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Original Research

Clinical and Radiographic Outcomes of Gap Osteotomy Versus Dorsal Opening Wedge Osteotomy for Extra-Articular Distal Radius Malunion and Internal Fixation Using a Volar Locking Plate Without Bone Graft

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Purpose: Metaphyseal corrective osteotomy and fixed-angle volar locking plate fixation have reduced the need for additional bone grafting in symptomatic distal radius malunions. This study evaluated the outcomes of gap versus dorsal opening wedge and locking plate fixation without bone grafts for distal radius malunions and the correlation between the osteotomy defect and the osteotomy's distance from the articular surface with the union time.
Methods: We retrospectively reviewed 62 patients who underwent corrective osteotomy between 2010 and 2021. Gap osteotomy (n = 44) was performed to correct the coronal deformity predominantly, whereas an opening wedge osteotomy (n = 18) was performed to correct the sagittal deformity. No bone graft was used in any patient. Radiological outcomes comprised of correction of radial height, inclination, ulnar variance, volar tilt and the correlation between the osteotomy defect and the distance from the distal radial articular surface with the union time. The functional assessment comprised the disabilities of arm, shoulder, and hand questionnaire and the patient-rated wrist evaluation scores.
Results: All patients had a union of the osteotomy and statistically significant improvement in the radial height, inclination, ulnar variance, and tilt, irrespective of the osteotomy technique ($P < .05$). The mean defect length of the osteotomy, the time to the union, and the distance of the osteotomy were 4.7 mm (1–8.3 mm), 11.7 weeks (5–24 weeks), and 13.9 mm (1.6–35.8 mm), respectively. Time taken for union showed a weak positive correlation with the defect length of the osteotomy and no correlation with the distance of the distal osteotomy site from the articular surface. Opening wedge osteotomies took less time than the gap osteotomies. The mean postoperative disabilities of arm, shoulder, and hand questionnaire and the patient-rated wrist evaluation scores were 6.89 and 12.18, respectively.
Conclusions: Corrective osteotomy and fixed-angle volar plate fixation for distal radius malunion provide satisfactory union rates and clinical and radiological outcomes even without bone graft, irrespective of the osteotomy type, size, or location. However, length of the osteotomy defect influenced the union time.
Type of study/level of evidence: Therapeutic IV.

Distal radius fractures account for 3% of all upper-extremity injuries and 17.5% of all extremity fractures, the treatment of which is broadly divided into surgical and nonsurgical techniques.[1] Complications and disability may be more common in fractures treated without surgery, based on some studies.[2–6] Malunion of distal radius fractures is the most prevalent complication, affecting up to 24% of nonoperatively treated and 11% of operatively treated fractures.[7,8] These malunions are broadly divided into two types based on the initial fracture pattern, that is, intra-articular malunions if the radiocarpal or radioulnar joint is involved or extra-articular if no joint is involved.[9] Not all malunions are symptomatic. When symptomatic, they cause significant disability such as activity

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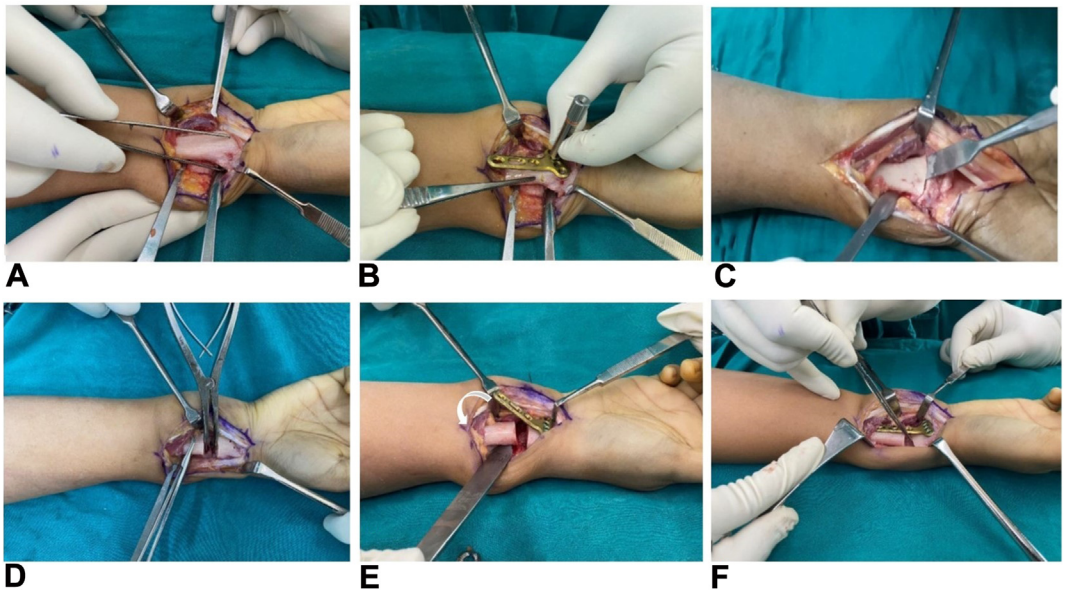

