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Outcomes of Ulnar Shortening Osteotomy with an Intramedullary Bone Graft for Idiopathic Ulnar Impaction Syndrome

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Background: Although several techniques for the treatment of ulnar impaction syndrome (UIS) have been introduced, there have still been reports on various complications such as delayed union, nonunion, refracture, wrist pain, plate irritation, and chronic regional pain syndrome. This study aimed to compare the differences in radiological and clinical outcomes of patients in which intramedullary bone grafting was performed in addition to plate stabilization with those without additional bone grafting during ulnar shortening osteotomies (USOs).

Methods: Between November 2014 and June 2021, 53 wrists of 50 patients with idiopathic UIS were retrospectively reviewed. Patients were divided into 2 groups according to whether intramedullary bone grafting was performed. Among the 53 wrists, USO with an intramedullary bone graft was performed in 21 wrists and USO without an intramedullary bone graft was performed in 32 wrists. Demographic data and factors potentially associated with bone union time were analyzed.

Results: There was no significant difference between the 2 groups when comparing postoperative radioulnar distance, postoperative ulnar variance, amount of ulnar shortening, and postoperative Disabilities of the Arm, Shoulder and Hand score. Compared to the without-intramedullary bone graft group, bone union time of the osteotomy site was significantly shortened, from 8.8 ± 3.0 weeks to 6.7 ± 1.3 weeks in the with-intramedullary bone graft group. Moreover, there were no cases of nonunion or plate-induced symptoms. Both in univariable and multivariable analyses, intramedullary bone grafting was associated with shorter bone union time.

Conclusions: USO with an intramedullary bone graft for idiopathic UIS has favorable radiological and clinical outcomes. The advantage of this technique is the significant shortening of bone union time.

Keywords: *Ulnar impaction syndrome, Ulnar shortening osteotomy, Intramedullary bone graft, Bone union*

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Ulnar impaction syndrome (UIS), which can lead to symptoms such as ulnar-side wrist pain, limitation of wrist motion, and diminished grip strength, is known to result from excessive pressure of the ulnar head against the triangular fibrocartilage complex (TFCC) and the carpal bones on the ulnar side of the wrist.[1] The etiology of this syndrome is categorized as idiopathic or secondary, such as traumatic conditions including malunion of the distal radius fracture, radial premature physeal arrest (Madelung syndrome), excision of the radial head, or Essex-Lopresti fracture-dislocation.[2-4]

Since Milch[5] described the ulnar shortening osteotomy (USO), it has been widely used to decompress the ulnocarpal articulation by restoring zero or negative ulnar variance. Moreover, this extra-articular procedure has the advantage of preserving the distal radioulnar joint (DRUJ) and surrounding structures over other intra-articular surgical methods, such as distal ulnar recession or the wafer procedure.[6,7] Since then, various surgical methods for the treatment of UIS have been introduced with the goal of restoring ulnar variance and reducing complications and have shown generally satisfactory outcomes.[8,9] However, despite these procedures, some studies have reported various complications, such as delayed union or nonunion, refracture, wrist pain, plate irritation, and chronic regional pain syndrome (CRPS).[10,11]

We hypothesized that grafting the osteotomized ulnar bone fragment, which was extracted during the USO, to the osteotomy site could decrease and improve such complications, especially those related to bone union. Hence, this study aimed to compare the differences in radiological and clinical outcomes depending on whether bone grafting was performed during USO or not.

METHODS

Patient Selection

This study's design was approved by the Institutional Review Board of the Seoul National University College of Medicine/Seoul National University Hospital (No. H-2004-121-1118), which waived the need for informed consent, owing to its retrospective nature. Among the patients who had a history of ulnar-side wrist pain that worsened by pronation and ulnar deviation and presented with positive physical examination, static or dynamic positive ulnar variance with wrist pronation, and forceful grip on plain radiographs, 65 wrists with idiopathic UIS that underwent the USO between November 2014 and June 2021 were included. Twelve wrists that had a history of congenital disease, trauma, surgery, inflammatory disease of the upper extremity, or less than 1 year of follow-up were excluded. Finally, 53 wrists of 50 consecutive patients with idiopathic UIS were enrolled. Patients were divided into 2 groups according to whether intramedullary bone grafting was performed: (1) without-intramedullary bone graft and (2) with-intramedullary bone graft. The former group comprised 32 wrists on which USO was performed without intramedullary bone graft by a single surgeon (JHK). While the latter group consisted of 21 wrists on which a single surgeon (GHB) performed USO with intramedullary bone graft. Both surgeons were fellowship-trained in hand surgery and had a minimum 15 years of clinical experience in the hand practice. There were 17 men (32.1%) and 36 women (67.9%), with a mean age of 46.8 years (range, 22–83 years).

