Research Square

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How to Achieve Faster Osteotomy Healing and Prevent Refracture after Ulnar Shortening Osteotomy?

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Abstract

Background: Parallel osteotomy is essential for favorable osteotomy reduction and healing and technically challenging during diaphyseal ulnar shortening osteotomy (USO). This study aimed to evaluate the advantages of guided osteotomy for parallel osteotomy and reduction osteotomies and healing over freehand osteotomy. It also aimed to identify surgical factors affecting healing after diaphyseal USO.

Methods: Between June 2005 and March 2016, 136 wrists that had undergone diaphyseal USO for ulnar impaction syndrome (UIS) were evaluated. The wrists were divided into two groups according to the osteotomy technique (Group 1: freehand osteotomy, 74 wrists; Group 2: guided osteotomy, 62 wrists). The osteotomy reduction gap and time to osteotomy healing (union and consolidation) were compared between the groups. A multiple regression test was performed to identify the surgical factors affecting healing. The cut-off length of the reduction gap to achieve osteotomy union on time and the cut-off period to decide the failure of complete consolidation were statistically calculated.

Results: The baseline characteristics were not different between the two groups. The osteotomy reduction gap, time to osteotomy union, and complete consolidation were shorter in Group 2 than in Group 1 ($p=0.002$, <0.001, 0.002). The osteotomy reduction gap was a critical surgical factor affecting both time to osteotomy union and complete consolidation ($p<0.001$, <0.001). The use of a dynamic compression plate affected only the time to complete consolidation ($p<0.001$). The cut-off length of the osteotomy reduction gap to achieve osteotomy union on time was 0.85 mm. The cut-off period to decide the failure of complete consolidation was 23.5 months after osteotomy.

Conclusions The minimal osteotomy reduction gap was the most important for timely osteotomy healing in the healthy ulna and a guided osteotomy was beneficial to reducing the osteotomy reduction gap during USO.

Introduction

Since Milch [1] first described distal diaphyseal ulnar shortening osteotomy (USO) in 1941, it has been the most famous surgical procedure for ulnar impaction syndrome (UIS)[2–7]. The clinical outcomes of USO have also been satisfactory [2, 4, 6, 7]. Despite its good clinical outcomes, its critical shortcomings, including nonunion or delayed union following the procedure, have variable incidence (0–12.7%) and remain unresolved [2, 4, 8].

Healing after USO is affected by multitudinous factors that are both patient- and surgery-related [9]. The representative and well-known patient-related risk factors for the nonunion or delayed union include age, low bone mineral density, obesity, diabetes, thyroid disease, smoking, and alcohol consumption [9–14]. Studies on surgical risk factors are limited, and the factors have not been identified clearly[9]. Because the surgical risk factors can be controlled by the surgeon while patient-related factors, cannot be resolved entirely, identifying and avoiding surgical risk factors are critical in preventing or overcoming nonunion or delayed union.

This study aimed to evaluate whether guided osteotomy using a dedicated ulnar shortening osteotomy system is beneficial for parallel and reduction osteotomies and healing after USO (union and complete consolidation [disappearance of any trace of osteotomy]) compared to conventional freehand osteotomy and to identify the surgical factors affecting healing after USO.

Methods

Patients

This study was approved by the local institutional review board and informed consent was obtained from all enrolled patients (2018AS0050). The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki. Of the 212 wrists that had undergone USO for idiopathic UIS between June 2005 and March 2016, we selected 136 wrists (124 patients, right wrist: 68, left wrist: 68, both wrists: 12) that met our inclusion and exclusion criteria and reviewed them retrospectively. The inclusion criteria included patients with idiopathic UIS who underwent USO and postoperative follow-up for at least one year. Patients with a prior trauma history and/or comorbidities, such as diabetes, thyroid or parathyroid disease, renal disease, congenital metabolic bone disease, rheumatoid arthritis, severe obesity, and low bone density, and patients on glucocorticoid therapy, or with a smoking or alcohol consumption history less than one month before USO were excluded to avoid false conclusions on the osteotomy healing.

The diagnostic criteria for UIS included symptoms of ulna-sided wrist pain that aggravated with pronation and ulnar deviation of the wrist, pain during the ulnar stress test, tenderness in the ulnocarpal joint, positive ulnar variance in pronated-grip radiographs during either neutral rotation or cystic changes in the lunate or triquetrum, and degeneration of the lunate or triquetral cartilage in Magnetic Resonance Imaging[15].

