Corrective Osteotomy of Distal Radius Malunion Using a Rectangular-shaped Iliac Bone Graft and Volar Plating

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Abstract: Distal radius fractures are one of the most common injuries seen by orthopedists at the emergency room and clinics. Severity and configuration may vary, and therapeutic options are broad, but regardless of the course of treatment, all cases can potentially lead to malunion. When malunion requires surgical correction, the surgery can be technically demanding. Here, we demonstrate an alternative technique to perform corrective osteotomies for extra-articular or minimally displaced articular distal radius malunion. We provide simplification of the procedure by eliminating one of the planes taken into consideration when performing an osteotomy. This technique includes the use of a tricortical iliac bone graft, which we feel, provides dependable structural support, preventing collapse. The technique allows the surgeon an easy means to access the osteotomy gap and apply the graft. Finally, we supplement this surgical technique by providing our outcomes. Our data suggest that the technique effectively restores radiographic wrist parameters and provides good union rates.

Key Words: distal radius malunion, distal radius corrective osteotomy, distal radius malunion management, Colles fracture malunion

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Distal radius fractures are one of the most common fractures seen by orthopedists. Regardless of management, 11% to 23% of these cases develop malunion.[1–3] The implications of malunion for a patient vary. Symptoms may range from mild pain on weight-bearing and grip, to inability to perform activities of daily living.[4]

Multiple sources have correlated radiographic malalignment of the wrist to patient symptoms. Historically, parameters requiring surgical correction have been radial height under 15 mm, dorsal angulation >15 degrees and radial inclination <25 degrees.[5–8] Some articles have placed additional importance to radial height, stating that it may be the most significant factor for predicting good functional outcomes.[9,10] Corrective osteotomies are complex procedures requiring thorough understanding of wrist biomechanics, anatomy, and good preoperative planning.

Many techniques for distal radius osteotomy exist, with the earliest descriptions advocating an opening wedge osteotomy to correct the deformity. The main principle was to correct the deformity and provide a buttress effect.[11] Results have been favorable but complications such as extensor tendinitis, and need for supplementary procedures, whether done volarly or dorsally, still leave us with room for improvement.

Recently, surgeons have grown comfortable approaching distal radius fractures from the volar surface regardless of the direction of the deformity. New implant designs, such as the volar locking plate, have re-enforced this approach in fracture management. This trend has also carried over to malunion treatment.[12,13] Evidence has also shown that the strength of this construct provides good functional outcomes and union rates.[14]

This surgical technique takes into consideration, established principles to maximize correction while reducing errors through a simplified technique. By adding an additional bone cut to the proximal fragment after the initial opening wedge osteotomy, a rectangular rather than a triangular gap is created. With this, a rectangular-shaped iliac bone graft can be slid into place. A tricortical structural bone graft is used because we feel it significantly aids correction of the malunion and prevents redisplacement or loss of reduction. Aside from this, our surgical technique descriptively narrates our step by step process and rationalizes our reasons for choosing such. Finally, we will present our index cases for the said procedure to further support our success.

INDICATIONS AND CONTRAINDICATIONS

This technique may be performed for symptomatic extra-articular malunion of the distal radius, or malunion of the distal radius where intra-articular involvement is minimal (<2 mm articular step off) within the radiocarpal joint. It is our technique of choice for distal radius malunion cases where radial height and inclination are the severely affected parameters. The most common symptoms experienced by patients include pain, limited range of motion, difficulties making a fist, and weakness of grip strength.

TECHNIQUE

Preoperative wrist anteroposterior and lateral radiographs are templated for all cases. Distal radius parameters are recorded and required amounts of correction are noted before surgery. All measurements were done both using the centers ancillary software program and manually on printed films. Central reference point was used for radial inclination and ulnar variance to avoid over or underestimation of malunion severity.[15] Additional diagnostics such as computed tomography scans were not utilized for any of the cases, but may be utilized if there is suspicion of significant intra-articular involvement.

The technique is performed with the patient in supine position with the arm abducted and fully supinated on an arm board. We prepare the ipsilateral iliac area as well by placing a bump on the posterior pelvic area to better appreciate the anterosuperior iliac spine. An image intensifier should be available throughout the surgery.