Surgical Techniques

In all patients, nonoperative treatments, such as immobilization, nonsteroidal anti-inflammatory drug medication, and life-style modification were attempted for over 3 months. An incision of approximately 8 cm was placed on the lateral aspect of the forearm, beginning 4 cm proximal to the tip of the ulnar styloid. While protecting the dorsal sensory branch of the ulnar nerve, the ulna was approached between the flexor carpi ulnaris (FCU) and extensor carpi ulnaris. After FCU retraction, the plate was placed on the volar side of the ulna and subsequently covered back with the FCU to reduce irritation. A transverse osteotomy was performed and a bone fragment was resected according to the preoperatively determined amount to restore the ulnar variance between –1 and 0 mm. Before compressing the osteotomy site using a low-profile dynamic compression plate (Arix; Jeil Medical), half of the osteotomized fragment was inserted into the medullary canal. After compression of the osteotomy site, the remaining screws were secured. The other half of the resected fragment was morselized and locally grafted around the osteotomy site (Fig. 1). During the entire procedure, the periosteum was preserved as much as possible. Postoperatively, a long-arm splint was applied for the first 2 weeks, followed by a removable long-arm splint for another 4 to 6 weeks.

Assessment of Outcomes

Demographic features such as age, sex, follow-up duration, diabetes mellitus, smoking, and radiological or clinical variables were compared between the 2 groups. Radiological variables were compared pre- and postoperatively. The anteroposterior plain radiographs of the wrist were taken with the shoulder at 90° of abduction, the elbow at 90° of