Figure 1. **A** Distal radius exposed through a modified Henry's approach and stripped off its periosteum and adhesions on the volar and dorsal surface. **B** Site of osteotomy is marked, and the distal aspect is provisionally fixed to the fixed-angle volar locking plate with locking screws. **C** Plate was removed, and osteotomy was performed using a bone saw and osteotome. **D** Distraction is performed to achieve correction of radial height using a laminar spreader. **E** Plate fixed to the distal fragment and used as a guide to achieving the required correction of distal radial inclination and tilt. **F** The plate is fixed proximally with cortical or locking screws after correction. Final fixation as seen from the radial aspect.

limitation, pain, unsightly appearance, nerve compression, or decreased grip strength because of changes in wrist biomechanics.[9,10]

There are no absolute indications for surgical intervention, but timely deformity correction is necessary to alleviate the symptoms and prevent future complications.[11,12] Good outcomes are seen when corrective osteotomy and reconstruction are performed and when the radiologic criteria correlate with functional limitation.[13] Sagittal plane deformities of dorsal or volar tilt can be corrected with an opening wedge hinge type of osteotomy when the distal segment is hinged over one cortex in contact to achieve reduction. However, coronal plane deformities of radial inclination, tilt, and rotational malalignment require complete detachment of the distal segment, distraction, and later fixation with corrected alignment. This translates to a gap type of osteotomy. As both these methods leave a void in the bone at the osteotomy site, there are multiple methods of filling this defect, which include the use of corticocancellous bone graft, bone allograft, synthetic bone substituting material, or no graft, showing erratic results with each method.[14–17] Bone graft or graft substitute has pros such as filling the gap and potentially faster time-to-union and better support at the osteotomy rather than relying completely on the plate and cons such as cost of using bone graft substitutes, additional time to harvest autogenous graft of bone grafting, and the potential for disease transmission via an allograft. Corrective osteotomy with fixed-angle volar plate fixation is gaining popularity because of its accurate restoration of bony anatomy, early mobilization, and early return of wrist function with good radiological outcomes.[18] Additional bone grafting can be avoided because of rigid fixation by volar locking plates and osteotomy at the metaphyseal region. Previous studies show osteotomy union time between 8 and 16 weeks and significant improvements in radiological and functional parameters.[19–21]

Although a vast amount of literature is available regarding the treatment of malunion of distal radius fractures by corrective osteotomy without bone graft, there is still a shortage in the literature comparing both types of osteotomies or the correlation between the union time and the type of osteotomy performed with the ensuing defect.

This study evaluated the outcomes of gap versus opening wedge osteotomy and locking plate fixation without bone grafts for extra-articular distal radius malunions and the correlation between the osteotomy defect length and the osteotomy's distance from the articular surface with the union time. Hence, this study intends to illustrate a single, safe, and relatively simple procedure of corrective osteotomy for extra-articular distal radius fractures that can be easily reproduced.

Methods

A retrospective cohort study involving 62 adult patients who underwent corrective osteotomy for a malunited distal radius fracture at a tertiary care hospital between January 2010 and January 2021 was conducted. The inclusion criteria comprised patients treated nonoperatively for the initial fracture and later presenting with symptomatic extra-articular distal radius malunion. Corrective osteotomy was performed using either gap or opening wedge methods, along with fixed-angle volar plate fixation without bone grafts. Patients initially operated on for acute distal radius fractures, those with intra-articular malunions, and those undergoing alternative corrective osteotomy methods were excluded. Demographic data, including age, sex, and predisposing medical conditions, were obtained from hospital records. The study adhered to the principles of the Declaration of Helsinki and received approval from the Institutional Ethics Committee. A written informed consent was obtained from each patient.

Surgical technique

A single highly experienced specialist surgeon with level five expertise, per Tang and Giddins criteria, performed all the surgeries.[22] Pain, limitation of wrist movements, and deformity of the wrist were the main indicators for surgery, whereas alteration of radiological parameters was not considered the sole indication for surgery. Malunion was defined as radial inclination less than 10 degrees, volar tilt less than 10 degrees, dorsal tilt more than 10 degrees, radial height less than 10 mm, and ulnar variance more

