Is distal ulna resection influential on outcomes of distal radius malunion corrective osteotomies?

B. Coulet a,∗, M. Id El Oualia a, J. Borettob, C. Lazergesa, M. Chammas a

a Lapeyronie Regional Academic Hospital Center, Upper Extremity and Hand Surgery Department, 371, avenue du Doyen-Gaston-Girard, Montpellier cedex 5, France
b Buenos Aires Italian Hospital, Orthopaedic and Hand Surgeon, Potosi 4247, C1199ACK Buenos Aires, Argentina

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Summary

Introduction: The mechanical repercussions of distal radius malunion on the distal radio-ulnar (DRU) joint are common and inconsistently corrected by radius osteotomy alone. Ulnar resection has thus become a palliative solution.

Hypotheses: Does ulna resection influence the outcomes of distal radius malunion corrective osteotomies? What preoperative factors warrant preserving the distal radio-ulnar joint?

Patients and methods: Twenty-one corrective osteotomies of the radius were retrospectively reviewed. Ulna resection was performed in cases of cartilage damage, joint incongruence, or persistent stiffness in pronosupination after osteotomy of the radius. After the osteotomies, two groups were identified: 10 cases with preservation of the distal end of the ulna (DRU+) and eleven with distal resections (DRU−).

Results: At review, all the osteotomies had united, with comparable anatomical restoration of the radial epiphysis for the two groups. We noted a statistically significant gain in mobility after osteotomy for both techniques (but no difference between them) and comparable grip strengths with 89.8% of the contralateral side for the DRU+ group versus 90.4% for the DRU− group. Pain (scale, 0–3) had significantly diminished for both groups decreasing from 1.9 to 0.3 for the DRU+ group and from 2.5 to 1.1 for the DRU− group, with no significant difference between them. The Mayo Clinic Wrist Score and the DASH score did not differ significantly with 73/100 and 13.5 for the DRU+ group compared with 68.2/100 and 20.2 for the DRU− group, respectively.

Discussion: These results show that the impact of ulna resection after distal osteotomy of the radius is limited as reflected by radiological correction, mobility and grip strength. However, after resection pain in the ulnar tilt of the wrist due to instability of the distal ulnar stump was noted. Besides cartilage damage, ulnar deviation of over 5 mm was, for this series, a constant factor in non-preservation of the DRU joint.

Level of evidence: Level IV. Retrospective study.

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∗ Corresponding author. Lapeyronie Regional Academic Hospital Center, Upper Extremity and Hand Surgery Department, 371, avenue du Doyen-Gaston-Giraud, Montpellier cedex 5, France. Tel.: +33 4 67 33 85 37; fax: +33 04 67 33 79 66.
E-mail address: Bertrand-coulet@wanadoo.fr (B. Coulet).

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Introduction

Distal radius malunions result from a defect or a loss of fracture reduction and result in misalignment of the radiocarpal joint surfaces as well as the distal radio-ulnar (DRU) joint surfaces [1,2].

Extra-articular forms lead to displacement of radiocarpal mobility sectors and for the most severe cases, compensatory misalignment of the carpus that may set in over time [3,4]. Disorganization of the DRU is the main source of pain in patients with pronosupination stiffness and invalidating pain. Other than cartilaginous lesions facing the fracture line, misalignment of the radial side of the DRU is the major cause of its incongruity. When necessary, osteotomy of the radius sometimes realigns the sigmoid fossa of the radius and thus rebalances the two bones of the forearm.

Inversely, substantial cartilaginous deformities or lesions make preservation of the DRU impossible, requiring palliative treatment. The decision to preserve the DRU is often made intraoperatively after realignment of the radial epiphysis.

Resection of the distal extremity of the ulna associated with stabilization was described at the beginning of the twentieth century by Darrach [2]. Widely used, it has been criticized over the past 30 years, resulting in certain authors reporting a loss of grip strength and residual pain. Nevertheless, in the context of distal radius malunion correction, this technique has the advantage of not requiring excessive resection of the ulna and not being dependent on new bone union.