Study design

To compare the osteotomy technique's effect on parallel osteotomy and osteotomy healing, the wrists were divided into two groups according to the osteotomy technique (Group 1: freehand osteotomy, 74 wrists; Group 2: guided osteotomy, 62 wrists). The osteotomy reduction gap (the longest distance between two osteotomized surfaces after osteotomy reduction, Fig. 1a), the time to osteotomy union and the time to complete osteotomy consolidation were compared between the groups.

To identify the surgical factors affecting the time to osteotomy union and the time to complete osteotomy consolidation, we performed multiple regression tests for the direction of osteotomy, the gap after reduction osteotomy, length of ulnar shortening, usage of a lag screw, and plate type used for osteotomy fixation. Additionally, the cut-off length of the osteotomy reduction gap to obtain union within six months and the maximum period to achieve complete osteotomy consolidation were statistically calculated.

Surgery and postoperative rehabilitation

Distal diaphyseal USO was performed by two experienced surgeons under general anesthesia or brachial plexus block. Both surgeons used the same criteria to diagnose idiopathic UIS and the same surgical techniques. The periosteum of the ulna was not stripped during surgery to preserve the local blood supply around the osteotomy site. In group 1, freehand osteotomy was performed according to the previously described technique, and the osteotomy was fixed with a 3.5 mm limited contact-dynamic (LC-DCP; Dupuy-Synthes, Paoli, PA, USA) or locked (LCP; Dupuy-Synthes, Paoli, PA, USA) compression plate, after manual reduction[6]. In group 2, guided osteotomy was performed with a 2.7 mm (Dupuy-Synthes, Paoli, PA, USA) or 3.5 mm (Acumed, Hillsboro, OR, USA) LCP-based ulna osteotomy system, the dedicated surgical system for guided USOs. All osteotomies were performed obliquely or transversely using an orthopedic oscillating saw around the distal one-third of the ulna, followed by plate fixation. To prevent heat injury to the osteotomized ulna during surgery, we stopped the sawing intermittently and cooled the osteotomy site by continuous cold saline irrigation in both groups [16]. We prioritized maintaining the inborn longitudinal and rotational alignment of the ulna over minimizing the osteotomy reduction gap during reduction osteotomy. Even in a non-paralleled osteotomy, we performed reduction by moving the distal segment proximally along the longitudinal axis to avoid angulated or rotated ulna after reduction osteotomy. Before osteotomy, arthroscopies were performed for all the wrists to verify UIS and debride degenerated ulnocarpal structures [6, 17]. After surgery, both groups followed the same protocol for postoperative rehabilitation. Tolerable active wrist and forearm movements were allowed after placing the wrists in a short-arm splint for four weeks.

Background data collection

The patients’ background data, including sex, age, affected side, body mass index (BMI), and bone quality (second metacarpal cortical percentage: 2MCP), were recorded [18]. BMI was calculated using the patients’ height and weight as BMI = weight [kg] / height [m]^2 [19]. Patients with severe obesity (BMI ≥ 30 kg/m^2) were excluded from this study[19, 20]. For bone quality assessments, we calculated the 2MCP from true posterior-anterior views of the preoperative hand or wrist radiographs [18]. All simple radiographs were taken on normal films (distance, 110 cm; power, 57 KV). The narrowest point (isthmus) of the second metacarpal shaft was focused and magnified to optimize visualization with the picture archiving and communication system (PiView STAR, Infinitt Healthcare Co. Ltd, Seoul, South Korea), a reliable method for orthopedic measurements [21, 22]. The transverse diameter of the isthmus of the second metacarpal bone was measured (A)[18]. Then, parallel measurements were made of the cancellous or intramedullary component at the same location (B) [18]. We used the formula [(A - B) / A] × 100 to calculate the 2MCP (Fig. 2) [18]. All variables were measured twice every two weeks by two independent orthopedists to avoid intra- or inter-observer errors, and the mean was calculated for each patient. Patients with 2 MCP < 50% were considered to have a higher likelihood of osteoporosis and were excluded from this study [18]. Complications associated with osteotomy healing, such as metal failure, screw loosening, delayed union, nonunion, and refracture after plate removal, were determined.