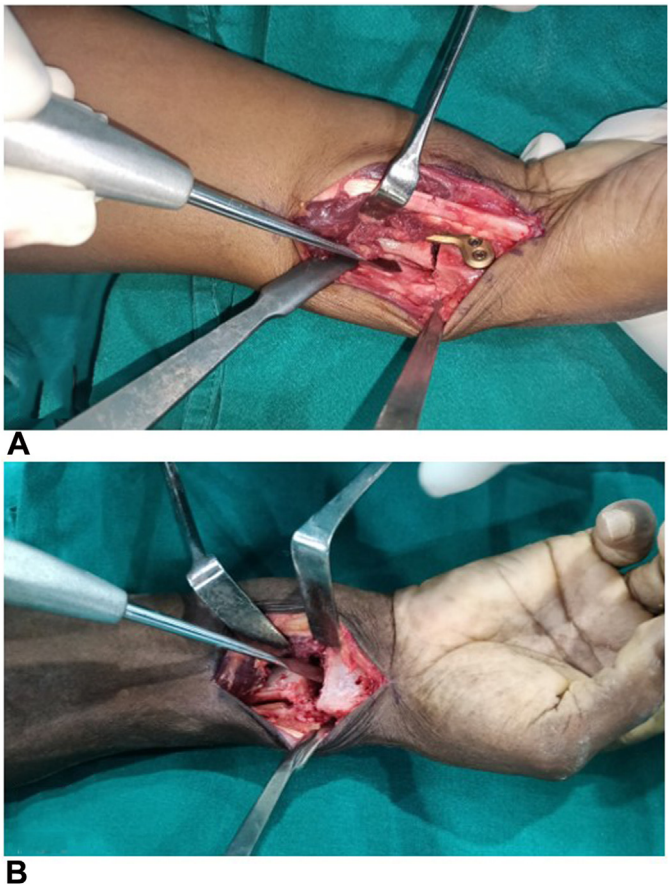

Figure 2. **A** Release of soft tissue adhesions can be performed with periosteum elevators over the dorsal surface of the radius. **B** Intrafocal release of dorsal soft tissue is performed through the osteotomy gap before distraction.

than 2 mm.[23] Corrective osteotomy was performed under either general anesthesia or brachial plexus block regional anesthesia with a tourniquet. The malunion was exposed through the modified Henry's approach, and soft tissue adhesions were cleared both volar and dorsally. Corrective osteotomy was performed and internally fixed using volar locking plates after correcting the distal radial anatomy (Fig. 1). Dorsal adhesions were released either on the dorsal surface or through an intrafocal release within the osteotomy itself (Fig. 2). Using a laminar distractor was crucial for achieving alignment and congruity of the distal radioulnar joint. Gap osteotomy (Fig. 3) was used for patients with coronal plane deformities (reduction in radial height and inclination or residual rotational deformity). Opening wedge osteotomy (Fig. 4) was performed for patients with predominantly sagittal plane deformities (dorsal or volar angulation). The osteotomy was performed through the same volar approach. After completion, the distal fragment was hinged, maintaining contact with the volar cortex, and fixed using a locking plate. After surgery, patients were immobilized in a plaster cast for 6 weeks. After cast removal, patients used a forearm splint for 3 weeks while gradually starting wrist and forearm mobilization. Light work was allowed after 6 weeks, and regular work after radiological union. Regular X-rays at 6 weeks, 3 months, 6 months, and 1 year assessed progress.

Radiographic outcomes

Radiographs were obtained from the hospital Picture Archiving and Communication System. Standard measurements were taken using both posteroanterior and lateral views (Fig. 5). These measurements included radial inclination, radial length, ulnar variance, and dorsal or volar angulation. The study followed patients before and after corrective osteotomy, with sequential radiographs taken at 6 weeks, 3 months, 6 months, and 1 year, which is the standard of care in the follow-up of upper limb fractures and osteotomy. The length of the osteotomy defect was measured, along with the distance of the osteotomy from the distal radial articular surface (Fig. 6A). For gap osteotomies, the length was measured on posteroanterior radiographs. In cases where osteotomy edges were not parallel, the maximum distance was used (Fig. 6B). In opening wedge osteotomies, the defect length was measured on lateral radiographs at the site of the maximum opening wedge on the noncontact cortical surface (Fig. 6C). The osteotomy site's distance from the distal radial articular surface was calculated by drawing a line along the radius's longitudinal axis from the distal end of the osteotomy gap to a point on the distal radial articular surface (Fig. 7).

Radiographic union was defined as the first appearance of a bridging callus in a minimum of three cortices in posteroanterior and lateral radiographs (Fig. 8). Time of union was the period from osteotomy to bone or callus appearance at the osteotomy site on follow-up X-rays. Outcome measures included radiographic indices, osteotomy type (gap or opening wedge), length of the osteotomy defect, and distance from the distal radius articular surface.

Functional outcomes

The patients were subjected to interview-based patient-rated outcome measures assessment 1 year after surgery. The shortened version of the disabilities of arm, shoulder, and hand questionnaire (quickDASH) and the patient-rated wrist evaluation (PRWE) were used as feasible for our study group.[24,25] The scores ranged from 0 to 100 and 0 to 150, respectively, and a lesser score indicated a lesser disability and a better outcome.

Statistical analysis

Descriptive statistics analyzed epidemiological variables (age, gender, smoking, diabetes, malunion type, osteotomy type, and complications). Incidence was measured as a percentage of the total sample size. Paired "*t*" tests compared pre- and postoperative radial height, inclination, ulnar variance, and dorsal/volar tilt. Independent "*t*" tests assessed unmatched variables (length of osteotomy, distance from articular surface to osteotomy, and union time) between the two osteotomy groups. Pearson's correlation explored linear relationships, including time-to-union correlations with osteotomy length and distance from the articular surface. A P value $< .05$ indicated statistical significance.

