

Appendix

Radiographic and Operative Variables

Dorsal subluxation of the distal radioulnar joint was quantified preoperatively by measuring the radioulnar distance on a true lateral radiograph of the wrist—i.e., one on which the pisoscapoid distance was <3 mm (**Figs. E-1A and E-1B**)³². If the direction of subluxation was volar, this was described as a positive. Perioperative ulnar variance was measured, using the method of perpendiculars, as the distance between a line drawn perpendicular to the longitudinal axis of the radius at its distal-ulnar aspect and a line at the end of the ulna³³. For accurate determination of ulnar variance, a posteroanterior radiograph of the wrist was obtained with the shoulder in 90° of abduction, the elbow in 90° of flexion, the forearm in neutral rotation, and the wrist in neutral alignment. The morphology of the distal radioulnar joint was classified as Type I (apposing joint surfaces parallel to the longitudinal axis of the ulna), Type II (apposing joint surfaces oblique, with a positive sigmoid notch angle), or Type III (apposing joint surfaces in a reverse oblique orientation, with a negative sigmoid notch angle)¹² (**Figs. 1-A, 1-B, and 1-C**). Radiographic findings suggestive of arthritic changes were joint space narrowing, osseous spur(s), osteophyte(s) on the inferior edge of the distal radioulnar joint, subchondral cyst(s), and sclerosis.

Some of the patients underwent treatment with width-specific parallel saw blades (DePuy Synthes), which produce 4 different amounts of shortening ranging from 2 to 5 mm and provided a simple and accurate parallel osteotomy. Other patients were treated using a thin single-blade saw (Conmed) with a thickness of 0.4 mm (**Fig. 2**). Three types of plate were used: (1) a conventional 6-hole plate—i.e., a 3.5-mm small-bone plate for transverse osteotomy (Osteonics; Stryker); (2) an Acumed plate for oblique osteotomy; and (3) a newly developed locking compression plate (LCP) for transverse ulnar osteotomy (DePuy Synthes). Six, 7, or 8 screws were used. The plates used after transverse osteotomy were generally fixed with 6 screws, except in a few patients with osteoporotic bone, in whom 8 screws were used. The position of the plate on the volar or dorsal ulnar surface was determined by the surgeon choosing the most anatomically accommodating position.

Surgical Procedure and Postoperative Care

All operations were performed by the senior authors. Arthroscopic procedures were carried out according to a previously described method, with use of a tourniquet and with the patient under general anesthesia¹¹. The lunotriquetral interosseous ligaments and TFCC were inspected thoroughly, as were the articular surfaces of the lunate and triquetrum. All patients underwent debridement of damaged TFCC tissue with use of a small joint cutter (Arthrex) or an electrothermal small joint probe (Vulcan EAS; Smith & Nephew) to achieve a stable margin. USO was performed after the arthroscopic procedures. In 229 patients, conventional plate fixation after transverse osteotomy was performed with a single-blade mini-saw according to the traditional method of Baek et al.⁷. Another 35 patients were treated with a specific USO system after oblique osteotomy through the guide attached to the plate, as recently reported by Clark and Geissler⁸. A third, recently reported method involving the LCP ulnar plate after transverse osteotomy with width-specific parallel saw blades (double-blade saw) was used for 61 patients⁵. The arm was elevated for 24 hours, and the patient was encouraged to move the fingers actively. The patient was discharged from the hospital on

postoperative day 3, after the wound had been examined and the bandage changed to a light dressing. Two weeks later, the sutures were removed, and the patient—fitted with a removable long arm splint that was usually worn for an additional 4 weeks—began range-of-motion exercises of the elbow and wrist.

Evaluation of Osseous Consolidation

Osseous union at the osteotomy site was defined as >3 regions of bone-bridging among the radial, ulnar, dorsal, and volar cortical aspects of the distal part of the ulna, as seen on anteroposterior, lateral, and both oblique projections, by a hand surgeon who had not performed the operation (but is one of the authors) in a blinded manner. Orthogonal radiographs were assessed for cortical bridging across the osteotomy site beginning at 10 weeks postoperatively and monthly thereafter until osseous union was achieved¹⁴. For patients with radiographic evidence of union, physical examinations were performed by the senior author to confirm a pain-free ulna, particularly in the osteotomy area. Thus, final osseous union was considered to have occurred only when both radiographic and clinical criteria had been met. A union that was achieved after 6 months was defined as a delayed union, whereas nonunion was defined as an osteotomy site that either lacked congruence of at least 3 of 4 cortices 6 months or longer after the surgery or did not show any radiographic changes for 3 consecutive months and was associated with clinical findings consistent with nonunion (inability to bear weight through the affected extremity, pain on palpation, or pseudomotion at the osteotomy site beginning 3 months following the USO).