Data collection on healing after osteotomy

We divided the healing process into osteotomy union and osteotomy consolidation. Osteotomy union was defined by a callus formation bridging all cortices of the four planes observed on simple radiographs and no pain at the osteotomy site in the manual stress test. Osteotomy consolidation was defined by the disappearance of any trace at the osteotomy site in all four planes of simple radiographs [15, 23]. A union achieved after six months was considered a delayed union; when no union occurs within six months and no radiographic improvements occur during three consecutive months, it was defined as a nonunion [23]. Four plane simple radiographs (posteroanterior, lateral, internal, and external oblique views) were taken monthly until osteotomy union was achieved and every three months until osteotomy consolidation was completed to determine the length of the osteotomy reduction gap, the time to osteotomy union, and the time to complete consolidation for all the wrists. Two orthopaedists blindly determined these values, twice every two weeks, and the average for each wrist was calculated.

Data collection on surgical factors affecting the healing process

We recorded the direction of osteotomy, length of ulnar shortening, usage of a lag screw, and plate type used in each wrist to analyze the surgical factors affecting osteotomy healing. Based on the direction (an acute angle between the osteotomy plane and longitudinal axis of the ulna), the osteotomy was classified as transverse and oblique. The transverse osteotomy was defined by the angle ≥ 60° between the osteotomy plane and longitudinal axis, while oblique osteotomy was defined by the angle < 60° (Fig. 1b). The ulnar variance was measured using the method of perpendicular in a true posterior-anterior simple radiograph of the wrist [24]. The length of ulnar shortening was calculated as the difference between the preoperative and immediate postoperative ulnar variance. The lag screw usage was recorded as a “yes” or “no”, and the plate type used for osteotomy fixation was recorded as either “LC-DCP” or “LCP”. The osteotomy direction and length of ulnar shortening were also blindly measured twice every two weeks by two orthopaedists and the average for each wrist was calculated.

Sample size and statistical analysis

Power analysis

Using data from the study by Gaspar et al.[9], a prior power analysis was performed to determine the sample size needed to detect a difference in time to osteotomy union between freehand and guided osteotomies using the t-test and Pearson's chi-square test. Assuming a normal distribution and effect size of 1, we needed to enroll a minimum of 62 wrists in each group to detect a significant difference with 80% power ($\alpha = 0.05$, $\beta = 0.2$). The sample size was calculated using the G*Power program (version 3.1.9).

Statistical analysis

To confirm that there were no differences in patients' background characteristics between the two groups, a T-test was performed for age and BMI and Pearson's chi-square test for sex, affected side, direction of osteotomy, use of a lag screw, and type of plate used. The Mann-Whitney test was performed for 2MCP and length of ulnar shortening. To compare the time to osteotomy union and complete consolidation, and osteotomy reduction gap between the two groups, the Mann-Whitney test was also performed following the Bonferroni correction ($\alpha = 0.05/4 = 0.0125$).

Multiple regression tests were performed to identify the surgical factors affecting healing. The factors, as described in the *study design* section, were considered as potential surgical factors associated with osteotomy healing. The cut-off length of the osteotomy reduction gap to obtain osteotomy union within six months and the maximal periods to achieving complete osteotomy consolidation were statistically calculated using receiver operating characteristic (ROC) curves. $P < 0.05$ was considered statistically significant in this regression test.

Results

The patients aged between 17 and 68 (mean: 42) years. Of the patients, 78 were in men and 58 in women. The patients were followed-up for an average of 73.5 (range: 29.7–160.7) months. Both groups matched well in terms of age, sex, affected side, BMI, and 2MCP (Table 1). There were eleven delayed unions in Group 1 (11 of 74, 14.9%) and six in Group 2 (6 of 62, 9.7%). Three of the eleven delayed unions in group 1 were accompanied by screw loosening. All screw loosening occurred in the LC-DCP. There were two refractures in group 1 and one in group 2 after plate removal. However, osteotomy unions were achieved in all the wrists by the last follow-up visit, without revision surgery.

Table 1
Comparisons of background characteristics between groups.

	Group 1 (n=74)	Group 2 (n=62)	*p* value
Age* (years)	40.45±9.18	40.29±12.03	0.932
Sex (Male:Female)	42 : 32	36 : 26	0.878
Affected side (Right:Left)	38 : 36	30 : 32	0.731
BMI* (kg/m2)	23.89±2.61	23.91±3.08	0.970
2MCP* (%)	66.72±4.62	65.58±4.49	0.320

BMI=Body mass index; 2MCP= Second metacarpal cortical percentage; *Continuous variables expressed as Mean±SD. Statistics were performed using T-test for age and BMI, Pearson's chi-square test for categorized variables, and Mann-Whitney test for 2MCP.

