 34090 Montpellier, France

2: Department of Hand Surgery, Plastic and Reconstructive Surgery. Centre Chirurgical Emile Gallé, University Hospital of Nancy, 49, rue Hermite, 54000 Nancy, France

Corresponding author:

Benjamin Degeorge

Phone number: +33 4 67 33 85 37

Fax number: + 33 4 67 33 79 66

E-mail: degeorge.benjamin@gmail.com

Other authors:

Louis Dagneaux^a, M.D., M.Sc. louisdagneaux@gmail.com

David Montoya-Faivre^b, M.D., david.montoyafaivre@gmail.com

Gilles Dautel^b, M.D., Ph.D., gillesdautel@me.com

François Dap^b, M.D., Ph.D., dapfrancois@gmail.com

Bertrand Coulet^a, M.D., Ph.D., bertrand-coulet@wanadoo.fr

Cyril Lazerges^a, M.D., c-lazerges@chu-montpellier.fr

Michel Chammas ^a, M.D., Ph.D., m-chammas@chu-montpellier.fr

Conflict of interest: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding statement: The authors received no financial support for the research, authorship, and/or publication of this article.

Informed consent: All patients give their informed consent for this study.

1 **Radioscapholunate fusion for posttraumatic osteoarthritis with consecutive excision**
2 **of the distal scaphoid and the triquetrum: a comparative study**

3
4 **Étude comparative des arthrodèses radio-scapho-lunaire post-traumatiques avec**
5 **excision consécutive du pôle distal du scaphoïde distal et du triquétrum**

6
7 **Abstract**

8 The aim of this study was to assess the clinical and radiographic outcomes after
9 radioscapholunate (RSL) fusion for posttraumatic osteoarthritis. This was a retrospective,
10 dual-center study of all patients who underwent RSL fusion between 1995 and 2015 for
11 posttraumatic radiocarpal osteoarthritis. Patients were assessed at the final review to
12 determine clinical (pain, wrist range of motion and strength), self-reported (QuickDASH,
13 PRWE and MWS scores) and radiological (degenerative osteoarthritis in the
14 scaphotrapeziotrapezoid (STT) or midcarpal joint and radiocarpal fusion) outcomes. We
15 analyzed three groups: RSL fusion alone, RSL fusion with distal scaphoid excision (DSE)
16 and RSL fusion with DSE and triquetrum excision (TE). Eighty-five patients were included; 10
17 were lost to follow-up and 11 required conversion to total wrist fusion before the final review.
18 Finally, 64 patients had both clinical and radiographic evaluations. The mean follow-up was
19 9.1 years (range 1-21.4). RSL fusion alone was performed in 29 patients, RSL fusion with
20 DSE in 23 and RSL fusion with DSE and TE in 12. At the final follow-up, the three groups did
21 not differ in their pain or wrist motion. Overall, 47 (73%) patients were satisfied or very
22 satisfied with the procedure. DSE significantly decreased STT osteoarthritis and radiocarpal
23 non-union. The total wrist osteoarthritis rate after RSL fusion was 55%. RSL fusion is an
24 effective procedure to preserve some motion in wrists with posttraumatic radiocarpal
25 osteoarthritis. DSE prevents STT osteoarthritis by removing bony impingement and
26 increases the fusion rate.

28 **Résumé**

29 Notre objectif était d'évaluer et de comparer les résultats cliniques et radiographiques des
30 arthrodèses radio-scapho-lunaires (RSL) post-traumatiques. Nous avons inclus
31 rétrospectivement tous les patients opérés d'une arthrodèse RSL pour arthrose radio-
32 carpienne post-traumatique entre 1995 et 2015 dans deux centres hospitalo-universitaires.
33 Une évaluation clinique (douleur, mobilité et force du poignet), fonctionnelle (scores
34 QuickDASH, PRWE et MWS) et radiologique (arthrose scapho-trapézo-trapézoïdienne (STT)
35 ou médiocarpienne et consolidation osseuse radio-carpienne) a été réalisée au dernier recul.
36 Étaient comparés trois groupes : arthrodèses RSL isolées, arthrodèses RSL avec excision
37 du pôle distal du scaphoïde (EPDS), et arthrodèses RSL avec EPDS et excision du
38 triquétrum (ET). Quatre-vingt-cinq patients ont été inclus : 10 ont été perdus de vue et 11 ont
39 nécessité une conversion en arthrodèse totale de poignet. Au total : 64 patients ont été
40 évalués au recul moyen de 9,1 années (1-21,4). Parmi eux, 29 patients avaient été opérés
41 d'une arthrodèse RSL isolée, 23 d'une arthrodèse RSL avec EPDS et 12 d'une arthrodèse
42 RSL avec EPDS et ET. Au dernier recul, les scores de douleurs et les mobilités n'étaient pas
43 statistiquement différents entre les 3 groupes. Quarante-sept patients (73%) étaient satisfaits
44 ou très satisfait de l'intervention chirurgicale. L'EPDS permettait une diminution significative
45 de l'arthrose STT et du taux de pseudarthrodèse. Cinquante-cinq pourcent des patients
46 présentaient des signes d'arthrose radiographique. L'arthrodèse RSL est une technique
47 chirurgicale fiable permettant la conservation d'une mobilité du poignet en cas d'arthrose
48 entre radius et rangée proximale d'origine post-traumatique symptomatique. L'EPDS permet
49 de prévenir l'arthrose STT par suppression du conflit et d'améliorer le taux de consolidation
50 osseuse.

51

52 *Keywords:* Arthritis; Arthrodesis; Distal radius fracture; Fusion; Radioscapholunate

53 *Mots-clés :* Arthrose ; Arthrodèse ; Fracture radius ; Radio-scapho-lunaire

54 **Level of evidence:** Level IV, Case series, Therapeutic studies.