The objective of this study was to assess the impact of palliative treatment compared to conservative treatment and to specify the preoperative radiological criteria for the immediate indication of this procedure.

Patients and methods

Inclusion criteria

Twenty-one distal metaphyseal osteotomies of the radius performed from 2002 to 2008 for correction of extra-articular malunion were studied retrospectively. The procedure was indicated for the most part because of pronosupination limitation and pain on the ulnar side of the wrist.

The decision not to preserve the DRU joint was made either preoperatively because of significant cartilage lesions based on the arthro-CT or more often intraoperatively when after correction of malunion DRU instability or pronosupination block persisted.

Patients with less than 18 months follow-up and those who had undergone another procedure than ulnar resection to correct DRU problems were excluded from the study.

Composition of the groups

Two groups were formed:

- DRU+ group: 10 patients who had undergone osteotomy of the radius with preservation of the DRU joint;
- DRU− group: 11 patients whose osteotomy of the radius was associated with resection of the distal extremity of the ulna using the same technique.

The demographic data on the two groups is reported in Table 1; only age at the time of the osteotomy differed between the two populations at the limit of significance ($P=0.07$).

As for the initial lesions, the DRU+ included eight malunions with posterior displacement, five secondary to orthopaedic treatment, two after reduction associated with styloid pins, and one after osteosynthesis with an anterior plate. Two cases presented anterior displacement, one after orthopaedic treatment and one from hypercorrection due to intrafocal pinning. In this group, seven patients presented a fracture of the ulnar styloid and DRU dislocation.

Treatement of the initial fracture was complicated by two cases of neurological algodystrophy syndrome, one case of neuroma on a sensory branch of the radial nerve, one tendon rupture, and one rupture of the extensor pollicis longus (EPL).

In the DRU− group, six cases of malunion presented posterior displacement despite styloid pinning and five

Figure 1  Different initial joint amplitudes (light shading) and at revision (dark shading) for both groups, with preservation of the distal radio-ulnar joint (DRU+) (first two columns) or non-preservation (DRU−) (last two columns).
Distal resection of the ulna and radial osteotomies for malunion

Table 1  Demographic data on both groups of patients.

<table>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>Age</th>
<th>Sex ratio f/m</th>
<th>Dominant side</th>
<th>Work injury</th>
<th>Heavy workers</th>
<th>Delay from fracture to osteotomy (months)</th>
<th>Follow-up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRU+</td>
<td>10</td>
<td>37.3 ± 14.4</td>
<td>4/6</td>
<td>5/10</td>
<td>2/10</td>
<td>3/10</td>
<td>10.7 ± 7.8</td>
<td>41.1</td>
</tr>
<tr>
<td>DRU−</td>
<td>11</td>
<td>49.8 ± 12.4</td>
<td>7/4</td>
<td>5/11</td>
<td>3/11</td>
<td>1/11</td>
<td>12.0 ± 10.9</td>
<td>45.6</td>
</tr>
</tbody>
</table>

DRU+: preservation of distal radio-ulnar joint; DRU−: non-preservation.

Presented anterior displacement, two after orthopaedic treatment and three secondary to hypercorrection due to intrafocal pinning. In eight cases, the DRU joint was dislocated and in five the ulnar styloid was fractured. The initial treatment was complicated by neural algodystrophy syndrome, two from ulnar nerve compression at the Guyon canal and one medial nerve of the carpal canal.

There was no statistically significant difference in initial mobility between the two groups (Fig. 1).

On the radiological level, considering anterior displacement malunions separately from posterior displacement malunions, despite the greater deformities in the DRU− group, no statistically significant difference was demonstrated between the two groups in terms of alignment of the distal radial joint surface (Figs. 2 and 3). Only ulnar deviation differed very significantly between the groups (P=0.002), with a value of 1.5 mm (range, 0–3 mm) in the DRU+ group versus 10.5 mm in the DRU− group (range, 0–18 mm).