Results

In this study, 62 patients met the inclusion criteria. Of these, 47 had dorsal malunion (reduced palmar tilt), whereas 15 had volar malunions (increased palmar tilt). Patient demographics are shown in Table 1.

Radiographic outcomes

The radiologic parameters of the distal radius were measured before and after surgery in a 1-year follow-up. The mean improvement of these parameters is described in Table 2. Regardless of osteotomy type, significant improvements were found in

Figure 3. Gap osteotomy was performed on a patient who required coronal plane deformity correction—radial height. **A** Preoperative radiograph, **B** immediate postoperative radiograph demonstrating a gap at the osteotomy, and **C** final follow-up radiograph demonstrating complete osteotomy union.

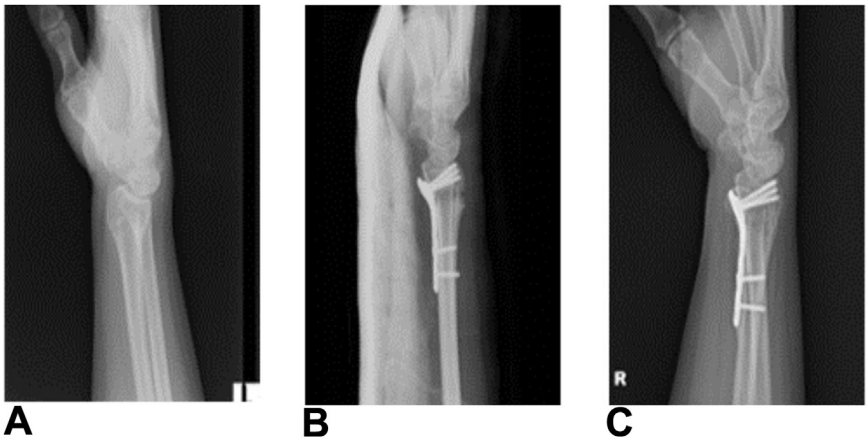

Figure 4. An opening wedge osteotomy was performed on a patient who required correction of sagittal plane deformity because of dorsal tilt. **A** Preoperative radiograph. **B** Immediate postoperative radiograph showing an opening wedge osteotomy leading to dorsal tilt correction. **C** Final follow-up radiograph demonstrating complete osteotomy union.

mean radial inclination, radial height, dorsal or volar tilt, and ulnar variance ($P = .001$). The comparison between radiological outcomes between the two types of osteotomies is depicted in Table 3. Both types of osteotomies showed similar significant mean gains in radial inclination, height, and dorsal tilt ($P = .001$). However, the opening wedge group had a correction of 15° of volar tilt ($P = .117$). Among 62 subjects, the mean osteotomy length was 4.65 mm (1–8.3 mm), union time was 11.72 weeks (5–24 weeks), and distance from articular surface to osteotomy was 13.88 mm (1.6–35.8 mm). No significant differences were observed between gap and opening wedge osteotomies (Table 4).

A scatterplot diagram (Fig. 9A) revealed a weak positive correlation (0.52) between time-to-union and osteotomy length. Larger osteotomy defects had longer healing times. Three patients who achieved union at 24 weeks had defect lengths of 6.8, 5.1, and 6.8 mm, which are close to the mean defect. Notably, these patients were nonsmokers and were reviewed only at 6 months postsurgery instead of the usual 3 months; thus, we can only speculate that the osteotomy may have united at 3 months, but they did not turn up.

Another plot diagram (Fig. 9B) showed an uneven distribution of values, which corresponded to no correlation (Pearson's correlation coefficient = 0.04) between time-to-union and the distance from the articular surface to the osteotomy ($P = .74$). Regardless of osteotomy location or type of osteotomy performed, union time remained dependent solely on the defect length.

Functional outcomes

Among participants, 48 patients underwent a questionnaire-based interview 1 year after surgery. The mean quickDASH score was 6.89, and the mean PRWE score was 12.18. Our study population showed excellent patient-rated functional outcomes.

Complications

The following postoperative complications were seen in four subjects: intra-articular screw (which required removal), median nerve compression in two patients (resolved with splinting and medical treatment), and hardware failure in one patient because of heavy weightlifting; however, the osteotomy had united at 6 months.