55 **Niveau de preuve :** Niveau IV, étude de cas rétrospective

56 **1. Introduction**

57 Prevalence of radiological osteoarthritis following distal radius fractures (DRF) has been
58 described in the literature to be high with a rate of 50% after 9.2 years of follow-up [1].
59 Posttraumatic cartilage injury or articular step-off are known to induce osteoarthritis [2].
60 Although rarely painful, a range of surgical procedures has been described to manage
61 symptomatic radiocarpal osteoarthritis, ranging from wrist denervation, arthroplasty, total
62 wrist arthrodesis or partial wrist fusion [3].

63 Partial wrist fusion is a viable surgical procedure for achieving pain relief and
64 correcting deformities in wrists with symptomatic radiocarpal osteoarthritis due to DRF [3–5].
65 The advantage is that it maintains some range of motion (ROM) of the wrist while improving
66 functional outcomes [5–8].

67 Several studies have reported the medium- to long-term outcomes of RSL fusion, with
68 variable results [6,9–12]. Although the clinical outcomes were often acceptable, some of the
69 radiological findings were alarming: midcarpal osteoarthritis frequency ranged from 0% to
70 100% and non-union rates were 0% to 29% [9,11–15]. Based on cadaver studies, additional
71 procedures were developed to improve wrist motion and avoid bone impingement [16,17].
72 Distal scaphoid excision (DSE) was suggested to increase flexion and radial deviation while
73 reducing the risk of scaphotrapeziotrapezoid (STT) osteoarthritis [9,13,14]. Excision of the
74 triquetrum (TE) has been proposed to improve motion in extension and ulnar deviation while
75 treating the ulnocarpal impaction [7,15].

76 Although several clinical studies have reported good clinical results after RSL fusion
77 combined with DSE with or without TE, only Ha et al. compared the three procedures in 15
78 patients [15]. Despite the long-term follow-up (mean 14.8 years), the authors did not find
79 significant differences in clinical outcomes, likely due to the small sample size.

80 The aim of our study was to compare the clinical and radiographic outcomes of
81 posttraumatic RSL fusion with or without DSE and TE. The secondary objective was to
82 assess the survival rate of RSL fusion without total wrist fusion.

83

84 **2. Materials and methods**

85 2.1. Patients

86 We retrospectively included all patients who had posttraumatic radiocarpal osteoarthritis and
87 who underwent RSL fusion at two university hospitals between 1995 and 2015 and had at
88 least 1 year of follow-up. Patients in the institutional database were identified by using
89 Current Procedures Terminology (CPT) codes. All patients still had wrist pain after well-
90 conducted conservative treatment for at least 6 months including anti-inflammatory
91 medication, physiotherapy, resting splints, and modification of daily activities. Radiocarpal
92 osteoarthritis was confirmed on preoperative CT arthrogram. We excluded patients with
93 radiocarpal osteoarthritis due to inflammatory disease and Kienböck's disease. Clinical and
94 radiographic evaluations were performed by an independent examiner at the last follow-up.
95 The study was approved by the institutional review board and patients' written consent was
96 obtained. The Strengthening the Reporting of Observational Studies in Epidemiology
97 (STROBE) guidelines were followed for the study.

98

99 2.2. Surgical technique

100 All surgical procedures were performed by senior surgeons trained in hand surgery with
101 patients receiving regional anesthesia. A midline dorsal approach was used. The extensor
102 retinaculum was incised over the third and fourth compartments, the posterior interosseous
103 nerve was resected to achieve partial denervation of the wrist and a Berger's capsulotomy
104 was performed to expose both the radiocarpal and midcarpal joints. The first step of the
105 procedure was to inspect the midcarpal joint to ensure that it was not damaged. Articular
106 surfaces of the radiocarpal joint were then denuded of cartilage down to cancellous bone
107 (Fig. 1C). The joint was temporarily fixed with a K-wire, with correction of any malalignment
108 under fluoroscopy. The primary aim of the technique was to restore congruency of the distal
109 surfaces of the proximal row with the proximal surfaces of the distal row [3] (Fig. 1D). In 63
110 patients, the joint was filled with a cancellous bone graft harvested in the distal radius (n=50)
111 or a cortico-cancellous graft from the iliac crest (n=13) depending on surgeon preferences.

112 Fixation was achieved with a locking T-plate (n=13), screws (n=42) and/or memory staples
113 (n=48) (Fig. 1E) and/or K-wires (n=23). DSE was performed in 42 patients at the surgeon's
114 discretion and TE was done in combination with DSE in 16 patients. Indications for TE were
115 ulnocarpal impaction syndrome in 9 cases (over 16), and without specific criteria in the
116 remaining cases. In 24 cases, concurrent distal radioulnar joint (DRUJ) arthroplasty was
117 performed with the Darrach procedure for ulnocarpal impaction syndrome, distal radioulnar
118 dislocation, or osteoarthritis. Finally, the dorsal capsular flap and extensor retinaculum were
119 closed, leaving the extensor pollicis longus under subcutaneous tissue, and the skin was
120 closed.

121

122 2.3. Postoperative care

123 All wrists were immobilized with a forearm plaster cast for a mean of 6.7 weeks (range 2-14),
124 depending on the surgeon. After cast removal, active and passive mobilization (i.e., without
125 strength training) was performed to prevent wrist stiffness.