The surgical site is marked by palpating the flexor carpi radialis (FCR) tendon. The incision is started at the level of the proximal wrist crease, extending ~5 cm proximally (Fig. 1). The dissection is carried down the same plane until the FCR sheath is opened, and the tendon is exposed, isolated and retracted toward the ulnar direction. On even deeper dissection, the flexor pollicis longus and wrist flexors are retracted with a Hohmann retractor. The pronator quadratus muscle is identified,

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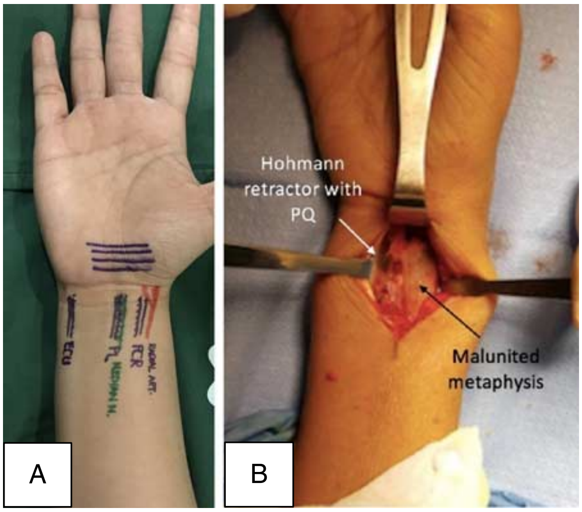

FIGURE 1. A, Forearm and hand position during corrective osteotomy technique with labelled superficial structures. B, Gross image of distal radius exposure. PQ indicates pronator quadratus.

and sharply incised at its radial most aspect, proceeding distally and ulnarly in an L-shaped manner. Care is taken throughout this process to remain proximal to the origin of the volar radiocarpal ligaments. This is crucial to preserve radiocarpal stability.

During the exposure of the distal radius, the brachioradialis insertion along the radial styloid is identified and released when needed. This step often tremendously aids in mobilizing a stubborn distal fragment, usually encountered in chronic malunion cases. We advise to perform this release with caution and must stress the need spend adequate time to identify structures. This allows us to avoid inadvertent transections of nearby tendons, specifically those within the first dorsal compartment.

Once the malunited distal radius is identified and adequately exposed, the osteotomy cuts can be performed. A lateral view of the distal radius is taken with a bone saw targeted at the exposed volar metaphyseal area of the distal radius, usually at the apex of the onset of deformity or slightly proximal to it (Fig. 2A). Emphasis should be placed in properly positioning the saw in parallel alignment to the distal radius articular surface both in anteroposterior and lateral views. Once parallelism is confirmed, the osteotomy may be continued in this position, taking care not to injure the extensors. After the first osteotomy cut is completed, the second osteotomy can be planned. This cut is made just below the first, but now, perpendicular to the axis of the radial shaft (Fig. 2B). Collectively, the first and second osteotomy cuts should produce a triangular-shaped loose bone fragment, which should be set aside for the remaining duration of the surgery (Fig. 2C).

At this point, a lamina spreader is applied and opened, creating a rectangular-shaped gap (Fig. 3). If there is unacceptable radial height and/or inclination, the brachioradialis is cut. If the volar tilt is still unacceptable, the dorsal periosteum must be released. This is done by inserting a curved osteotome through the rectangular gap, and releasing the dorsal part of the distal fragment from any adhesions. Ensure that the tip of the osteotome is flushed to the dorsal cortex in order to avoid damage of the nearby extensor tendons. This step will further mobilize the distal fragment, and maximize the permissible correction.

A sterile ruler is then used to measure the size of the rectangular defect and this will be the minimum required size of tricortical iliac graft collected. If the surgeon is still not satisfied with the radial inclination or volar tilt, then the shape of the graft is modified to a trapezoid, rather than a rectangle.