Surgical techniques

Corrective osteotomies of the radius
The same techniques were used in both groups.

The osteotomies with dorsal opening were performed through a posterior approach to the radius. Osteosynthesis was provided by styloid pinning following a diverging pattern. Anteriorly tilting malunions were corrected with palmar opening osteotomy maintained by an anterior interlocking plate. The bone defect was filled with trapezoid bone graft harvested either on the iliac crest or from the resected ulnar head (DRU− group). After realignment of the radius, the DRU joint stability and the pronosupination aspect were assessed; in cases of instability or pronosupination stiffness, the ulnar head was resected.

Ulnar head resection technique
Through a dorsal approach to the distal radius and ulna, the sixth compartment was opened opposite the extensor carpi ulnaris (ECU) tendon. The longitudinal capsulotomy of the DRU was performed at the base of the joint space, so that a wide capsuloperiosteal flap with a medial hinge could be detached. The ulnar head was resected after a transversal osteotomy of the distal part of the neck. The joint capsule and the retinaculum of the extensors were carefully closed, with the ulna in the reduced position. A retinacular flap stabilized the ECU in the dorsal position.

No other complementary stabilization procedure on the ulna was performed in this series.

The details of the different procedures can be found in Table 2.

Evaluation method
All the patients were seen at the last follow-up by a different physician who was not among the operators.

Subjective satisfaction and the degree of pain experienced were scored according to the following criteria: (4: very satisfied; 3: moderately satisfied; 2: dissatisfied but able to work; 1: dissatisfied, unable to work), (0: no pain;
Table 2  Details of surgical procedures performed in both groups depending on type of malunion.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Type of malunion</th>
<th>n</th>
<th>Surgical procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 Dorsal opening wedge osteotomy stabilized with pins + synthetic bone</td>
</tr>
<tr>
<td></td>
<td>Dorsal tilt deformity [2]</td>
<td>1</td>
<td>Anterior opening wedge osteotomy stabilized with plate + iliac crest bone graft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Anterior opening wedge osteotomy stabilized with plate without graft</td>
</tr>
<tr>
<td></td>
<td>Palmar tilt deformity [5]</td>
<td>4</td>
<td>Anterior opening wedge osteotomy stabilized with plate + graft with ulnar head</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>Dorsal closing wedge osteotomy stabilized with pins</td>
</tr>
</tbody>
</table>

1: slight pain during intense activities and/or pain only with changes in weather; 2: pain during simple movements with no limitation in activities; 3: pain with limitations in daily activities.

Joint mobility was measured using a goniometer and grip force with a dynamometer (Jamar™).

The Mayo Clinic wrist score provided an overall assessment [5] (Table 3), the DASH score [6] evaluated functional incapacity.

X-rays were used to assess radial epiphyseal misalignment; ulnar sliding was assessed with the Bouman index [7] (Fig. 4) (a value less than 0.83 was considered pathological).

The statistical analysis was carried out with ExcelStat®, using Wilcoxon nonparametric tests to compare paired variables and the Mann-Whitney test for ordinal variables.

**Results**

All the patients were seen for follow-up at a mean 43.5 months (range, 23–67 months).

**Complications**

In the DRU+ group there was one rupture of the EPL and the extensor digitorum communis of the fourth metacarpal. In the DRU− group, four patients reported painful ECU tendinopathy. Three wrists presented ulnar sliding with a pathological Bouman index score and two of them ossifications of the resection cavity of the ulna, but with no clinical repercussions.

**Functional results**

Satisfaction index and overall wrist assessment

In both groups, patient satisfaction was high: with a maximum value of 4, this score was 3.5 (range, 2–4) for DRU+ and 3.6 (range, 2–4) for DRU− (NS). In the DRU+ group, 84% returned to their former activities versus 82% in the other group.

The Mayo Clinic Wrist Score at revision was 73.0 out of 100 in the DRU+ group (range, 65–80) and 68.2 (range, 35–85) in the DRU− group; the difference between the two groups was not significant (P = 0.76). In the DRU+ group, this corresponded to one good result and nine fair results, and for the DRU− group to three good, four fair, and four poor results.