126

127 2.4. Clinical analysis

128 Patients' characteristics assessed included age, sex, limb dominance, heavy manual labor,
129 and workplace accidents. Pain was assessed with a visual analog scale (VAS, /10) at rest
130 and during daily living activities. Active ROM (in degrees) was assessed using a standard
131 goniometer for wrist motion in flexion, extension, radial and ulnar deviation. ROM in flexion-
132 extension (ROM FE) and radioulnar deviation (ROM RUD) were then calculated. Grip
133 strength (expressed in Kg/F and as a percentage of the opposite side) was averaged over
134 three consecutive measurements using the Jamar hydraulic hand dynamometer (Kit
135 Baseline1™, Arex®, Palaiseau, France). Patient satisfaction was self-evaluated as not
136 satisfied, moderately satisfied, satisfied and very satisfied. Patient-reported outcomes
137 included the short version of the Disabilities of the Arm, Shoulder and Hand questionnaire
138 (QuickDASH, /100, 0=best), Patient-Related Wrist Evaluation score (PRWE, /100, 0=best),
139 and Modified Mayo Wrist Score (MMWS, /100, 100=best).

140

141 2.5. Radiography

142 Radiographic analysis involved strict anteroposterior and lateral views at the last follow-up
143 evaluated by two specialized hand surgeons (B.D. and D.M.F.). Radiocarpal fusion and
144 degenerative osteoarthritis were rated as present/absent for both criteria. Fusion was
145 considered achieved when clear trabecular bone could be seen crossing from the radius to
146 both the scaphoid and lunate [7]. Degenerative changes were described as joint space
147 narrowing and/or localized subcortical sclerosis changes and/or osteophytes and/or
148 subchondral cysts. The latter were described as affecting the STT joint or the medial part of
149 the midcarpal joint (scaphocapitate and/or lunocapitate and/or lunohamate and/or
150 triquetrohamate). Total wrist osteoarthritis included both STT and midcarpal degenerative
151 changes.

152

153 2.6. Complications

154 Postoperative complications (e.g., non-union) and surgical revisions (e.g., bone grafting for
155 non-union) were counted separately. Implant discomfort was not considered a complication
156 but was counted as a surgical revision.

157

158 2.7. Statistical methods

159 Patients who underwent total wrist fusion were included in the radiographic assessment but
160 excluded from the clinical one. Patients were classified into three groups: those who
161 underwent RSL fusion alone, those with RSL fusion and DSE and finally, those with RSL
162 fusion, DSE and TE.

163 Categorical variables were expressed as frequencies (%) and compared by Chi-
164 square or Fisher's exact test depending on the data distribution. The distribution of the
165 continuous data was evaluated using the Shapiro test. Continuous data were described with
166 mean and standard deviation (SD) or range and were compared by Student's *t* test for
167 normally distributed data, Mann-Whitney test if not or ANOVA. The Kaplan-Meier method

168 was used to estimate radiocarpal fusion survival without total wrist fusion. Time to total wrist
169 fusion was compared by a Log rank test. The significance threshold was set at $p < 0.05$.
170 Significant values are presented with mean difference and 95% confidence interval (CI).

171

172 **3. Results**

173 We included 85 consecutive patients (74 males, 11 females). Procedures were performed for
174 articular malunion of DRF in 73 cases, dislocation-fracture of the distal radius in 9 and
175 scapholunate advanced collapse (stage 2) in 3. Ten patients (12%) were lost to follow-up (4
176 deaths, 4 untraceable and 2 refusals). The remaining 75 patients were included for
177 radiographic assessment. Eleven (13%) underwent total wrist fusion for early midcarpal
178 osteoarthritis at a mean time from surgery of 24.6 months (SD 18, range 9-74), with no
179 significant differences between groups ($p = 0.42$, Table 1). Finally, 64 patients were included
180 for clinical examination; 23 had DSE and 12 had both DSE and TE. The mean follow-up was
181 9.1 years (SD 6.7, range 1-21.4) and mean age at revision 52.6 years (SD 13.2, range 19-
182 78). The three groups did not differ in patient characteristics or follow-up (Table 2, $p > 0.05$).

183

184 3.1. Complications and revisions before final follow-up

185 In total, 12 patients (19%) had complications and 35 (47%) required surgical revision (Table
186 3). Altogether, 36 patients (48%) had a complication and/or underwent surgical revision after
187 RSL fusion, with no significant differences between groups ($p = 0.46$). Complications and
188 surgical revisions did not significantly differ between groups. No infection was noted.

189

190 3.2. Clinical outcomes

191 At the last follow-up, the mean VAS pain score was 1.78 (SD 1.9) at rest and 4.1 (SD 2.3)
192 during activity, with no significant differences between groups (Table 4, $p = 0.37$ and $p = 0.18$
193 respectively). Overall, 47 patients (73%) were satisfied or very satisfied with the procedure,
194 with no significant differences between groups ($p = 0.25$). Grip strength was statistically
195 lower after RSL fusion alone than the other procedures ($p = 0.005$). No other statistical

196 differences were found between groups in terms of wrist motion or patient-reported outcome
197 measures.

198 Compared to RSL fusion alone, patients who had RSL fusion with DSE had
199 significant better grip strength (33.1 vs 22.1 kg/F, $p=0.001$, 95% CI [-17.5; -4.8]). The two
200 groups did not differ statistically in terms of wrist motion especially in flexion ($p = 0.14$) or
201 radial deviation ($p = 0.33$). Compared to RSL fusion with DSE, RSL fusion with DSE and TE
202 did not differ statistically in terms of grip strength ($p = 0.30$) or wrist motion, especially in
203 extension ($p = 0.093$) or ulnar deviation ($p = 0.79$)

204

205 3.3. Radiography outcomes (Fig. 2)

206 The total wrist osteoarthritis rate after RSL fusion was 61%. Patients with RSL fusion and
207 DSE, with or without TE, had significantly lower incidence of STT and total wrist osteoarthritis
208 ($p < 0.001$, Table 5). At the final follow-up, grip strength was lower for patients with STT
209 osteoarthritis than without (22.7 vs 29.5, $p = 0.044$, 95% CI [0.2-13.4]). Wrist motion was
210 greater but not significantly in flexion (25° vs 20°, $p = 0.09$) and ROM FE (56° vs 48°, $p=0.09$)
211 in patients without STT osteoarthritis. Compared to patients without midcarpal osteoarthritis,
212 those with midcarpal osteoarthritis had significantly lower ROM FE (47° vs 57°, $p = 0.032$,
213 95% CI [0.9-19.7]) and grip strength (21.9 vs 30.3 kg/F, $p = 0.01$, 95% CI [2.1-14.7]).