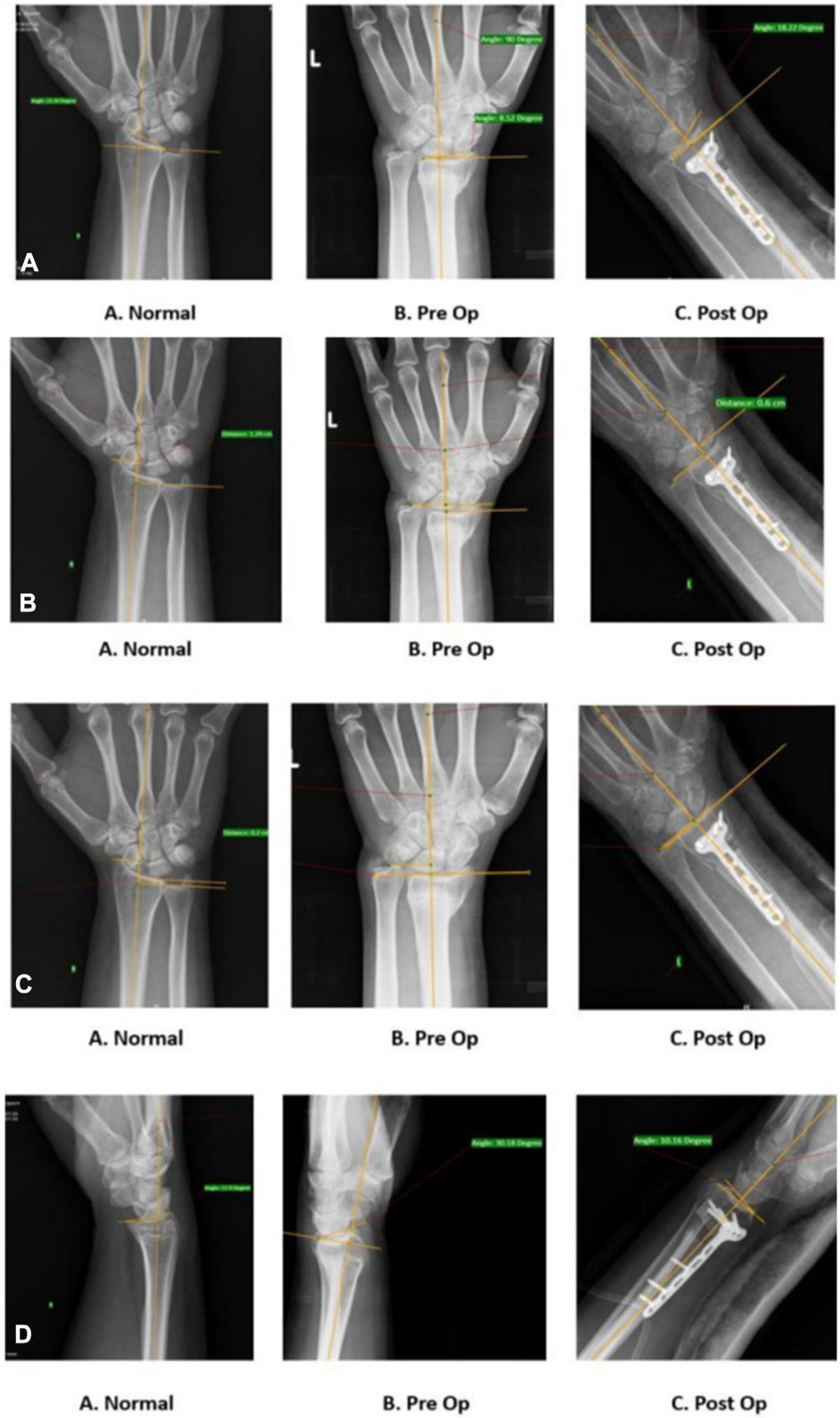

Figure 5. **A** Radial inclination. **B** Radial height. **C** Ulnar variance measured on posteroanterior radiograph. **D** Dorsal/volar tilt measured on a lateral radiograph.

Discussion

Traditionally malunited distal radius fractures have been managed by dorsal opening wedge osteotomy and bone grafting.[26,27] The osteotomy was approached from the volar side after the introduction of angle-stable volar locking plates.[28] The need for bone grafting was also disputed because the locking plate offered excellent stability, and the osteotomy's metaphyseal area was well

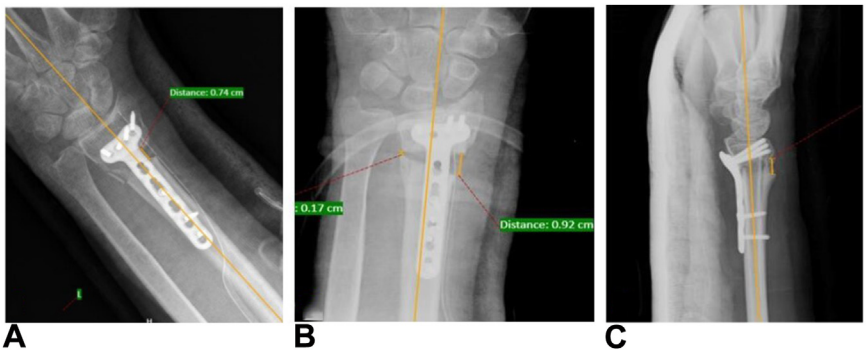

Figure 6. **A** The osteotomy defect (mm) length is measured on the postoperative radiograph. **B** A larger osteotomy length is considered for final evaluation in the case of oblique gap osteotomy. **C** The osteotomy length at the noncontact cortex was measured and considered for final evaluation.