The osteotomy reduction gap was longer in group 1 than in group 2 (Group 1 = 0.60 mm ± 0.64; Group 2 = 0.28 mm ± 0.14; p = 0.002). The time to osteotomy union was longer in group 1 than in group 2 (Group 1 = 5.11 months ± 2.67, Group 2 = 3.61 months ± 1.97, p < 0.001), and the time to complete osteotomy consolidation was also longer in group 1 than in group 2 (Group 1 = 20.24 months ± 9.46; group 2 = 15.81 months ± 6.60, p = 0.002) (Table 2).

Table 2
Comparisons of surgical technique and osteotomy healing between groups.

	Group 1 (n = 74)	**Group 2 (n = 62)**	***p* value**
Osteotomy direction (Transverse:Oblique)	18 : 56	32 : 30	0.001†
Use of lag screw (Yes:No)	27 : 47	25 : 37	0.647
Plate type (LC-DCP:LCP)	60 : 14	0 : 62	< 0.001†
Length of ulnar shortening* (mm)	3.08 ± 1.05	2.86 ± 1.47	0.070
Osteotomy reduction gap* (mm)	0.60 ± 0.64	0.28 ± 0.41	0.002†
Time to union* (months)M	5.11 ± 2.67	3.61 ± 1.97	< 0.001†
Time to consolidation* (months)	20.25 ± 9.46	15.81 ± 6.60	0.002†

LC-DCP = Limited contact dynamic compression plate; LCP = Locking compression plate; *Continuous variables expressed as Mean ± SD. Statistics were performed using Pearson's chi-square test for categorized variables and Mann-Whitney test for continuous variables. † indicates a statistical difference between the groups.

The osteotomy reduction gap had a strong positive correlation with both the time to osteotomy union (p < 0.001) and complete osteotomy consolidation (p < 0.001). The LC-DCP plate lengthened the time to consolidation ($p < 0.001$) (Table 3, 4). Statistically, the osteotomy reduction gap to predict timely osteotomy union (within six months) was 0.85 mm with 75% sensitivity and 90.2% specificity (area under the curve: 0.83; $p < 0.001$), and the time to complete consolidation of longer than 23.5 months was 66.7% sensitive and 89.3% specific for differentiating failure of osteotomy consolidation (area under curve: 0.792; $p < 0.001$) (Fig. 3a). Therefore, surgeons should avoid osteotomy reduction gaps of > 0.85 mm for timely osteotomy union. Osteotomy that was not completely consolidated within 23.5 months were expected to have permanent consolidation failure (Fig. 3b).

Table 3
Univariate regression analysis of the surgical factors affecting osteotomy healing.

Variable	Univariate regression analysis					
	Time to osteotomy union			Time to osteotomy consolidation		
	R	t value	p value	R	t value	p value
Osteotomy direction	0.002	0.500	0.618	0.00	0.171	0.864
Length of ulnar shortening	0.002	-0.461	0.646	0.017	-1.538	0.126
Use of lag screw	0.003	0.585	0.560	0.021	1.689	0.094
Plate type						
LC-DCP	0.047	1.033	0.303	0.124	2.910	0.004†
LCP	0.047	-1.094	0.276	0.124	-0.517	0.606
Osteotomy reduction gap	0.330	8.117	< 0.001†	0.175	5.324	< 0.001†

R = coefficient of determination; LC-DCP = Limited contact dynamic compression plate; LCP = Locking compression plate. † indicates a statistical difference between the groups.

Table 4
Multivariate regression analysis of the surgical factors affecting osteotomy healing.

Variable	Multivariate regression analysis					
	Time to osteotomy union			Time to osteotomy consolidation		
	adjR	t value	p value	adjR	t value	p value
Length of ulna shortening	-	-	-	0.280	-1.920	0.060
Use of lag screw	-	-	-	0.280	1.440	0.150
Plate type						
LC-DCP	-	-	-	0.280	3.270	< 0.001†
LCP	-	-	-	0.280	0.790	0.430
Osteotomy reduction gap	0.330	8.030	< 0.001†	0.280	4.180	< 0.001†

adjR = adjusted coefficient of determination; LC-DCP = Limited contact dynamic compression plate; LCP = Locking compression plate. † indicates a statistical difference between the groups.