214 The fusion rate was 76%. Non-unions were limited to the radioscaphoid joint in nine
215 cases, the radiolunate joint in two cases and extended to the entire radiocarpal joint in seven
216 cases. The fusion rate was better after RSL fusion with DSE (with or without TE) than with
217 RSL alone ($p = 0.004$, Table 5).

218

219 3.4. Survival rate without total wrist fusion

220 The overall survival rate after radiocarpal fusion was 85%. Survival rate without total wrist
221 fusion was better with RSL fusion and DSE than the other procedures but not significantly
222 ($p = 0.42$, Fig. 3). Time to total wrist fusion did not differ among groups ($p = 0.52$).

223

224 **4. Discussion**

225 Because it involves fusion of pathological joints only, partial radiocarpal fusion has been
226 proposed as a treatment option to achieve pain relief while preserving motion [18–22]. Here,
227 we report the results of the largest clinical series of RSL fusion in two university hospitals
228 with a mean follow-up of 9.1 years. After surgery, the three groups—RSL fusion alone, with
229 DSE and with DSE and TE—did not differ in terms of pain or wrist motion. Patients with RSL
230 fusion alone had significant lower grip strength than the others. DSE significantly reduced the
231 progression of STT osteoarthritis and promoted radiocarpal fusion. The remaining cases of
232 STT osteoarthritis after DSE were most likely caused by insufficient initial resection; Garcia-
233 Elias advised removing the distal third of the scaphoid to avoid recurrence of STT
234 impingement [3,13]. Midcarpal osteoarthritis was more frequent but not significantly with RSL
235 fusion with DSE and TE than with other procedures. The survival rate of radiocarpal fusion
236 without total wrist fusion was better with RSL fusion and DSE.

237 RSL fusion has been extensively described in the literature, and several authors
238 emphasized that DSE increased motion in both flexion and radial deviation [13–15]. In our
239 study, we did not find a significant improvement in motion after DSE, but even with limited
240 wrist motion, RSL fusion led to a high satisfaction rate, with 73% of patients being satisfied or
241 very satisfied with the procedure. Moreover, the importance of the dart thrower’s motion,
242 which consists of a movement in an oblique direction from radial extension to ulnar flexion,
243 has been emphasized [23,24]. Saffar and Semaan stated that this motion mainly involves the
244 midcarpal joint [25]. Crisco et al. drew similar conclusions from a kinematics analysis of 160
245 wrists [23]. Thus, RSL fusions allow the dart thrower’s motion to be performed [23,25].
246 Garcia-Elias emphasized that radiocarpal fusion may result in less motion than intercarpal
247 arthrodesis but provides a much more natural and efficient wrist motion [3]. Therefore,
248 although they limit wrist motion, radiocarpal fusions are not necessarily functionally
249 detrimental.

250 The non-union rate after RSL fusion ranges from 0% to 25% depending on the study
251 [6,10,12]. This worrisome rate could be explained by several factors such as lack of bone
252 graft or rigid bone fixation, especially with the use of K-wires in most older studies
253 [6,10,19,22]. Recent studies highlighted requirements for effective compression to achieve
254 fusion with a locking plate or memory staples [7]. Moreover, several authors highlighted that
255 DSE could promote fusion. Among the 103 published cases of RSL fusion with DSE, only 4
256 (4%) reported non-unions [7,9,13–15,26]. We found that DSE promoted radiocarpal fusion in
257 a statistically significant manner. In agreement with the literature [13,15,26], we recommend
258 performing at least cancellous bone grafting (from the distal radius or the resected scaphoid)
259 to promote fusion [27]. Extrinsic factors such as smoking or previous corticosteroid therapy
260 could have contributed to non-union but were not investigated in this study.

261 As shown in most studies, the progressive development of midcarpal osteoarthritis is
262 not unusual and is found in 0% to 100% of cases after RSL fusion alone [6,9–12,15]. STT
263 osteoarthritis can be explained by excessive mechanical strain between the scaphoid and
264 distal row [13]. Authors describing RSL fusion with DSE reported only 15 cases of midcarpal
265 osteoarthritis among 69 patients (23%) [9,13,14,26]. Bain et al. and Ha et al. did not report
266 the midcarpal osteoarthritis rate at the last follow-up [7,15]. We found different results: 18
267 midcarpal osteoarthritis cases among 42 patients with DSE (43%). However, the previous
268 studies mostly had a short-term follow-up (<5 years) or few cases, which could have
269 lessened the reports of midcarpal osteoarthritis. Montoya-Faivre et al. reported a 37%
270 midcarpal osteoarthritis rate (7/19 patients) after RSL fusion and DSE at a mean follow-up of
271 4.4 years [9]. In a cadaver study, Holleran et al. highlighted increased contact pressure in the
272 lunocapitate joint after RSL fusion with DSE as compared with RSL fusion alone [28]. Our
273 midcarpal osteoarthritis rate was not higher with RSL fusion and DSE than with RSL fusion
274 alone (35% vs 49%).