Fig. E-1A

Figs. E-1A and E-1B The method for quantification of the dorsal subluxation of the wrist described by Nakamura et al.³². First, the pisoscaphoid distance was measured between the long axes of the radius and ulna at the most prominent ulnar point (top parallel lines) to ensure that it was <3 mm and the image was thus a true lateral radiograph of the wrist. All measurements were performed using a picture archiving and communication system (PACS; Marosis m-view 5.4). **Fig. E-1A** A few patients showed volar ulnar subluxation compared with the radius.



Fig. E-1B

Most patients showed dorsal subluxation of the ulna.

TABLE E-1 Outcomes at Final Follow-up

Variables	Group 1 (Union)	Group 2 (Delayed Union or Nonunion)	P Value
Postop. VAS pain score	0.44 ± 0.18	1.92 ± 0.73	0.021
Postop. wrist flexion-extension arc (°)	146.35 ± 13.02	132.41 ± 11.67	0.033
Postop. forearm pronation-supination arc (°)	163.28 ± 17.61	150.08 ± 11.67	0.019
Postop. modified Mayo wrist score	92.25 ± 8.61	80.28 ± 9.45	0.031

TABLE E-2 Comparison of Demographic, Clinical, Radiographic, and Operative Data Between Groups in Univariate
Analysis with Exclusion of Patients Who Underwent Oblique Osteotomy

Variable	Group 1 (Union, N = 260)	Group 2 (Delayed Union or Nonunion, N = 30)	P Value
Age* (yr)	39 ± 13	48 ± 14	<0.001
Sex (M:F) (no. [%])	151:109 (58:42)	16:14 (53:47)	0.698
Injury on dominant side (yes:no) (no. [%])	157:103 (60:40)	19:11 (63:37)	0.845
Workers' Compensation (yes:no) (no. [%])	18:242 (7:93)	2:28 (7:93)	1.000
Smoking (yes:no) (no. [%])	73:187 (28:72)	20:10 (67:33)	<0.001
Diabetes mellitus (yes:no) (no. [%])	80:180 (31:69)	9:21 (30:70)	1.000
BMD* (mean T score)	0.49 ± 1.45	-0.24 ± 1.77	0.012
Preop. VAS pain score*	4 ± 1	4 ± 0	0.343
Preop. wrist flexion-extension arc* (°)	120 ± 5	115 ± 6	<0.001
Preop. forearm pronation-supination arc* (°)	145 ± 6	140 ± 9	<0.001
Preop. grip strength* (% of unaffected side)	80 ± 4	80 ± 4	0.370
Preop. modified Mayo wrist score*	67 ± 5	67 ± 5	0.958
Symptom duration* (mo)	28 ± 8	29 ± 6	0.763
Duration of symptom aggravation* (mo)	3 ± 1	2 ± 1	0.455
History of trauma (yes:no) (no. [%])	23:236 (9:91)	0:30 (0:100)	0.221
Distal radioulnar joint subluxation* (mm)	1.79 ± 1.13	2.17 ± 0.70	0.077
Preop. ulnar variance* (mm)	3.98 ± 1.21	3.93 ± 1.11	0.851
Postop. ulnar variance* (mm)	-0.63 ± 0.73	-0.53 ± 0.63	0.484
Distal radioulnar joint type ³⁴ (I:II:III) (no. [%])	113:100:47 (43:38:18)	12:12:6 (40:40:20)	0.930
Osteotomy site gap after fixation* (mm)	0.55 ± 3.74	0.73 ± 0.45	0.785
Newly developed radiographic findings of arthritis (yes:no) (no. [%])	48:212 (28:82)	7:23 (23:77)	0.471
TFCC degeneration class ³⁰ (IIA:IIB:IIC:IID) (no. [%])	1:104:148:7 (0:40:57:3)	1:8:21:0 (3:27:70:0)	0.101
Use of double-blade saw (yes:no) (no. [%])	81:179 (31:69)	15:15 (50:50)	0.043
Plate type (conventional:for oblique osteotomy:LCP ulnar osteotomy) (no. [%])	209:51 (80:20)	20:10 (67:33)	0.97
No. of screws for fixation (6:7:8) (no. [%])	251:1:8 (97:0:3)	30:0:0 (100:0:0)	0.879
Plate position (volar:dorsal) (no. [%])	9:251 (3:97)	0:30 (0:100)	0.605

TABLE E-3 Independent Variables Investigated with Multivariate Logistic Regression Analysis with Exclusion of Patients
Who Underwent Oblique Osteotomy

Variable	OR	95% CI	P Value
Smoking	9.88	3.41-28.65	<0.001
BMD	0.56	0.41-0.77	<0.001
Preop. wrist flexion-extension arc	0.86	0.78-0.94	<0.001
Preop. forearm pronation-supination arc	0.91	0.86-0.97	0.003
Use of double-blade saw	2.76	1.01-7.54	0.047