Once the bone graft is cut to its desired size and shape, it is inserted into the gap. Once the graft is in place, we stabilize the

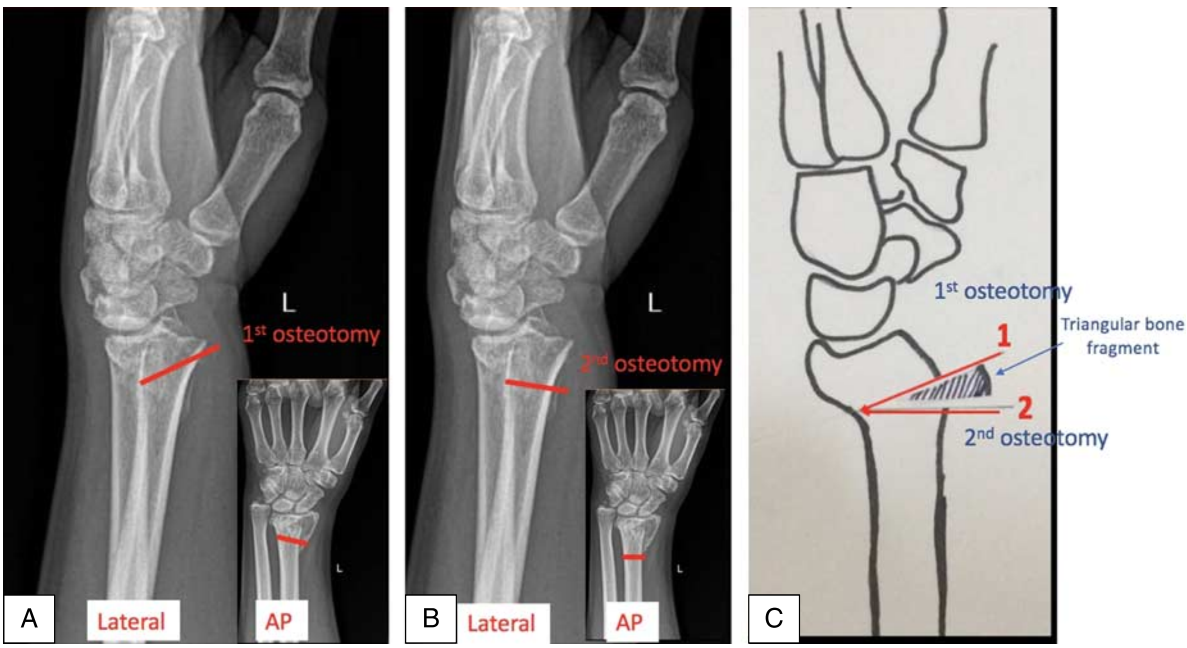

FIGURE 2. A, Lateral view x-ray of the wrist with the red line indicating the position and direction of the first osteotomy cut using a saw. Note the line to be parallel with the distal radius articular surface. B, Lateral view x-ray of the wrist with the red line indicating the position and direction of the second osteotomy cut. Note that the line is perpendicular to the axis of the radial shaft. C, The osteotomy cuts and its production of a triangular-shaped loose bone fragment.

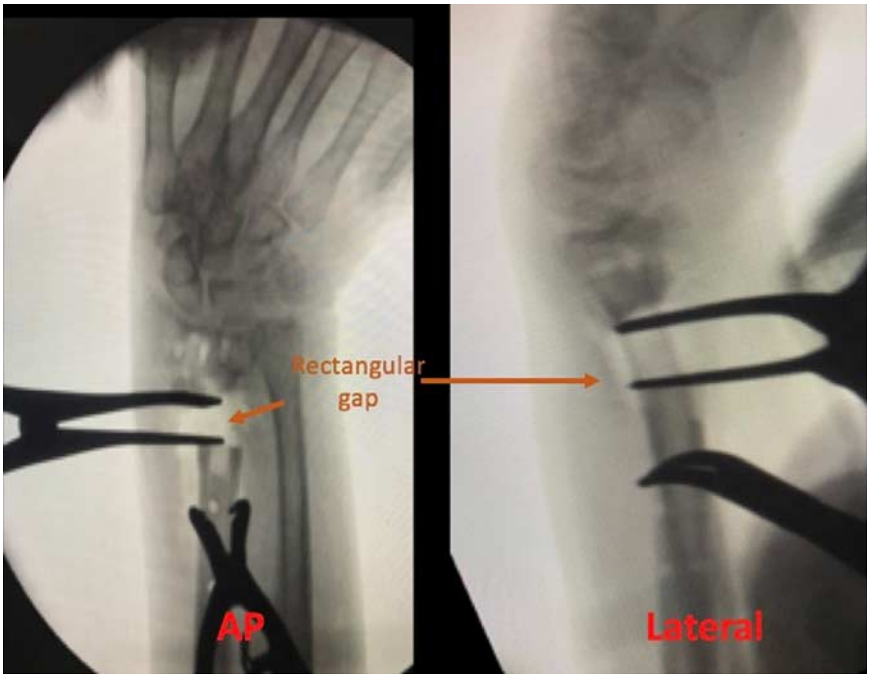

FIGURE 3. Anteroposterior and lateral view x-ray of the distal radius with a lamina spreader distracting the osteotomy site.