275 Additional TE has been promoted by a few authors to increase wrist motion and treat
276 ulnocarpal impaction syndrome [7,29]. We did not find a significantly increased ROM in FE or
277 RUD in patients with RSL fusion, DSE and TE compared to others. Moreover, the midcarpal

278 osteoarthritis rate was higher with both additional procedures (DSE and TE) than with DSE
279 alone (50% vs 26%) but not significantly. Because we did not observe significantly better
280 ROM after TE, we believe this procedure should be limited to treating ulnocarpal impaction
281 syndrome. Thus, it should be considered an alternative to DRUJ arthroplasty (Darrach's
282 procedure in our experience). In this context, Keuchel-Strobl et al. proposed shifting the
283 carpus more distally to treat ulnocarpal impaction syndrome and avoid any procedure at this
284 level (i.e. DRUJ arthroplasty or TE) [30]. Cancellous bone graft harvested from the radius
285 and the distal scaphoid was used to fill the arthrodesis site. However, we recommend
286 compressing the joint to promote radiocarpal fusion and performing DRUJ arthroplasty in
287 case of ulnocarpal impaction syndrome.

288 Only Ha et al. compared the three types of RSL fusion in a small case series (n = 15)
289 with a mean follow-up of 15 years (minimum 10 years) [30]. The authors reported good
290 clinical outcomes but less wrist motion in both FE and RUD as compared with our results.
291 These authors concluded that excising the distal scaphoid with or without TE would increase
292 ROM more in RUD than FE, which is more functional [23]. They did not describe
293 osteoarthritis changes but measured the narrowing of midcarpal joint. The lunocapitate joint
294 was narrower with RSL fusion with DSE and TE than with only DSE (0.8 vs 1.7 mm). We
295 observed similar radiographic results with a greater midcarpal osteoarthritis rate in patients
296 with additional TE versus only DSE (42% vs 26%).

297 We found a very high cumulative rate of complications/surgical revision after RSL
298 fusion (56% in our series). In 1997, Nagy and Büchler concluded that RSL surgical
299 techniques should be improved before they could be considered reliable [6]. Because RSL
300 fusion with DSE seems to yield fewer complications and a better outcome—with 38%
301 osteoarthritis, 8% non-union and 11% total wrist fusion—we strongly believe that it is the
302 better procedure for managing radiocarpal osteoarthritis. Additional TE seems to be
303 detrimental for midcarpal osteoarthritis and total wrist fusion rate, but not significantly.

304 Key technical points must be checked to ensure a good functional outcome: 1) first,
305 inspection of the midcarpal joint is essential to ensure that it is free of osteoarthritis; 2) an

306 appropriate fusion technique must be used that includes dynamic compression; 3) the use of
307 bone graft, either iliac crest or distal radius, is encouraged to avoid non-union.

308 This study has several limitations, including its retrospective design, the lack of
309 randomization, the disparate follow-up period, and the small number of participants, in
310 particular for rare events (such as complications or surgical revision). Splitting the RSL
311 population into three different groups greatly decreased the statistical power but allowed us
312 to assess the clinical and radiographic impact of doing the additional procedures (DSE and
313 TE). The small sample size invites caution in interpreting the findings. Moreover, this was a
314 dual-center study in which several surgeons with different skills performed RSL fusions. The
315 different techniques for stabilization could have influenced radiocarpal fusion. We did not
316 assess the clinical impact of the Darrach procedure, which may have skewed the results.
317 Further clinical studies are needed to draw conclusions about the real impact of TE on
318 radiographic results and confirm our results for RSL fusion and DSE.

319

320 **5. Conclusion**

321 RSL fusion is an effective procedure for maintaining some wrist motion and achieving pain
322 relief in patients with posttraumatic radiocarpal osteoarthritis. DSE seems to be associated
323 with reduced osteoarthritis and increased fusion rate. Because of a related increase in
324 midcarpal osteoarthritis rate, we believe that TE should be avoided and should be
325 considered an alternative to DRUJ arthroplasty to prevent ulnocarpal impaction syndrome.

326

327 **Conflict of interest:** The authors declared no potential conflicts of interest with respect to
328 the research, authorship, and/or publication of this article.

329

330 **Funding statement:** The authors received no financial support for the research, authorship,
331 and/or publication of this article.

332

333 **Informed consent:** All patients give their informed consent for this study.

334

335 **Acknowledgements:** Marie-Christine Picot, M.D. and Guillaume Nicolet, M.D. for statistical
336 analysis.