Discussion

The most popular osteotomy technique for USO was freehand transverse osteotomy [25]. However, the osteotomy union was slow and the incidence of nonunion was high with freehand transverse osteotomy because performing a precise and parallel osteotomy was challenging [26–28]. Rayhack et al. demonstrated a guided oblique osteotomy technique with an osteotomy jig for a precise USO [27]. It resulted in a shorter union time than with freehand transverse osteotomy [27]. They explained that the broader cross-section and lag screw usage in oblique osteotomy aided healing[27]. However, their explanations were theoretical and were not be proved objectively. Besides, they did not consider the effects of patient-related factors on bone healing while comparing the two osteotomies [27].

This study excluded patients with patient-related factors to eliminate bias in analyzing the effects of osteotomy techniques on osteotomy healing. Similar to the previous studies, the osteotomy reduction gap, time to osteotomy union, and time to complete consolidation were shorter in guided than in freehand osteotomy [26–28]. It was because parallel surfaces for osteotomy could be obtained more easily with guided than with freehand osteotomy and the parallel osteotomy surfaces enabled better osteotomy reduction and contact (minimal osteotomy reduction gap). Thirty-eight of 62 osteotomies (61.3%) in group 2 had osteotomy reduction gaps of 0 mm, while only 28 of 74 osteotomies (37.8%) in group 1 had osteotomy reduction gaps of 0 mm.

The effects of detailed surgical techniques on osteotomy healing have not been investigated yet because past studies only involved patients who underwent freehand transverse or guided oblique osteotomies with lag screws [28, 29]. In the present study, in contrast, the nine combinations of surgical techniques evaluated to statistically analyze the effects of surgical techniques on osteotomy healing were as follows: *1) Manual transverse osteotomy + LC-DCP fixation: 16 wrists, 2) manual transverse osteotomy + LCP fixation: 2 wrists, 3) Manual oblique osteotomy + LC-DCP fixation: 20 wrists*, *4) Manual oblique osteotomy + LC-DCP fixation + Lag screw: 24 wrists, 5) Manual oblique osteotomy + LCP fixation: 9 wrists, 6) Manual oblique osteotomy + LCP fixation + Lag screw: 3 wrists, 7) Guided transverse osteotomy + LCP fixation: 32 wrists, 8) Guided oblique osteotomy + LCP fixation: 5 wrists, and 9) Guided oblique osteotomy + LCP fixation + Lag screw: 25 wrists.*

The previous studies reported that osteotomy union was faster in oblique than in transverse osteotomy because the broad osteotomy surface and usage of a lag screw in oblique osteotomy enhanced the compression, contact, and stability of the osteotomy [27–29]. However, our regression analysis revealed that only the osteotomy reduction gap affected osteotomy union and consolidation. The longer the osteotomy reduction gap had the longer time to osteotomy healing regardless of other surgical factors (direction of osteotomy, usage of a lag screw, length of ulnar shortening, and type of plate used) in this study. And the broad surface in oblique osteotomy was not also crucial for timely osteotomy healing because the time to osteotomy healing was similar to that in transverse osteotomy if the osteotomy reduction gap was minimal. Besides, the lag screw could not even compress the osteotomy in a long osteotomy reduction gap (Fig. 4, 5).

The plate type did not affect the osteotomy union in this study. It is because both LC-DCP and LCP had enough initial stability to withstand postoperative loads [30, 31] and, moreover, the wrist immobilization and the bone strength of healthy ulna assisted stability maintenance at the initial stage of osteotomy healing. The LC-DCP delayed the osteotomy consolidation; the time to complete osteotomy consolidation with LC-DCP > LCP. It was thought that the osteotomy reduction gap was longer in the LC-DCP than in the LCP because most of the freehand osteotomies were fixed by the LC-DCP. Besides, the long-term stability of LCP is better in osteotomy with a gap [30, 32]. The length of ulnar shortening did not affect osteotomy healing. It means that parallel osteotomy leads to better osteotomy reduction regardless of shortening length.

Our statistical calculation with ROC curves revealed that a reduction gap of less than 0.85 mm is essential to obtain union within six months and osteotomy traces that did not disappear within 23.5 months after osteotomy will remain permanently. On the other hand, most osteotomies on healthy ulnas achieved complete consolidation within 23.5 months. For reduction gaps of longer than 0.85 mm, we recommend filling the gaps with the resected bones for better osteotomy healing. In this study, all refractures occurred in the osteotomies with traces, while no refractures occurred in osteotomies without traces. The osteotomy trace represents incomplete consolidation. The reasonable time for plate removal is approximately two years after USO. If an osteotomy trace does not disappear even after two years, the plate should not be removed. Otherwise, it is better to change the thick plate to a low-profile mini plate to prevent refracture and diminish the irritation (Fig. 6).