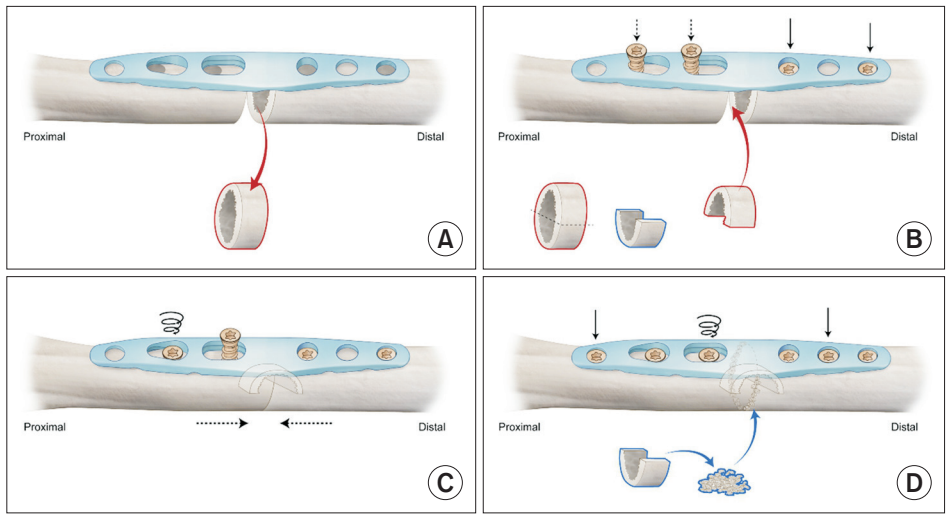

Fig. 1. Schematic diagram of the ulnar shortening osteotomy with an intramedullary bone graft. From the proximal side, the second oblong compression hole and the third sliding hole are for the cortical screws. The remaining holes are combination holes, and both cortical and locking screws can be used, depending on the purpose. (A) After predrilling the proximal and distal holes along the marked line to verify the alignment and to prevent malrotation, the ulnar bone was cut by a transverse osteotomy to the length that had been preoperatively measured. (B) Through the predrilled distal screw holes, the plate was secured to the bone by screws. After the osteotomized fragment, which had been cut in half, was grafted in the medullary canal, the proximal oblong compression and sliding holes were temporarily secured. (C) The osteotomy site was compressed by securing the oblong compression hole. (D) After tightening the screw in the sliding hole, the rest of the screws were tightened in sequence. Additionally, the remaining half of the resected bone was morselized and placed at the osteotomy site as a graft.

flexion, and the forearm in a neutral position. To quantify the dorsal subluxation of DRUJ, radioulnar distance was measured in the true lateral position of the wrist with a pisoscaphoid distance of less than 3 mm.[12] Moreover, ulnar variance was analyzed by measuring the distance between a line drawn perpendicular to the longitudinal axis of the radius on its distal ulnar side and the horizontal line at the end of the distal ulna.[3] The amount of ulnar shortening, signs of preoperative radiographic carpal chondromalacia, postoperative arthritic change in the DRUJ, and bone union were also evaluated. Radiological as well as clinical variables, such as pre- and postoperative Disabilities of the Arm, Shoulder and Hand (DASH) score, were measured.

The union of the osteotomy site was radiographically determined and clinically confirmed. Radiographic assessments were performed immediately, 1 week after surgery, and then every 2 weeks until bone union was verified. Bone union was defined as the radiographic presence of confluent bony bridging on either side of the osteotomy site. In addition, nonunion was defined when 3 of 4 cortices of the osteotomy site had not shown continuity over 6 months or had not shown any radiographic change for 3 consecutive months and were accompanied by clinical features of nonunion.[13] The radiographic features were measured by 2 independent orthopedic surgeons who were blinded to the demographic data (KWK and KJB). Postoperative radiological complications such as nonunion or refracture and clinical complications such as plate related symptoms, infection, or CRPS were also evaluated.

Statistical Analysis

Changes in variables were compared according to whether intramedullary bone grafting was performed. Categorical variables were compared using the chi-square test and continuous variables were compared using an independent *t*-test. Factors potentially associated with bone union time, such as intramedullary bone graft, age, sex, diabetes mellitus, smoking, radioulnar distance, ulnar variance, and amount of ulnar shortening, were analyzed. Univariable and multivariable analyses were performed using a linear regression model to identify the factors associated with bone union time. In the multivariable linear regression model, intramedullary bone graft (yes/no), sex (men/women), and age were selected as predictor variables using the stepwise Akaike Information Criterion regression method. Statistical power was calculated using the statistical software R version 4.0.1 (R Foundation for Statistical Computing).

RESULTS

The average follow-up duration was 37.1 months (range, 14–78 months). Among the all cases, 1 case of diabetes and 6 cases of smoking history were confirmed. The average preoperative radioulnar distance was 2.7 ± 1.3 mm and 2.9 ± 1.5 mm in the without- and with intramedullary bone graft groups, respectively. Meanwhile, the postopera-

Table 1. Demographics of the Groups without and with Intramedullary Bone Grafts

Variable	Overall	Without-intramedullary bone graft	*p*-value*	With intramedullary bone graft	*p*-value*	*p*-value†
No. of patients	53	32		21		-
Age (yr)	46.8 ± 13.4	46.5 ± 13.8		46.2 ± 13.1		0.951
Sex						0.551
Male	17	9		8		
Female	36	23		13		
Follow-up duration (mo)	37.1 ± 20.0	33.0 ± 17.2		43.3 ± 22.7		0.671
Diabetes mellitus						0.604
–	52	31		21		
+	1	1		0		
Smoking						0.671
–	47	29		18		
+	6	3		3		
Radioulnar distance (mm)			< 0.001		< 0.001	
Preoperative	2.8 ± 1.4	2.7 ± 1.3		2.9 ± 1.5		0.610
Postoperative	1.1 ± 1.0	1.1 ± 1.0		1.0 ± 1.1		0.635
Ulnar variance (mm)			< 0.001		< 0.001	
Preoperative	3.5 ± 1.1	3.3 ± 1.0		3.7 ± 1.3		0.209
Postoperative	–0.1 ± 0.6	–0.1 ± 0.6		0.1 ± 0.7		0.251
Amount of ulnar shortening (mm)	3.4 ± 1.1	3.3 ± 0.8		3.5 ± 1.0		0.320
DASH score			< 0.001		< 0.001	
Preoperative	45.5 ± 10.3	44.0 ± 9.5		47.7 ± 11.2		0.195
Postoperative	15.8 ± 5.0	15.8 ± 5.8		15.8 ± 3.7		0.981
Preoperative radiographic carpal chondromalacia						0.738
–	47	28		19		
+	6	4		2		
Postoperative arthritic change						0.415
–	46	29		17		
+	7	3		4		