337

338 **References**

- 339 [1] Lameijer CM, Ten Duis HJ, Dusseldorp I van, Dijkstra PU, van der Sluis CK. Prevalence
340 of posttraumatic arthritis and the association with outcome measures following distal radius
341 fractures in non-osteoporotic patients: a systematic review. *Arch Orthop Trauma Surg*
342 2017;137:1499–513.
- 343 [2] Giannoudis PV, Tzioupis C, Papathanassopoulos A, Obakponovwe O, Roberts C.
344 Articular step-off and risk of post-traumatic osteoarthritis. *Evidence today. Injury*
345 2010;41:986–95.
- 346 [3] Garcia-Elias M, Lluch AL, Ferreres A. Partial arthrodesis for the treatment of radiocarpal
347 osteoarthritis. *J Am Soc Surg Hand* 2005;5:100–8.
- 348 [4] Bach AW. Radiocarpal fusion. *Tech Hand Up Extrem Surg* 2003;7:63–9.
- 349 [5] McGuire DT, Bain GI. Radioscapholunate fusions. *J Wrist Surg* 2012;1:135–40.
- 350 [6] Nagy L, Büchler U. Long-term results of radioscapholunate fusion following fractures of
351 the distal radius. *J Hand Surg Br* 1997;22:705–10.
- 352 [7] Bain GI, Ondimu P, Hallam P, Ashwood N. Radioscapholunate arthrodesis - a
353 prospective study. *Hand Surg* 2009;14:73–82.
- 354 [8] Linscheid RL, Dobyns JH. Radiolunate arthrodesis. *J Hand Surg Am* 1985;10:821–9.
- 355 [9] Montoya-Faivre D, Pomares G, Calafat V, Dap F, Dautel G. Clinical and radiological
356 outcomes following radioscapholunate fusion. *Orthop Traumatol Surg Res* 2017;103:1093–8.
- 357 [10] Mühldorfer M, Hohendorff B, Prommersberger K-J, van Schoonhoven J, van
358 Schoonhoven J. Medium-term results after radioscapholunate fusion for post-traumatic
359 osteoarthritis of the wrist. *Handchir Mikrochir Plast Chir* 2009;41:148–55.
- 360 [11] Hug U, Guggenheim M, Kilgus M, Giovanoli P. Treatment of radiocarpal degenerative
361 osteoarthritis by radioscapholunate arthrodesis: long-term follow-up. *Chir Main* 2012;31:71–
362 5.
- 363 [12] Kilgus M, Weishaupt D, Künzi W, Meyer VE. Radioscapholunate fusion: long-term
364 results. *Handchir Mikrochir Plast Chir* 2003;35:317–22.

365 [13] Garcia-Elias M, Lluch A, Ferreres A, Papini-Zorli I, Rahimtoola ZO. Treatment of
366 radiocarpal degenerative osteoarthritis by radioscapolunate arthrodesis and distal
367 scaphoidectomy. *J Hand Surg Am* 2005;30:8–15.

368 [14] Mühlendorfer-Fodor M, Ha HP, Hohendorff B, Löw S, Prommersberger KJ, van
369 Schoonhoven J. Results after radioscapolunate arthrodesis with or without resection of the
370 distal scaphoid pole. *J Hand Surg Am* 2012;37:2233–9.

371 [15] Ha NB, Phadnis J, MacLean SBM, Bain GI. Radioscapolunate fusion with triquetrum
372 and distal pole of scaphoid excision: long-term follow-up. *J Hand Surg Eur* 2018;43:168–73.

373 [16] Bain GI, Sood A, Yeo CJ. RSL fusion with excision of distal scaphoid and triquetrum: a
374 cadaveric study. *J Wrist Surg* 2014;3:37-41.

375 [17] Pervaiz K, Bowers WH, Isaacs JE, Owen JR, Wayne JS. Range of motion effects of
376 distal pole scaphoid excision and triquetral excision after radioscapolunate fusion: a
377 cadaver study. *J Hand Surg* 2009;34:832–7.

378 [18] Watson HK, Goodman ML, Johnson TR. Limited wrist arthrodesis. Part II: Intercarpal
379 and radiocarpal combinations. *J Hand Surg Am* 1981;6:223–33.

380 [19] Minami A, Ogino T, Minami M. Limited wrist fusions. *J Hand Surg Am* 1988;13:660–7.

381 [20] Bach AW, Almquist EE, Newman DM. Proximal row fusion as a solution for radiocarpal
382 arthritis. *J Hand Surg Am* 1991;16:424–31.

383 [21] Taleisnik J. Subtotal arthrodeses of the wrist joint. *Clin Orthop Relat Res* 1984;187:81–
384 8.

385 [22] Watson HK, Weinzwieg J, Guidera PM, Zeppieri J, Ashmead D. One thousand
386 intercarpal arthrodeses. *J Hand Surg Br* 1999;24:307–15.

387 [23] Crisco JJ, Coburn JC, Moore DC, Akelman E, Weiss APC, Wolfe SW. In vivo
388 radiocarpal kinematics and the dart thrower’s motion. *J Bone Joint Surg Am* 2005;87:2729–
389 40.

390 [24] Wolfe SW, Crisco JJ, Orr CM, Marzke MW. The dart-throwing motion of the wrist: is it
391 unique to humans? *J Hand Surg* 2006;31:1429-37.

- 392 [25] Saffar P, Semaan I. The study of the biomechanics of wrist movement in an oblique
393 plane-a preliminary report. In: Schuind F, An KN, Cooney WP 3rd, Garcia-Elias M (ed.)
394 Advances in biomechanics of the hand and wrist. New York, . Plenum Press & Springer,
395 1994, p. 305–11.
- 396 [26] Quadlbauer S, Leixnering M, Jurkowitsch J, Hausner T, Pezzei C. Volar
397 radioscapholunate arthrodesis and distal scaphoidectomy after malunited distal radius
398 fractures. J Hand Surg Am 2017;42:754.e1-e8.
- 399 [27] Degeorge B, Montoya-Faivre D, Dap F, Dautel G, Coulet B, Chammas M.
400 Radioscapholunate fusion for radiocarpal osteoarthritis: prognostic factors of clinical and
401 radiographic outcomes. J Wrist Surg 2019;8:456–62.
- 402 [28] Holleran AM, Quigley RJ, Rafijah GH, Lee TQ. Radioscapholunate arthrodesis with
403 excision of the distal scaphoid: comparison of contact characteristics to the intact wrist. J
404 Hand Surg Am 2013;38:706–11.
- 405 [29] Berkhout MJ, Shaw MN, Berglund LJ, An KN, Berger RA, Ritt MJPF. The effect of
406 radioscapholunate fusion on wrist movement and the subsequent effects of distal
407 scaphoidectomy and triquetrectomy. J Hand Surg Eur 2010;35:740–5.
- 408 [30] Keuchel-Strobl T, Quadlbauer S, Jurkowitsch J, Rosenauer R, Hausner T, et al.
409 Salvage procedure after malunited distal radius fractures and management of pain and
410 stiffness. Arch Orthop Trauma Surg 2020;140:697-705.