This study has limitations. First, the effects of the saw blade on osteotomy healing was not estimated. A single blade saw of 0.5 mm thickness was used during freehand and guided osteotomies using the 3.5 LCP osteotomy system. A double blades saw of 0.6 mm thickness was used in guided osteotomy with the 2.7 LCP osteotomy system. Heat injury can be severe in low-speed cutting with a thicker blade and can cause irreversible bone damage [16]. However, it can be prevented by copious saline irrigation into the osteotomy site [33]. In this study, the authors stopped the sawing intermittently and cooled the osteotomy site by cold saline irrigation continuously to prevent heat injuries. Also, the type of saw was a dependent surgical factor associated with the osteotomy technique and system. Therefore it was inappropriate for our regression analysis. Second, we did not analyze the effects of the 2.7 and 3.5 LCPs on osteotomy healing separately because the number of 2.7 LCP was small and the primary purpose of the present study was to compare the osteotomy healing between guided osteotomy and freehand osteotomy.

Conclusions

The minimal osteotomy reduction gap was the most important for timely osteotomy healing in the healthy ulna and a guided osteotomy was beneficial to reducing the osteotomy reduction gap during USO. The trace of osteotomy means the failure of complete osteotomy consolidation. If there is any trace of osteotomy, the plate should not be removed to prevent refracture of the osteotomy.

Abbreviations

USO: Ulnar shortening osteotomy; UIS: Ulnar impaction syndrome; LC-DCP: Limited contact-dynamic compression plate; LCP: Locking compression plate; 2MCP: Second metacarpal cortical percentage; BMI: Body mass index; ROC: Receiver operating characteristic

Declarations

Ethics approval and consent to participate

This study was approved by the local institutional review board and informed consent was obtained from all enrolled patients (2018AS0050). The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki.

Consent for publication

Informed consents were obtained from all enrolled patients

Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the Mendeley Data, [http://dx.doi.org/10.17632/d5kx7xnywg.1].

Competing interests

The authors declare that they have no conflict of interest.

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Authors' contributions

Jong woo Kang, Soo min Cha, and Sang-gyun Kim contributed to the study design, data collection, data analysis, and writing of the manuscript. In cheol Choi and Dong hun Suh supervised the investigation and reviewed the initial manuscript for intellectual content. Jong woong Park was controlled overall investigation as the principal investigator of the project. The authors approved all the contents and agreed with the submission.