The mean DASH values were 13.5 (range, 5–28) in the DRU+ and 20.2 (range, 5–29) in the other (NS).

*Figure 4  Bouman ulnar translation index of the wrist [7]. AB / (AC–DC) = 0.87 ± 0.04. A: tip of radial styloid; B: medial side of the radial joint surface; C: medial part of the lunatum joint surface; D: lateral edge of the lunatum. A value less than 0.83 indicates pathological ulnar translation of the carpus.*
Table 3  Mayo Clinic functional score [5] taking pain, function, mobility, and strength of the wrist, out of 100 points.

<table>
<thead>
<tr>
<th>Mayo Clinic wrist score (100 points)</th>
<th>Score</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain (25 points)</td>
<td>25</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Low, occasional</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Moderate, tolerable</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Severe, intolerable</td>
</tr>
<tr>
<td>Function (25 points)</td>
<td>25</td>
<td>Resumed work activity</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Returned to work, adapted position</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Work possible but unemployed</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Cannot work because of pain</td>
</tr>
<tr>
<td>Mobility (25 points)</td>
<td>25</td>
<td>≥ 120°</td>
</tr>
<tr>
<td>(flexion/extension)</td>
<td>15</td>
<td>91°—119°</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>61°—90°</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>31°—60°</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>≤ 30°</td>
</tr>
<tr>
<td>Grip strength (25 points) (percentage of contralateral side)</td>
<td>25</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>75—99%</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>50—74%</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>25—49%</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0—24%</td>
</tr>
<tr>
<td>Overall assessment</td>
<td>Excellent</td>
<td>90—100 points</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>80—89 points</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>65—79 points</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>&lt; 65 points</td>
</tr>
</tbody>
</table>

Clinical results

Pain
Initially, the mean pain score was 1.9 out of a maximum value of 3 (range, 0—3) in the DRU+ group and 2.5 (range, 0—3) in the other group. This difference was not statistically significant (P = 0.21). This pain was exclusively on the ulnar side of the wrist.

At revision, these values decreased significantly, dropping to 0.3 (range, 0—1) and 1.1 (range, 0—2), respectively. The difference between the two groups at revision was statistically close to the significance threshold (P = 0.17).

In the DRU+ group, three patients complained of pain, but only during intense activities. On the other hand, after resection of the ulna, only three patients were strictly pain-free, five presented pain only during intense activities, and two for activities of daily life. Following a work accident, one patient could not perform his daily activities.

Mobility
The initial wrist mobility values and those at revision are reported in Fig. 1.

The gain in mobility in the different sectors after osteotomy was statistically significant for both groups except for radial inclination and in the DRU— group for flexion (P = 0.083).

Supination, which was consistently limited preoperatively, recuperated in both groups.

For all of the patients, the osteotomy did not displace the mobility sector, but increased it statistically significantly, rising in the DRU+ group from 89.5° initially (range, 70—160°) to 113.8° at the last follow-up (range, 75—130°) and in the DRU— group from 75° (range, 20—115°) to 112.9° (range, 80—140°).

Digitopalmar grip strength
The absolute value of grip strength at revision was 31 kg (range, 20—44 kg) for the DRU+ group and 19.5 kg (range, 4—38 kg) for the DRU— group. This difference was statistically significant. Expressed as a percentage of the contralateral score, these values were 89.8% (range, 64—138%) and 90.4% (range, 33—200%), respectively.

Radiological results

At revision, all the osteotomies had united.

The anterior and medial tilt values are reported in Figs. 2 and 3. Anatomic restoration was identical in the two groups for all types of malunion. Ulnar variance in the DRU+ group decreased from 1.4 mm (range, 0—4) to 0.3 mm (range, 1.5 to −4 mm) (NS); it was a mean 10.5 mm (range, 0—17 mm) in the DRU— group.