411

412 **Figure legends**

413 Fig. 1. Radioscapholunate (RSL) fusion procedure. Preoperative X-rays (A) and CT
414 arthrogram (B) showing degenerative changes after articular malunion of the distal radius.
415 Surgical procedure with inspection of the midcarpal joint and excision of the radiocarpal
416 cartilage (C), temporary fixation with K-wires (D) and final fixation with memory samples
417 associated with K-wires, distal scaphoid excision, and triquetrum excision (E). Postoperative
418 X-rays showing good compression and alignment of the radiocarpal joint (F, G).

419

420 Fig. 2. X-rays after RSL fusion with distal scaphoid excision (DSE) and no degenerative
421 changes in the midcarpal joint (A), midcarpal osteoarthritis (B) or non-union at the
422 radioscaphoid joint (C).

423

424 Fig. 3. Kaplan-Meier analysis of the survival of radioscapholunate fusion without total wrist
425 fusion for each group.

426 *RSL*: radioscapholunate; *DSE*: distal scaphoid excision; *TE*: triquetrum excision.

427

428 **Table titles**

429 Table 1. Comparison of total wrist fusion rate in each group

430 *RSL*: radioscapholunate; *DSE*: distal scaphoid excision; *TE*: triquetrum excision

431

432 Table 2. Baseline characteristics of the patients

433 *RSL*: radioscapholunate; *DSE*: distal scaphoid excision; *TE*: triquetrum excision; *SLAC*:

434 scapholunate advanced collapse

435

436 Table 3. Number and types of complications and revisions for patients with

437 radioscapholunate (*RSL*) fusion alone, with distal scaphoid excision (*DSE*) and with *DSE* and

438 triquetrum excision (*TE*).

439 *CRPS*: complex regional pain syndrome; *DRUJ*: distal radioulnar joint; *TWF*: Total wrist

440 fusion

441 Indications for tenoarthrolysis were wrist and finger extension stiffness after well-conducted

442 conservative treatment. Indications for *DRJU* arthroplasty were ulnocarpal impaction

443 syndrome.

444

445 Table 4. Comparison of clinical results at last follow-up

446 *RSL*: radioscapholunate; *DSE*: distal scaphoid excision; *TE*: triquetrum excision; *PROMs*:

447 patient-reported outcome measures; *ROM*: range of motion; *FE*: flexion-extension; *RUD*:

448 radioulnar deviation; QuickDASH: short version of the Disabilities of the Arm, Shoulder, and

449 Hand questionnaire; *PRWE*: Patient-Related Wrist Evaluation; *MMWS*: Modified Mayo Wrist

450 Score; *: statistically significant value.

451

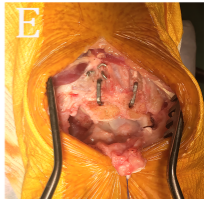
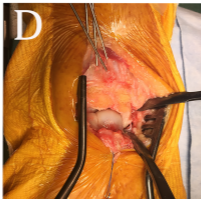
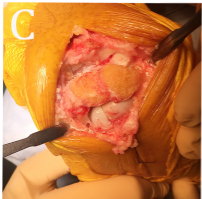
452 Table 5. Radiography results during follow-up and at review

453 *RSL*: radioscapholunate; *DSE*: distal scaphoid excision; *TE*: triquetrum excision; *STT*:

454 scaphotrapeziotrapezoid; *TWOA*: total wrist osteoarthritis; *: statistically significant value.

455 ^x All patients with non-union noted during follow-up underwent reoperation for bone grafting
456 or conversion to total wrist fusion in case of concurrent midcarpal osteoarthritis.

457 ^y The same patient had an early non-union treated by bone grafting with persistent non-union
458 at review.





- RSL fusion alone
- RSL fusion + DSE
- RSL fusion + DSE + TE

▲ Mean follow-up: 9.1 years

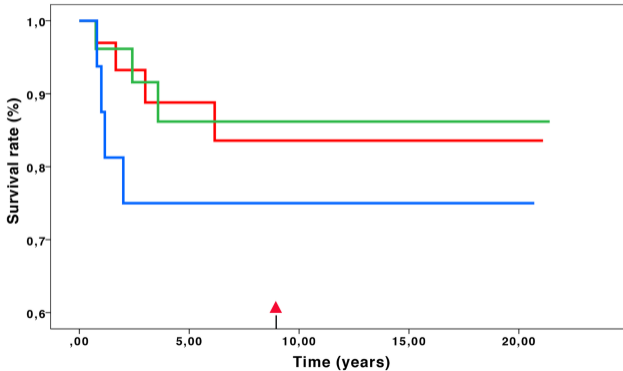


Table 1. Comparison of total wrist fusion rate in each group.