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Figures

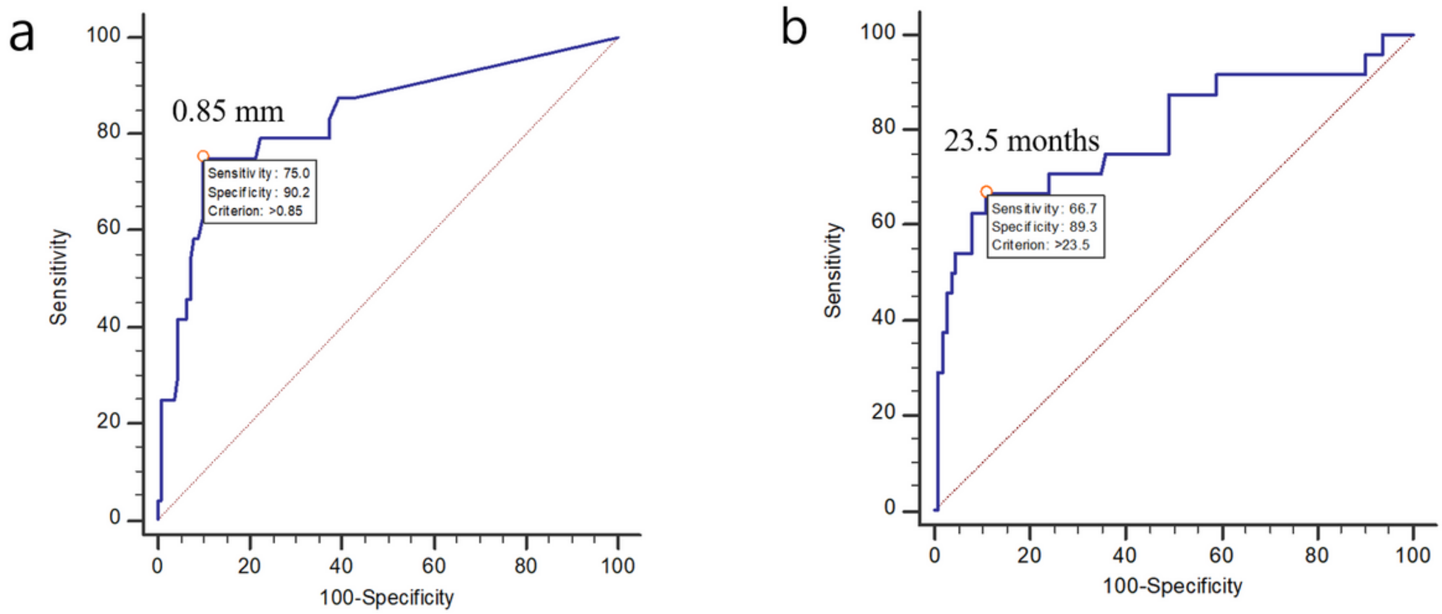

Figure 1

Receiver operating characteristic curves to predict the cut-off value for a the osteotomy reduction gap to obtain osteotomy union within six months (0.85mm) and b the time to complete osteotomy consolidation to differentiate the failure of osteotomy consolidation (23.5 months).

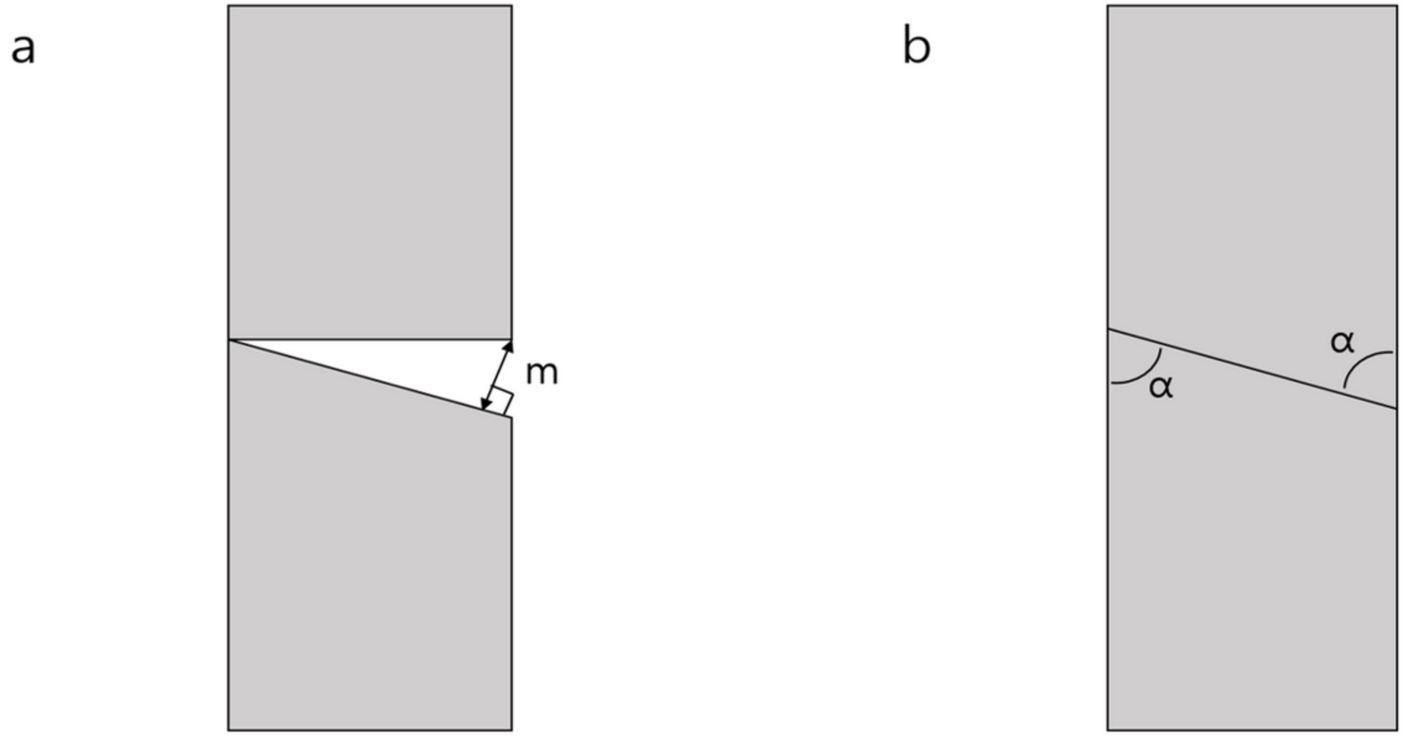

Figure 1

a The osteotomy reduction gap (m) was measured along with the longest distance between two surfaces of the osteotomy. b The osteotomy direction was classified as transverse or oblique osteotomy according to the acute angle (α) between the longitudinal axis and the osteotomy surface.