In Fig. 5, the cases in each group are reported according to their anterior tilt on the X-ray along the x-axis (sagittal plane) and their ulnar deviation along the y-axis. All the subjects are reported for the preoperative measurements and only those in the DRU+ group at revision (those who had a measurable ulnar deviation). A high level of consistency in the distribution of the groups was observed. The cases whose DRU was preserved all had ulnar deviation less
when it is limited to pins in the dorsal addition osteotomies. It seems to alter the stability of the osteosynthesis, even if this factor is the main cause of patient satisfaction. Even if the mean pain score between the two groups did not differ significantly, this parameter is the main discriminating factor. In the DRU—group, the pain relief results were clearly less systematic. 27% reported pain in elementary tasks of daily life and only 27% of the patients presented a pain-free wrist versus 70% after DRU preservation.

This study did not aim to compare the two techniques but simply to evaluate the impact of ulnar resection. The DRU—group was made up of cases of failure restoring radio-ulnar congruence after isolated radial osteotomy, they presented more severe forms in older and less demanding patients. This notion induces a bias in favor of this group in terms of patient satisfaction, the functional result, and particularly the variables expressed as a percentage of the contralateral side. This notion should definitely be taken into consideration in the analysis of the results. Thus, this study confirms that preservation of the DRU is preferable, but that a Darrach-type palliative procedure in severe forms can provide satisfactory results.

In contrast, the fact that the DRU—group comprised conservative treatment failures allowed us to detail the preoperative factors conditioning the effectiveness of radial osteotomy in restoring DRU congruity.

The initial shortening of the radius quantified by ulnar deviation seems to be one of the main advantages. Fig. 5 clearly shows that beyond 5 mm of ulnar deviation, DRU congruity cannot be restored by radial osteotomy alone and that ulnar surgery is therefore necessary. We also noted that the small amounts of shortening making conservative treatment possible were for the most part in cases of malunion with posterior displacement, with the anterior forms having a less favorable prognosis. The research on extra-articular malunion correction of the radius [9—12,14,16—22] shows that all the authors who did not intervene on the DRU had ulnar deviation values in their series less than 5 mm, contrary to those associating a palliative procedure on the DRU joint or ulnar shortening, who reported deviation values greater than 5 mm [8,23]. Yet in the same series, despite satisfactory realignment of the radial epiphysis, only a few millimeters of ulnar deviation correction with radial osteotomy was observed. This explains why many authors recommend shortening the ulna to preserve DRU congruity after osteotomy of the radius [23].

Residual pain on the ulnar side of the wrist was the main difference between the two groups, resulting essentially from instability of the ulnar stump [9,24]. In a series of Darrach procedures associated with osteotomy of the radius, Bour et al. [13] reported that 71% of wrists remained intermittently painful. On the other hand, when resection of the ulna was isolated, Hartz et al. [25] as well as Tulipan et al. [26] reported rates of 9—33%, and more recently Mansat et al., based on a series of isolated Darrach procedures seen at more than 6 years of follow-up, did not report these pain phenomena.

The significant reduction in pain in both groups is the main source of patient satisfaction. Even if the mean pain score between the two groups did not differ significantly, this parameter is the main discriminating factor. In the DRU—group, the pain relief results were clearly less systematic. 27% reported pain in elementary tasks of daily life and only 27% of the patients presented a pain-free wrist versus 70% after DRU preservation.

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Distal resection of the ulna and radial osteotomies for malunion

Figures 6 and 7  Preoperative AP and lateral X-rays of extra-articular malunion of the distal radius. The parameters taken into consideration are shown: AP image, medial tilt (MT) of the radius and ulnar deviation; lateral image, anterior tilt (AT). This was a case of radial malunion with posterior displacement with distal radio-ulnar incongruity and ulnar deviation greater than 5 mm.

presenting the most invalidating pain had the highest initial ulnar deviation values.

When DRU congruity cannot be restored by radial osteotomy alone, the alternatives to resection of the ulna are either palliative (Bowers-type hemiresection or a Sauvé-Kapandji-type procedure) or conservative (shortening osteotomy and realignment of the ulna).