RSL: radioscapulohumeral; *DSE*: distal scaphoid excision; *TE*: triquetrum excision

| | RSL fusion alone (n=33) | RSL fusion + DSE (n=26) | RSL fusion + DSE + TE (n=16) | P value |
|--------------------|----------------------------|-------------------------------|------------------------------------|---------|
| Total wrist fusion | 4 (12%) | 3 (11%) | 4 (25%) | 0.42 |

Table 2. Baseline characteristics of the patients

RSL: radioscapulohumeral; *DSE*: distal scaphoid excision; *TE*: triquetrum excision; *SLAC*: scapholunate advanced collapse

| | RSL fusion alone (n=29) | RSL fusion + DSE (n=23) | RSL fusion + DSE + TE (n=12) | P value |
|-------------------------------|-------------------------------|-------------------------------|------------------------------------|---------|
| Age (years) | | | | |
| mean (SD) | 54 (SD 12) | 48 (SD 14) | 56 (SD 11) | 0.162 |
| Gender (male) | | | | |
| n (%) | 24 (83) | 20 (87) | 10 (83) | 0.912 |
| Dominant limb affected | | | | |
| n (%) | 16 (55) | 14 (61) | 8 (66) | 0.780 |
| Heavy manual labor | | | | |
| n (%) | 20 (69) | 14 (61) | 8 (67) | 0.827 |
| Work-related accident | | | | |
| n (%) | 12 (41) | 9 (39) | 5 (42) | 0.983 |
| Indication: n (%) | | | | |
| Articular malunion | 25 (86) | 20 (87) | 9 (75) | 0.612 |
| Dislocation-fracture | 4 (14) | 2 (9) | 2 (17) | |
| SLAC wrist | - | 1 (4) | 1 (8) | |
| Follow-up (years) | | | | |
| Mean (SD) | 8.9 (SD 7.2) | 8.0 (SD 5.9) | 11.7 (SD 6.6) | 0.298 |

Table 3. Number and types of complications and revisions for patients with radioscapholunate (RSL) fusion alone, with distal scaphoid excision (DSE) and with DSE and triquetrum excision (TE).

CRPS: complex regional pain syndrome; *DRUJ*: distal radioulnar joint; *TWF*: Total wrist fusion

Indications for tenoarthrolysis were wrist and finger extension stiffness after well-conducted conservative treatment. Indications for DRJU arthroplasty were ulnocarpal impaction syndrome.

| | RSL fusion alone (n=33) | RSL fusion + DSE (n=26) | RSL fusion + DSE + TE (n=16) | P value |
|---------------|--|---|--|------------|
| Complications | 2 CRPS 1 non-union 1 stiffness | 1 non-union 1 stiffness | 1 non-union | 0.75 |
| Total: n (%) | 4 (12) | 2 (8) | 1 (6) | |
| Revisions | 5 DRUJ arthroplasty 6 implant removals 1 dorsal tenoarthrolysis 1 bone grafting 4 TWF | 1 dorsal tenoarthrolysis 1 bone grafting 5 implant removals 3 TWF | 1 bone grafting 3 implant removals 4 TWF | 0.58 |
| Total: n (%) | 17 (51) | 10 (38) | 8 (50) | |

Table 4. Comparison of clinical results at last follow-up

RSL: radioscapulohumeral; *DSE*: distal scaphoid excision; *TE*: triquetrum excision; *PROMs*: patient-reported outcome measures; *ROM*: range of motion; *FE*: flexion-extension; *RUD*: radioulnar deviation; QuickDASH: short version of the Disabilities of the Arm, Shoulder, and Hand questionnaire; PRWE: Patient-Related Wrist Evaluation; MMWS: Modified Mayo Wrist Score; *: statistically significant value.

| | | RSL fusion alone (n=29) | RSL fusion + DSE (n=23) | RSL fusion + DSE + TE (n=12) | P value |
|----------------------------------|---------------------|-------------------------------|-------------------------------|------------------------------------|---------|
| ROM (°) | Flexion | 22 ± 12 | 27 ± 12 | 21 ± 12 | 0.25 |
| | Extension | 28 ± 12 | 29 ± 10 | 38 ± 18 | 0.08 |
| | ROM FE | 49 ± 17 | 55 ± 20 | 59 ± 18 | 0.28 |
| | Radial deviation | 11 ± 9 | 14 ± 9 | 11 ± 6 | 0.56 |
| | Ulnar deviation | 19 ± 7 | 19 ± 9 | 20 ± 10 | 0.95 |
| | ROM RUD | 30 ± 12 | 32 ± 14 | 31 ± 11 | 0.78 |
| Grip strength | Kg/F | 22 ± 10 | 33 ± 13 | 28 ± 14 | 0,005* |
| Patient- reported outcomes | QuickDASH | 42.7 ± 21.6 | 35.7 ± 20.1 | 34,8 ± 20 1 | 0.40 |
| | PRWE score | 40.7 ± 21.9 | 32.8 ± 20.4 | 33,6 ± 19,2 | 0.38 |
| | MMWS | 61.1 ± 21.0 | 71.1 ± 18.1 | 75,9 ± 18,3 | 0.07 |

Table 5. Radiography results during follow-up and at review

RSL: radioscapulohunate; *DSE*: distal scaphoid excision; *TE*: triquetrum excision; *STT*: scaphotrapeziotrapezoid; *TWOA*: total wrist osteoarthritis; *: statistically significant value.

^x All patients with non-union noted during follow-up underwent reoperation for bone grafting or conversion to total wrist fusion in case of concurrent midcarpal osteoarthritis.

^y The same patient had an early non-union treated by bone grafting with persistent non-union at review.

| | | RSL fusion alone (n=33) | RSL fusion + DSE (n=26) | RSL fusion + DSE + TE (n=16) | P value |
|--------------------------|-------------------------------|-------------------------------|-------------------------------|------------------------------------|---------|
| Osteoarthritis (n, %) | STT | 21 (64) | 1 (4) | 2 (12) | <0.001* |
| | Midcarpal | 16 (49) | 9 (35) | 9 (56) | 0.34 |
| | TWOA | 25 (76) | 10 (38) | 11 (69) | 0.011* |
| Non-union (n, %) | During follow-up ^x | 5 (5) | 1 (4) | 1 (13) | 0.79 |
| | At review | 9 (31) | 2 (9) | 1 (8) | 0.072 |
| | Total | 14 (42) | 2 (8) ^y | 2 (12) | 0.004* |