Figure 7. Distance from the distal radial articular surface to the distal end of osteotomy site (mm) on a postoperative radiograph.

vascularized.[29] Our study evaluated radiological and functional outcomes after corrective osteotomy for malunited extra-articular distal radius fractures. We used a volar locking plate without a bone graft and explored the correlation between the osteotomy defect length, distance from the articular surface, and union time.

Our study included 62 malunited wrists, of which the majority were of dorsal variety (75.8%). All participants were treated with a volar locking plate without the interposition of bone graft or graft substitute. All patients had a complete union of the osteotomy site and significant radiological improvement of the wrist at 1 year. Tarng et al[30] and Opel et al[20] retrospectively analyzed corrective osteotomy and fixed-angle volar locking plate fixation without bone graft and achieved complete union by 12 weeks with no complications. Mahmoud et al[21] similarly analyzed outcomes of 22 wrists with a mean age of 31.8 years and a follow-up of 18 months, much like our study.

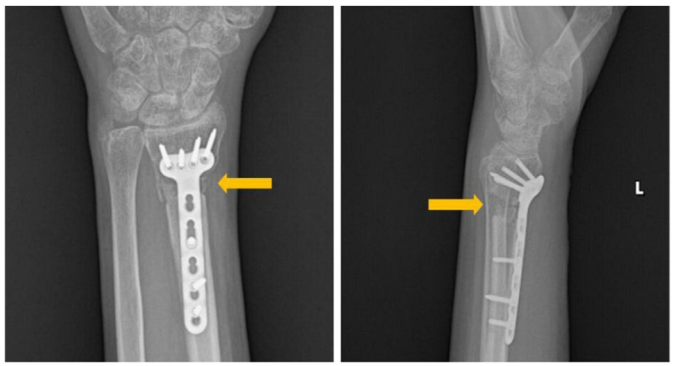

Figure 8. Bridging callus (yellow arrows) seen for the first time on postoperative posteroanterior and lateral radiographs at 12 weeks in all three cortices.

Table 1
Demographics

Variables	No (Percent)
Age (y)	
Mean ± SD	39.15 ± 15.5
Range (y)	15–72
Gender	
M	46 (74)
F	16 (26)
Smoking	
Yes	2 (3.2)
No	60 (96.8)
Diabetes	
Yes	1 (1.6)
No	61 (98.4)
Osteotomy type	
Gap	44 (71)
Open wedge	18 (29)

They, too, reported radiological union in all patients, although a computed tomography scan had to be performed in three patients to confirm the X-ray findings. Mulders et al in 2017 compared the outcomes of additional bone grafting versus no bone grafting following corrective osteotomy and found a union of all osteotomies except one in the bone grafting group.[14] This further emphasizes that corrective osteotomy for malunited distal radius fractures can be performed effectively without bone grafting, especially using the volar locking plate. Our study, based on an extensive literature search, represents the largest cohort of patients undergoing this procedure without interposing bone grafts. Table 5 enlists the studies performed in the past on corrective osteotomy for malunited distal radius fractures without the use of bone graft.

Table 2
Comparison of Mean Preoperative and Postoperative 1-Year Follow-Up Measurements for Radial Inclination, Radial Height, Ulnar Variance, and Tilt (Dorsal and Volar) for the Entire Population

Radiographic Parameter	N	Mean ± SD	Mean Gain	*P* Value
Radial inclination				
Before surgery	62	15.4 ± 7	4.1	.001
After surgery	62	19.5 ± 4.5		
Radial height				
Before surgery	62	2.06 ± 5.5	5.84	.001
After surgery	62	7.9 ± 2.9		
Ulnar variance				
Before surgery	62	5.2 ± 3.8	3.45	.001
After surgery	62	1.65 ± 1.7		
Dorsal tilt				
Before surgery	47	-22.6 ± 12.5	23.8	.001
After surgery	47	1.2 ± 7.3		
Volar tilt				
Before surgery	15	23.6 ± 5.6	12.9	.001
After surgery	15	10.7 ± 3.7		

Table 3
Mean Improvement in the Radiological Indices Between the Two Types of Osteotomies

Radiological Index	Osteotomy	N	Pre	Post	Gain	*P* Value
Radial inclination	Gap	44	15.6 ± 6.7	19.3 ± 4.1	3.7	.37
	Open wedge	18	15.03 ± 7.9	20.1 ± 5.6	5.07	
Radial height	Gap	44	1.8 ± 5.8	7.9 ± 2.4	6.1	.58
	Open wedge	18	2.5 ± 5.05	7.9 ± 3.9	5.4	
Dorsal tilt	Gap	32	-22 ± 13.1	1.1 ± 7.3	23.1	.56
	Open wedge	15	-23.9 ± 13.1	1.4 ± 7.3	25.3	
Volar tilt	Gap	12	23.6 ± 4	10.7 ± 4	12.9	.51
	Open wedge	3	25.8 ± 11.5	10.8 ± 3.03	15	
Ulnar variance	Gap	44	5.5 ± 4.2	1.5 ± 1.7	4	.14
	Open wedge	18	4.5 ± 2.2	2 ± 1.6	2.5	