construct with a volar locking plate, ensuring adequate compression (Figs. 4, 5). The decision on choosing the length of the plate used is made at this point. Often times, a 4-hole plate is applied because the most distal hole on the plate tends to be in very close proximity to the applied bone graft. There are instances however, where a 3-hole plate may suffice; these were cases where the size of the bone graft used in the construct were relatively smaller.

We believe having a rectangular gap and graft, rather than a triangular one allows the best surface contact and congruency between graft and native bone. This allows maximum compression with the plate providing better stability and union. At this point, the previously stored loose bone fragment may be morselized and applied around the osteotomy site, otherwise this bone may be discarded.

We cover the plate with the pronator quadratus or the brachioradialis (if cut). We complete our closure by suturing the cut FCR sheath and skin with absorbable sutures.

Our preference is to immobilize the wrist for 4 weeks and do delayed wrist and forearm range of motion with aggressive

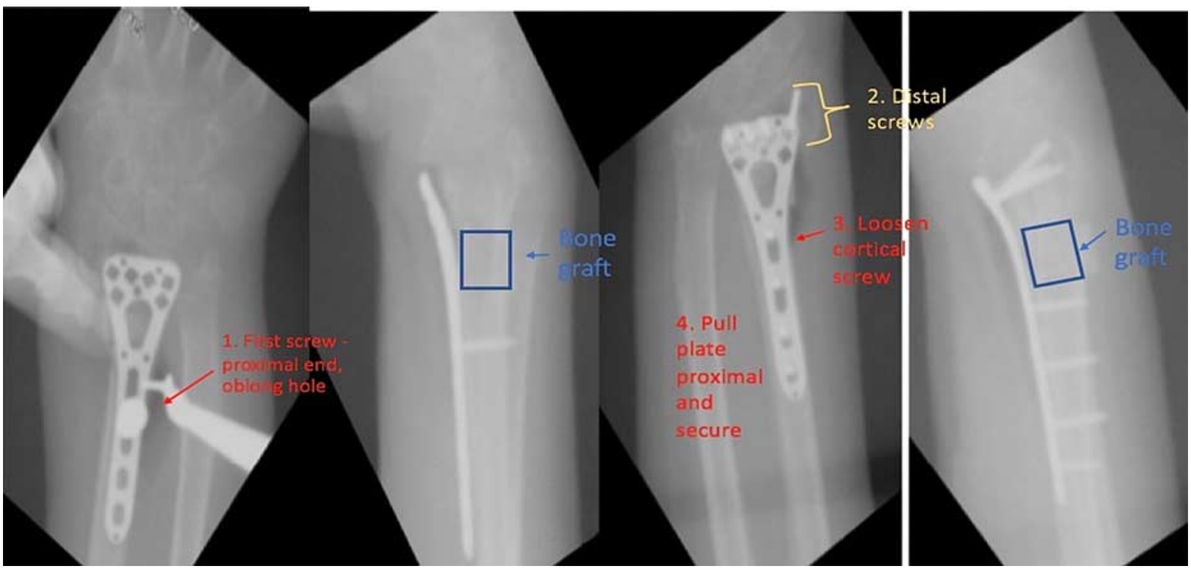

FIGURE 4. Intraoperative radiographs showing sequence of screw application. Cortical screw is placed first (1) within the oblong hole, usually at the most proximal area or center. Following this, distal screws are applied (2, 3). Cortical screw is then loosened, the plate pulled proximally (arrows) and cortical screw is once more tightened to allow compression of the bone graft area.