Values are presented as mean ± standard deviation.
DASH: Disabilities of the Arm, Shoulder and Hand.
*Comparison of preoperative to postoperative values in each group. †Comparison of the 2 groups.

tive radioulnar distance was 1.1 ± 1.0 mm and 1.0 ± 1.1 mm in the without- and with-intramedullary bone graft group, respectively. The average of preoperative ulnar variance was 3.3 ± 1.0 mm and 3.7 ± 1.3 mm, and postoperative ulnar variance was –0.1 ± 0.6 mm and 0.1 ± 0.7 mm, respectively, in without- and with-intramedullary bone graft group. Additionally, the average amount of ulnar shortening was 3.4 ± 1.1 mm. The average preoperative DASH score of the without- and with-intramedullary bone graft groups was 44.0 ± 9.5 and 47.7 ± 11.2, respectively; at the final follow-up, and the score significantly improved to 15.8 ± 5.8 and 15.8 ± 3.7, respectively. However, in terms of the postoperative DASH score, there was no significant difference between the 2 groups. Six of the 53 wrists showed cystic changes in the carpal bones preoperatively: 4 wrists had changes in the lunate, 1 in the lunate and ulna, and 1 in the lunate, ulna, and triquetrum bones. These cystic changes began to disappear at least 1 year after USO and had vanished at the last follow-up. Moreover, 7 of the 53 wrists showed degenerative changes in the DRUJ postoperatively (Table 1). However, no other clinical symptoms were noted.

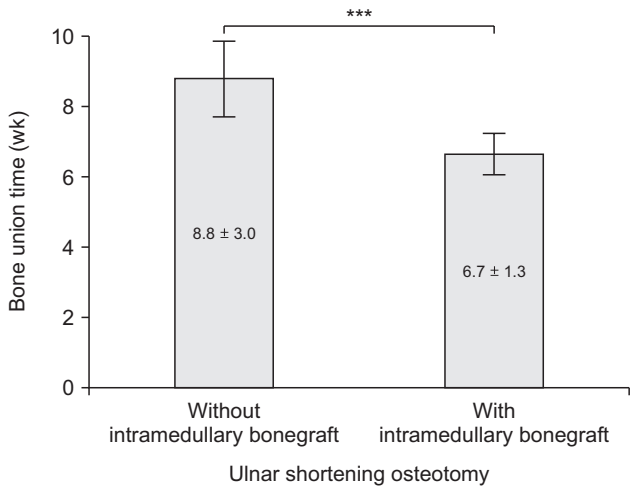

Fig. 2. Comparison of the mean value (and standard deviation) for bone union time between the without or with intramedullary bone grafts. The bone union time was significantly shortened from 8.8 ± 3.0 to 6.7 ± 1.3 weeks in the with-intramedullary bone graft group (***$p < 0.001$).

Union of the osteotomy site was achieved in all patients at a mean of 8.0 ± 2.7 weeks (range, 4–19 weeks).