Table 4
Comparison of Mean Values for the Defect Length of Osteotomy, the Distance Between the Articular Surface to Osteotomy, and Time-to-Union Between the Types of Osteotomies

Radiographic Parameter	N	Mean ± SD	*P* Value
Defect length of osteotomy			
Gap	44	4.7 ± 2.4	.73
Open wedge	18	4.9 ±1.6	
Distance-articular surface to osteotomy			
Gap	44	14.5 ± 6.3	.23
Open wedge	18	12.5 ± 5	
Time-to-union			
Gap	44	12.2 ± 5.4	.533
Open wedge	18	11.44 ± 2.8	

Contrary to our study, Izmalkov et al described using an additional dorsal incision to free adhesions and any persistent callus and perform the osteotomy along with the traditional volar approach for the placement of the locking plate.[31] We, however, found that the dorsal incision was not required, as both the volar and dorsal surfaces of the distal radius can be approached via the volar approach alone. Moreover, the dorsal adhesions could be freed through the osteotomy itself.

In all our patients, we found statistically significant improvement in radiological parameters such as radial height, inclination, ulnar variance, and distal radial tilt. Our results were consistent with the work performed in the past by various studies.[19–21,27,30] Thus, using an angle-stable distal radius volar locking plate to correct malunion because of its prefixed angulation allows for adequate distal radius articular anatomy restoration. The rigid construct maintains the reduction for a long duration without failure. This allows for mobilization in the postoperative period and good clinical outcomes at the long-term follow-up.[20,32] Nevertheless, we immobilized all patients in a cast for 6 weeks to protect the fixation till initial callus formation.

Our study found that the osteotomy in all patients showed radiological union, with the mean time-to-union being 11.72 weeks without using bone grafts. Opel et al[20] also showed an average time-to-union of 12 weeks. In contrast, Taleb et al[33] reported an average union time of 20.22 weeks following a minimally invasive method of corrective osteotomy and volar locking plate fixation without bone graft. Distal radius metaphysis has a rich vascular supply and adequate soft tissue cover, alleviating the need for a structural bone graft to achieve union. Most studies show an average time to the union to be between 12 and 16 weeks, irrespective of the use of bone graft.[18–20,34,35] In a recent study by Fuchs et al,[36] 11 palmar osteotomies were evaluated, and the average time-to-union was found to be 22 weeks, irrespective of the measured gap of osteotomy. This variation could be because of several factors, such as the size of the osteotomy defect, the presence of an intact cortical continuity, the period of immobilization, or the placement of the osteotomy site. Hence, we also analyzed this time-to-union based on the type of osteotomy performed, the length of osteotomy, and the location of osteotomy from the distal radius articular surface.

We noticed a weak positive correlation between the length of the osteotomy and the time-to-union. All the patients in our study were found to have a defect length in the range of 2–7.2 mm, and despite the smaller average length in the gap osteotomy group, the time-to-union in gap type was found to be slightly higher (12.2 weeks) than the opening wedge type (11.4 weeks) because of the maintenance of one cortical continuity. We also measured the distance between the distal end of the osteotomy and the articular surface to see if the osteotomy site, whether metaphyseal or metadiaphyseal, had anything to do with the union time. We discovered no link between the two, indicating that the osteotomy defect size is the most important

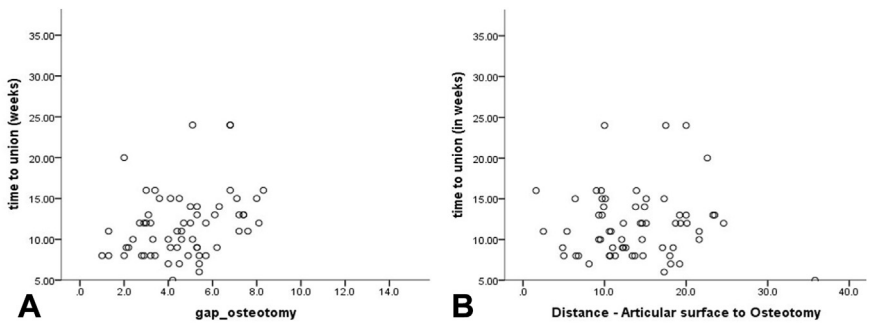

Figure 9. **A** Correlation between time-to-union (in weeks) and the length of osteotomy (in mm). **B** Correlation between time-to-union (in weeks) and distance from the articular surface to osteotomy (in mm)

Table 5
List of Studies Performed in the Past on Corrective Osteotomy for Distal Radius Malunion Without Bone Graft