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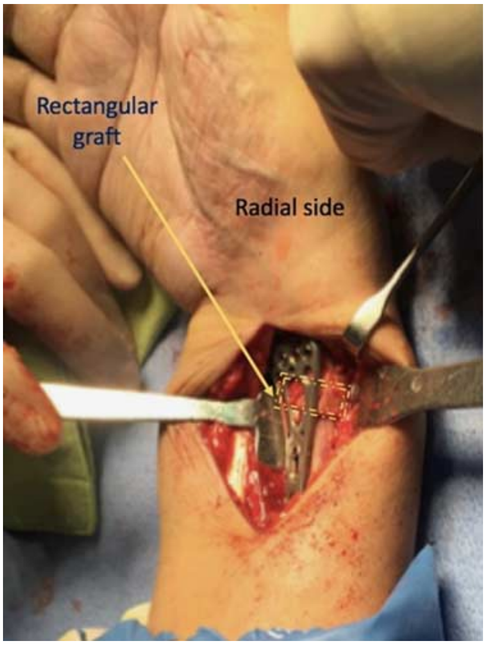

FIGURE 5. Gross appearance of operative site with graft and plate.

finger range of motion. We prefer to use an ulnar-based semicircular splint which grasps approximately three quarters the circumference of the forearm. The splint is fashioned immediately after the surgery and should begin at the level of the metacarpal heads and end just distal to the elbow joint. This splint is chosen because it aids in restricting pronosupination but allows elbow flexion and extension. After 4 weeks, patients are given a physician instructed home regimen for wrist and forearm range of motion and stretching exercises, while maintaining night splinting. At 6 to 8 weeks postoperatively, marked improvement in wrist and forearm movement is expected, otherwise the patient may be referred to a physiotherapist. We perform radiographs every 2 weeks to monitor the condition of the construct. We specifically look out for signs of nonunion. The frequency of radiographs is part of our protocol, but this may be adjusted and done less frequently once more cases are done and results become more predictable.

EXPECTED OUTCOMES

A total of 13 cases were performed using this technique. Preoperative and postoperative distal radius radiographic parameters were all measured and plotted for comparison purposes (Table 1). All measurements were again done both using the centers ancillary software program and manually. The central reference point was used in measuring ulnar variance and radial inclination.

In terms of radial inclination, 12 of 13 (92%) cases were successfully restored to values within the normal range. Radial height, on the other hand was restored to acceptable limits in all 13 (100%) cases. As for ulnar variance, 2 cases fell short of adequate correction. Included among these is subject J.Q., who began with an ulnar positive variance of 12 mm. This large correction was noted preoperatively and the patient was advised on possibly needing a concomitant ulnar shortening procedure. Intraoperatively, release of the brachioradialis and dorsal periosteum was done but in spite of this, a positive ulnar variance was still observed. We then proceeded to do an ulnar shortening osteotomy and ended still with an ulnar variance of +4 mm. This may possibly have been addressed if a more aggressive ulnar shortening was undertaken.

Palmar tilt was the least corrected parameter with only 9 of 13 (69%) cases falling to acceptable ranges. However, the 4 subjects with persistent abnormal parameters were all improved when compared with their preoperative measurements.

All cases were able to demonstrate improvement of functional outcomes as recorded in their respective preoperative and postoperative disabilities of the arm, shoulder and hand (DASH) scores. Common difficulties noted in DASH score questionnaires were persistence of some stiffness and weakness on the affected extremity and difficulty performing high impact recreational activities. All cases successfully concluded in radiographic and clinical union (Fig. 6).

TABLE 1. Preoperative and Postoperative Radiographic Parameters and DASH Scores

	Radial Inclincation (n: 13-30) (deg.)		Radial Height (n: 8-18) (mm)		Ulnar Variance (mm)		Palmar Tilt (n: 0-28) (deg.)		DASH	
Patient	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
V.L.	15.6	25.8	8	10.5	4+	2+	32.5 dorsal	10 dorsal	56.8	25
I.B.	11.7	24.2	7	9	2	0	0	12	50	22.7
M.B.	11.7	24.2	5	13	5+	0	20 dorsal	13.7	93.2	36.4
F.C.	14.2	16.2	10	10	8	1	16	12	45.5	22.7
S.A.	15.9	17.4	8	12	0	0	19 dorsal	0	38.6	15.9
O.R.	16	28	8	12	6	1	32.5 dorsal	0	54.5	29.5
J.Q.	0	26.6	0	17	12	4+	5 dorsal	13	93.2	25
E.C.	2	10	1	5	5	−2	27 dorsal	10 dorsal	45.5	20.5
E.M.	8	19.5	3	10	3	1	18 dorsal	2 dorsal	47.7	29.5
J.M.	15.5	21	6	9	2	0	23 dorsal	0	38.6	22.7
R.S.	11.5	24	2	15	4	1	18 dorsal	5 dorsal	61.4	27.3
D.K.	14	26	9	14	4	0	30 dorsal	0	75	34.1
M.S.	5	18	2	9	5	−1	24 dorsal	0	36.4	20.5

DASH indicates disabilities of the arm, shoulder and hand.