Table 2. Linear Regression Analyses for Factors Associated with Bone Union Time

Variable	Univariable linear regression			Multivariable linear regression		
	β	SE	*p*-value	β	SE	*p*-value
Intramedullary bone graft						
–	Ref			Ref		
+	–2.2	0.7	0.003*	–2.3	0.7	0.001*
Age (yr)	0.1	0.0	0.089	0.0	0.0	0.121
Sex						
Male	Ref			Ref		
Female	–1.1	0.8	0.148	–1.2	0.7	0.091
Smoking						
–	Ref					
+	0.3	1.2	0.816			
Radioulnar distance (preoperative) (mm)	0.3	0.6	0.654			
Radioulnar distance (postoperative) (mm)	–0.1	0.3	0.756			
Ulnar variance (preoperative) (mm)	–0.1	0.4	0.828			
Ulnar variance (postoperative) (mm)	0.0	0.3	0.988			
Amount of ulnar shortening (mm)	–0.0	0.4	0.987			

β: correlation coefficient, SE: standard error, Ref: reference.
*Indicates significant value.

When comparing the bone union time according to whether the intramedullary bone grafting was used, the time significantly decreased from 8.8 ± 3.0 weeks to 6.7 ± 1.3 weeks in the with-intramedullary bone graft group ($p < 0.001$) (Fig. 2). Additionally, there were no cases of nonunion. However, there were 3 cases in which bone union had taken more than 3 months in the without-intramedullary bone graft group. Regarding clinical manifestations, there were no cases of plate-induced symptoms, infection, neurologic deficits, or CRPS.

Prior to the linear regression analyses, the distribution between the 2 groups was compared based on the median value of overall bone union time (7.1 weeks) to find the factors related to bone union time. As a result, the proportion of intramedullary bone grafting was higher in the group with low bone union time ($p = 0.033$) (Supplementary Table 1). In the univariable analysis, intramedullary bone grafting was significantly associated with bone union time. Moreover, in the multivariable regression analysis, which was adjusted for other covariates (age and sex), intramedullary bone grafting showed a significant association with bone union time ($\beta = -2.3$, $p = 0.001$) (Table 2). The intraclass correlation coefficient for bone union was 0.92 for intraobserver reliability and 0.81 for interobserver reliability.

DISCUSSION

Although several novel techniques and devices have been introduced for the treatment of UIS over the past decades,[8,9] a previous systematic review[11] reported that the average rates of delayed union and nonunion of osteotomy sites after USO were 5.7% and 4.0%, respectively. In general, bone grafting in USO has been performed when a nonunion has occurred, rather than in primary surgery.[14] Furthermore, in cases where bone grafting is required, bone is usually harvested from the iliac bone, but this can lead to various donor-site complications such as pain, nerve injury, hemorrhage, or infection, delaying return to daily activities.[15] However, by using the bone fragment that would normally be discarded, rather than performing any invasive or additional procedures, our surgical method is useful in that not only are there no cases of nonunion, but the bone union time is significantly reduced.

Moreover, from the perspective of bone healing, endosteal bone healing has not received sufficient attention, unlike periosteal bone healing.[16] However, Schwartz and Boyan[17] mentioned the importance of cellular responses during endosteal bone healing in animal models. In addition, McKinley[18] focused on the responses of endosteal bone healing that differ from healing responses in the surrounding periosteum, soft tissue, and between the cortical ends. Hence, in this study, we considered the combination of osteogenic, osteoinductive, and osteoconductive properties of autologous bone grafts[19] and also the fact that the mid-distal of the ulna contains less than 10% cancellous bone.[20] Therefore, in addition to adequate saline irrigation to reduce thermal damage[21] and maximal preservation of the periosteum during USO, intramedullary bone grafting was applied to promote bone healing

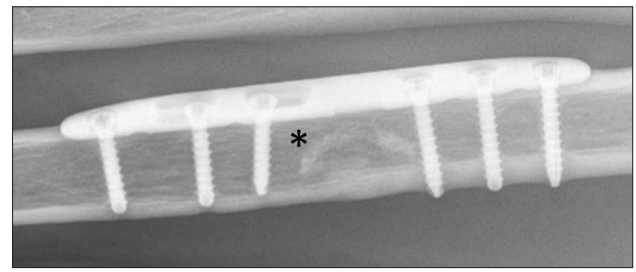

Fig. 3. Postoperative plain radiographs of a 57-year-old man with ulnar impaction syndrome. At the last follow-up, the osteotomized fragment that was cut in half and grafted in the medullary canal was still well-settled (asterisk). Solid bone union was achieved and there were no complications.