In terms of mobility and grip strength, for these palliative procedures the literature review shows results comparable to ours, on the order of 80% of the contralateral side. Ulnar sliding of the carpus after resection of the ulna seems insignificant in the posttraumatic context, as we have observed and as demonstrated by the large series reviewed at the long-term reported by Mansat et al. [15].

However, pain in the distal stump of the ulna is the essential problem: the more a shortening procedure is necessary, the more frequently this pain is experienced by the patient. Comparison of the different techniques in this precise context is not easy because the analysis of pain phenomena has not been standardized and the series are relatively small. In a posttraumatic context after an isolated Sauvé-Kapandji (SK) procedure, Sanders et al. [27], Taleisnik et al. [28], and Nakamura et al. [29] reported between 30 and 40% of patients with pain during moderate effort. Despite stabilization of the distal stump of the ulna, using the flexor carpi ulnaris, Lamey et al. [30] still had 20% painful wrists. Only Carter et al. [31] reported a series that was comparable to ours associating four cases undergoing a Sauvé-Kapandji procedure with osteotomy of the radius: only two cases improved and 50% of the patients still experienced pain.

The notion of the length of the distal stump of the ulna is essential. Daecke et al. [32] showed that ulnar
Figures 8 and 9  Postoperative AP and lateral X-rays after radial osteotomy using a dorsal approach, graft using the ulnar head and dorsal osteosynthesis with pin fixation.

resection after the Sauvé-Kapandji procedure should not exceed 35 mm; otherwise, an unstable stump could appear. In cases of substantial shortening of the radius, the Darrach-type resection makes it possible to limit the height of the ulnar cut, whereas a Sauvé-Kapandji procedure necessarily requires cutting the ulna more proximally, a source of instability and pain.

Bowers-type [33] hemiarthroplasty is not an answer to all problems. The author reports 11% painful stumps, Bain et al. [34] 32% based on a series of 49 cases, and Watson 27% [24].

Osteotomy shortening the ulna is a logical alternative to restore DRU congruence. Some authors propose this osteotomy at the same time as radial osteotomy [23,34,35], others at a later time [8]. Irrespective of the risk for non-union, these authors report satisfactory recuperation of mobility and grip strength 73% of the contralateral side, comparable to our results. As for pain, in three cases Wada et al. [23] and El-Karef et al. [8] in six cases, report 33% persistent pain with certain cases showing substantial loss of strength. Ulnar realignment osteotomy is effective when the main deformity of the radius is shortening, but much less so in cases with a rotational component or incomplete malunion correction.

In 37 malunions of the distal radius, Prommersberger et al. [36] showed a rotational component in 27 cases, with a majority of anterior malunions. This deformity is rarely taken into account in correcting malunion, even though it affects restoration of DRU congruity after osteotomy. Moreover, in cases of ulnar section, it increases loss of colinearity between the axes of the two forearm bones, resulting in overhanging of the ulnar stump.
Finally, the integrity of the interosseous membrane conditions the stability of the distal extremity of the ulna. This factor, put forward by Wolfe et al. [37], is in fact difficult to assess preoperatively but can explain certain unstable stumps.

Conclusion

This study shows that the impact of distal resection of the ulna associated by necessity with the correction of malunion of the distal radius is limited in terms of mobility and grip strength. However, it induces more residual pain on the ulnar side of the wrist, for the most part through instability of the distal stump. We observed that beyond 5 mm of radius shortening (ulnar variance), radial osteotomy alone did not suffice to restore DRU congruity. Darrach-type distal resection of the ulna then becomes an option but carries the risk of residual pain on an unstable stump and should be reserved for older patients. In younger patients, ulnar shortening and realignment osteotomy should be preferred when loss of radius height is substantial and the rotational component of distal radius malunion is limited. An SK procedure could be entertained in cases of substantial cartilaginous lesions with moderate initial ulnar deviation.

Disclosure of interest

The authors declare they have no conflicts of interest concerning this article.

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