FIGURE 6. Preoperative, immediate postoperative, and 2 months postoperative x-rays of 3 cases done using our technique.

DISCUSSION AND RATIONALE

We prefer the volar approach because of the surgeon's familiarity and the relatively flat surface of the radius in this area. The use of the volar locking plate adds to the ease of correcting the deformity. It also lessens our incidence of dorsal tendon irritation as screws may be placed in a unicortical manner. The presence of the pronator quadratus or brachioradialis theoretically provides a soft tissue barrier to protect flexor tendons from the hardware, particularly when this is successfully repaired back after the plate is fixed into the bone.[16,17] Although a number of publications have argued that this step may be unnecessary[18,19] we choose to utilize these soft tissues if they are available as a precaution.

The creation of a rectangular defect, instead of a triangular one may have many advantages that contribute to this technique's success. The rectangular shape is much easier to reproduce from the iliac bone donor site. Making fine adjustments in the grafts shape and configuration is much simpler when straight lines are made instead of precise angles. In addition, a rectangular-shaped graft immensely solves issues regarding adequate correction of radial height and ulnar variance. As these grafts can be large more extreme and severe cases of distal radius malunion can be successfully restored.

As the created defect is rectangular in shape, congruency between the created graft and the distracted gap is more easily achieved. By creating a congruent gap-graft construct, we create easily opposable contact between graft and native bone. The flat surface between graft and native bone affords higher chances of equal distribution of weight, and stress transmission along the radial shaft. The rectangular graft also decreases the chances of shear, once weight is placed on the extremity and axial force is applied. These factors are particularly useful in promoting union, especially once compression is applied by the locking plate as it is pulled proximally and secured.

The rectangular gap also allows simple and easy access to the dorsal side of the radius, which can be very useful when adjusting the distal fragment during correction of malunion. This access can afford easy and adequate mobilization of the distal fragment, allowing the surgeon better chances of correction of palmar tilt and radial height.

We do acknowledge that the use of a rectangular graft omits cortical contact between native bone in the distal radius metaphyseal area. We agree that interposition of bone graft of this size poses a concern regarding union, which is why this technique is especially indicated for cases where the degree of deformity is large, and the use of big blocks of structural bone may be warranted. The choice to use bone graft is also crucial, in order to promote the high chances of bone incorporation and union.

EXPECTED COMPLICATIONS

The most common complication noted was pain and/or numbness at the graft donor site. Cases were managed with intake of nonsteroidal anti-inflammatory drugs for 1 to 2 weeks.

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In most cases this was sufficient to relieve symptoms and symptoms were usually noted to resolve within this 2-week period.

Finger and wrist stiffness may occur during the first few weeks postoperatively. This was addressed with patient assurance and a physician instructed home exercise program. If patients are not comfortable doing this, or if stiffness is persistent, they may be referred for supervised physiotherapy sessions.

One subject was noted to experience reflex sympathetic dystrophy. The subjected was managed with high dose vitamin C supplements. She was also referred for physiotherapy and was instructed to do home desensitization exercises. The patient showed gradual improvement of symptoms and graduated from therapy sessions after 8 weeks.

Throughout the follow-up period it is also important to watch out for signs of nonunion which may lead to implant failure, especially as the construct in our technique involves creation of a segmental type of gap. This can be monitored with serial x-rays and inquiring about any persistence of pain on the postoperative site. In our current series, there were no cases of nonunion

CONCLUSIONS

Many techniques are available in order to correct malunited fractures of the distal radius. Ultimately, an adequate understanding of important parameters and knowledge of means of correction is needed in order to achieve success. Here, we offer an alternative technique for correcting distal radius malunion. We propose the creation of a rectangular gap and graft within the osteotomy site to aid in restoration of distal radius parameters and at the same time, take advantage of this flat surface configuration to compress the osteotomy site to promote stability and union.