Table 3. Comparison of Outcomes with Previous USO Studies

Study	Case (n)	Follow-up duration (mo)	Union time (wk)	Delayed union	Nonunion	Plate-induced symptom
Darrow et al. (1985)[6]	36	25	13	8	1	2
Wehbe et al. (1995)[22]	24	32	9.7	3	0	24
Clark et al. (2012)[23]	93	6	7	0	0	5
Ahsan et al. (2013)[14]	30	8	10	Not documented	2	4
Iniesta et al. (2020)[24]	20	16	11	Not documented	1	3

USO: ulnar shortening osteotomies.

and reduce complications. As a result, not only were there no delayed union or nonunion cases, but bone union time was significantly shortened. Although many studies have reported satisfactory results for USO, the bone union time and complications related to USO in this study are superior to those of previous studies (Table 3).[6,14,22-24] It is suspected that autologous bone grafting in the medullary canal and around the osteotomy site could promote bone union. At the final follow-up period, the osteotomized fragment that had been cut in half and grafted in the medullary canal was confirmed to be well-settled (Fig. 3).

Diabetes mellitus and smoking are known significant risk factors for delayed union or nonunion in USO.[25] However, in this study, the influence of these factors was limited. Although diabetes mellitus and smoking were considered, statistical significance could not be drawn due to their low prevalence in the sample. In particular, due to the extremely low prevalence of diabetes mellitus in the sample, we could not adjust for it in our linear regression models. However, regardless of the presence or absence of these factors, delayed union or nonunion did not occur.

This study has some limitations. First, it was limited by the relatively small sample size and its retrospective nature. Although statistical significance was obtained, a more robust result could have been achieved if a prospective randomized study design with a larger number of samples had been conducted. Second, this study is an observational study, which means that potential confounding variables could not be fully excluded since the surgical approach was not randomly assigned. However, the inclusion and exclusion criteria were strictly applied to ensure that the preoperative characteristics of the subjects were comparable. Additionally, it was confirmed that the baseline characteristics were not statistically significantly different between the without- and with-intramedullary bone graft groups (Supplementary Table 1). Using a multivariable regression model, possible confounders that might affect the association of graft intervention with bone union time were adjusted. Third, as different surgical methods were performed by 2 different surgeons, bias could have occurred. However, not only was there no preference about the patients' allocation, but the surgeries were performed by 2 experienced surgeons (experience levels IV and V[26]) in the hand practice and were followed by the same perioperative protocol at the same institution. Fourth, only a transverse cut osteotomy for the USO was performed. Although it has been hypothesized that oblique osteotomy could provide a large surface area for bone healing,[4] there was no statistically significant difference in the rate of bone healing time, nonunion, or functionality between transverse and oblique cut osteotomy.[12,14] Fifth, bone grafting was performed using bone material that was extracted from the osteotomy site of each patient. Because the thickness of the removed bone fragment at the osteotomy site was different for each patient, the amount of bone fragments used for bone graft was not the same. Finally, we did not proceed with further examinations or additional surgeries for TFCC. Previous studies have reported that TFCC tears are associated with UIS.[27,28] However, recent arthroscopic and radiologic studies have reported on the effectiveness of USO alone for TFCC tears in UIS.[29,30] In particular, Nishiwaki et al.[31] reported that USO leads to a suspension effect on the TFCC, resulting in the stabilization of the DRUJ. Furthermore, excellent clinical outcomes were observed in our study regardless of TFCC repair.

USO with an intramedullary bone graft for idiopathic UIS, which provides the effects of an autologous bone graft, significantly shortens the bone union time compared to USO without an intramedullary bone graft. Particularly, it is significant that such remarkable results were obtained without any additional devices or invasive procedures. Hence, this technique, which aims to promote bone healing, can be an alternative treatment option for UIS.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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SUPPLEMENTARY MATERIAL

Supplementary material is available in the electronic version of this paper at the CiOS website, www.ecios.org

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