Sl. No.	Author	Year	Number of Patients	Mean Gap of Osteotomy (mm)	Time-to-Union (wk)	Radial Inclination (degrees)		Radial Height (mm)		Palmar tilt (degrees)		Postoperative Functional Outcomes		Complications (No. of Patients)
						Before surgery	After surgery	Before surgery	After surgery	Before surgery	After surgery	QuickDASH	PRWE	
1	Tarn[25]	2011	7	-	12	13.6	18.7	-	-	−20.7	0	-	-	-
2	Ozer[13]	2011	14	-	11 ± 3.5	4 ± 5	11 ± 2	−2 ± 1	0 ± 1	−18 ± 12	9 ± 4	10 ± 4.5	2.8 ± 2.2	Nil
3	Mahmoud[16]	2012	22	-	10.4	10.0 ± 6.9	18.9 ± 4.2	2.6 ± 5.4	8.0 ± 2.6	−37.6 ± 12.7	4.3 ± 8.4	12.9 ± 5.3	-	4
4	Opel[15]	2013	20	-	12	17.25 ± 5.12	22.67 ± 3.18	-	-	−26.13 ± 8.37	3.69 ± 6.23	13.48	-	-
5	Tarallo[14]	2014	20	-	4	29 ± 6.9	22.3 ± 6.1	-	-	−23.1 ± 6.5	11.3 ± 4.4	25.3 ± 7.7	-	2
6	Mulders[11]	2017	19	-	22	16.4 ± 6.0	19.0 ± 3.5	8.1 ± 3.2	9.6 ± 2.6	−16.9 ± 10.1	4.5 ± 3.5	15	32.5	9
7	Andreasson[34]	2020	19	-	-	-	-	-	-	-	-	20	23	5
8	Fuchs[31]	2023	11	7	20	18.6	24	6.9	11	−28	2	-	-	1
9	Our Study	2023	62	4.65	11.72	15.4 ± 7	19.5 ± 4.5	2.06 ± 5.5	7.9 ± 2.9	−22.6 ± 12.5 (Dorsal malunions) 23.6 ± 5.6 (Volar malunions)	1.2±7.3 (Dorsal malunions) 10.7 ± 3.7 (Volar malunions)	6.89	12.18	4

factor in predicting union time. Thus, we suggest performing osteotomy in the metaphyseal region, preserving some cortical continuity, and taking precautions to avoid venturing more proximally into the radial diaphysis to perform the osteotomy.

We broadly divided the corrective osteotomy procedure into two types—namely, gap osteotomy, where a bicortical osteotomy is performed at the distal radius metaphysis level, and the distal segment is distracted to achieve correction of coronal plane deformities, and the opening wedge osteotomy, where the distal segment of the bone is hinged on one cortex to correct the sagittal plane deformity primarily. Mulders and Haghverdian described the usage of bone grafts in patients when the osteotomy led to a loss of bone contact between the segments and no bone graft usage when the correction allowed maintenance of a single cortical continuity.[14,37] Despite these, we believe ours is the first study with a division and analysis of corrective osteotomy technique into these two types, fixation with a volar locking plate, and no usage of bone graft. Based on the number of subjects selected and the duration of follow-up, we believe this is the largest study on distal radius malunions treated with osteotomy.

All the osteotomy sites united with comparable union time and significant improvement were seen in all radiological parameters. Gap osteotomy improved radial length and ulnar variance more than the opening wedge osteotomy, which improved the palmar tilt. However, there was no significant difference between the two groups.

Our patients reported excellent functional outcomes based on the quickDASH and PRWE scores. This was consistent with work performed by Mulders, who reported scores of 15 and 32.5, and Ozer, who reported scores of 10 and 2.5, respectively.[14,18] Our study had a low complication rate (6.45%), which was comparable with studies performed in the past. Median nerve neuropathy, complex regional pain syndrome, prominent implants, or hardware failure are the common complications to be kept in mind.[14,19,21,38,39]

Limitations

In our study, some patients deviated from the recommended follow-up schedule, potentially affecting the calculated union time. This could have led to overestimating the actual union time. We followed the routine follow-up intervals of 6 weeks, 3 months, 6 months, and 1 year, which is the standard of care for all upper limb fractures or osteotomy. Getting weekly radiographs is neither ethical nor practical in this situation. However, we considered the first appearance of the bridging callus in three cortices, which was nearest to the routine follow-up scheduled date as the time-to-union. The osteotomy size was measured as the maximal distance from one divided cortex to the other in opening wedge osteotomies. As one cortex was intact, the total volume of osteotomy may be lower than the gap type, leading to faster union time, although the single largest gap was significant. This may have led to paradoxical results. Hence, the total volume of osteotomy might be a better measuring tool for the osteotomy gap but was not used as the assessment was performed using two-dimensional radiographs. We assessed unions routinely on radiographs, as it is easily visible, but a more sensitive tool like a computed tomography scan was not employed.

Conflicts of Interest

No benefits in any form have been received or will be received related directly to this article.

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