With this technique, we are successfully able to restore radial height. Other parameters such as radial inclination, palmar tilt, and ulnar variance are also correctible with this technique. In terms of functional outcome, DASH scores of subjects who have undergone this technique yielded improvements in their ability to perform activities of daily living. We therefore encourage the use of this technique especially when radial height is of particular concern during the reconstructive osteotomy.

REFERENCES

1. Fernandez DL, Jupiter JB. *Fractures of the distal radius: a practical approach to management*. New York: Springer-Verlag; 1996:263–316.
2. Slagel BE, Luenam S, Pichora DR. Management of post-traumatic malunion of fractures of the distal radius. *Orthop Clin North Am*. 2007;38:203–216.
3. Lodha SJ, Wysocki RW, Cohen MS. Malunions of the distal radius. In: Chung KC, Murrary PM, eds. *Hand Surgery Update V*. Rosemont, IL: American Society for Surgery of the Hand; 2011:139–146.
4. Jupiter JB, Fernandez DL. Complications following distal radial fractures. *J Bone Joint Surg*. 2001;83:1244–1265.
5. Fernandez DL. Corrective osteotomy for extra-articular malunion of the distal radius. In: Saffar P, Cooney WP III, eds. *Fractures of the Distal Radius*. London: Martin Dunitz; 1995:104–117.
6. Fourrier P, Bardy A, Roche G, et al. Approche d'une definition du cal vicieux du poignet [Approach to a definition of mal-union callus after Pouteau-Colles fractures]. *Int Orthop*. 1981;4:299–305.
7. Graham T, Hastings H. Management of the distal radio-ulnar joint in post- traumatic deformity of the radius. In: Vastamäki M, Vilkki S, Göransson H, Jaroma H, Raatikainen T, Viljakka T, eds. *6th Congress of International Federation of Societies for Surgery of the Hand (IFSSH)*. Bologna, Italy: Monduzzi; 1995:571–574.
8. Graham T. Surgical correction of malunited fractures of the distal radius. *J Am Acad Orthop Surg*. 1997;5:270–281.
9. Keleş G, Desteli EE, Erdoğan M, et al. Conservative treatment of distal radius fractures, importance of radial height. *J Clin Anal Med*. 2014;7:601–605.
10. Cai L, Zhu S, Du W, et al. The relationship between radiographic parameters and clinical outcome of distal radius fractures in elderly patients. *Orthop Traumatol Surg Res*. 2015;101:827–831.
11. Fernandez DL. Correction of post-traumatic wrist deformity in adults by osteotomy, bone-grafting, and internal fixation. *J Bone Joint Surg*. 1982;64:1164–1178.
12. Rothenfluh E, Schweizer A, Nagy L. Opening wedge osteotomy for distal radius malunion: dorsal or palmar approach? *J Wrist Surg*. 2013;2:49–54.
13. Peterson B, Gajendran V, Szabo RM. Corrective osteotomy for deformity of the distal radius using a volar locking plate. *Hand (NY)*. 2008;3:61–68.
14. Mugnai R, Tarallo L, Lancellotti E, et al. Corrective osteotomies of the radius: grafting or not? *World J Orthop*. 2016;7:128–135.
15. Medoff RJ. Essential radiographic evaluation for distal radius fractures. In: Slutsky DJ, ed. *Principles and Practices of Wrist Surgery*. London: Saunders; 2005:59–67.
16. Ahsan ZS, Yao J. The importance of pronator quadratus repair in the treatment of distal radius fractures with volar plating. *Hand*. 2012;7:276–280.
17. Nanno M, Kordera N, Tomori Y, et al. Transverse ultrasound assessment of the flexor pollicis longus tendon movement on the distal radius during wrist and finger motion in distal radius fracture with volar plating. *J Med Ultrason*. 2016;43:29–36.
18. Brown EN, Lifchez SD. Flexor pollicis longus tendon rupture after volar plating of a distal radius fracture: pronator quadratus plate coverage may not adequately protect tendons. *Eplasty*. 2011;11:e43.
19. Mulders M, Walenkamp M, Bos F, et al. Repair of the pronator quadratus after volar plate fixation in distal radius fractures: a systematic review. *Strategies Trauma Limb Reconstr*. 2017;12:181–188.