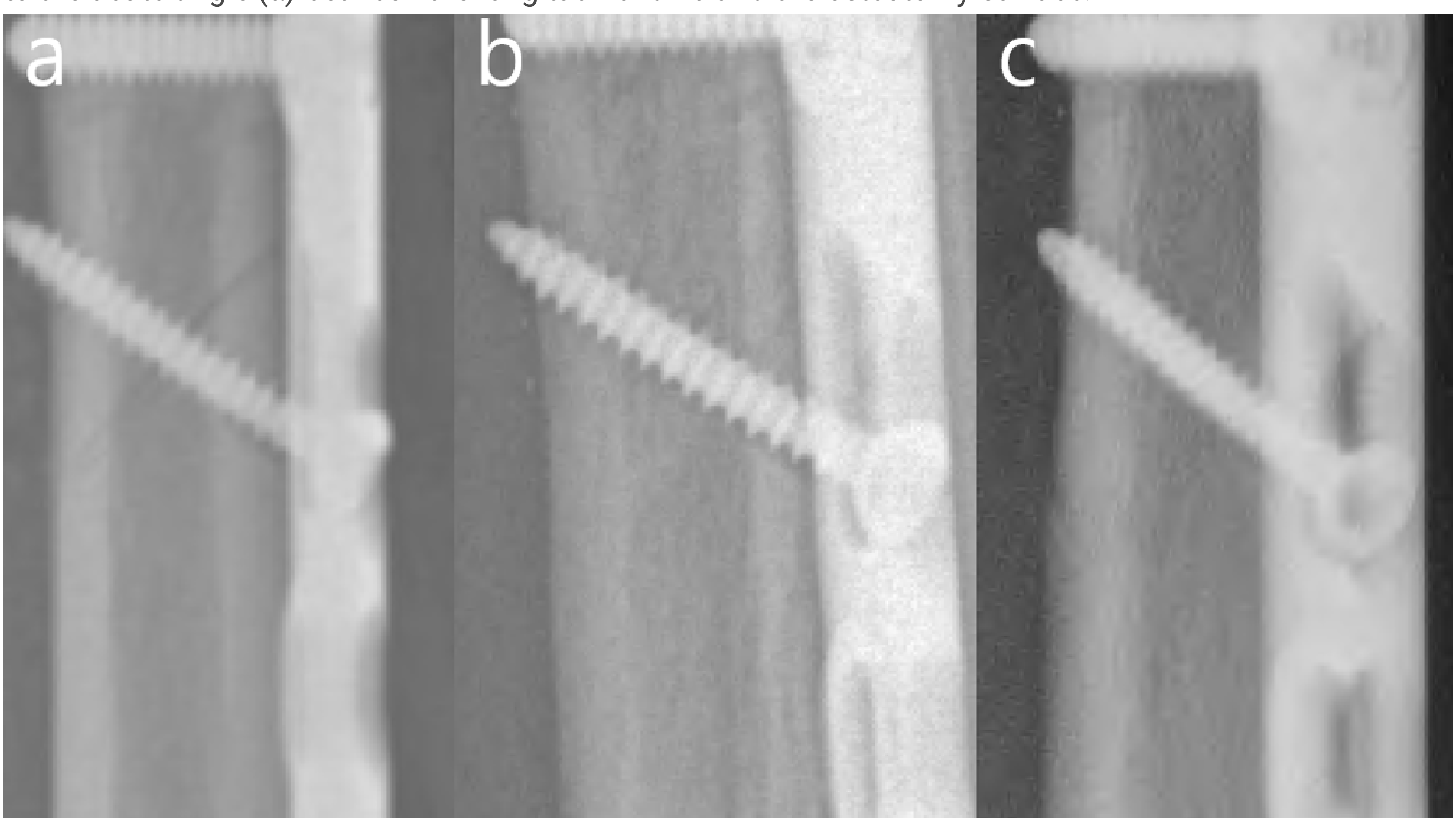

Figure 1

Serial radiographs of a guided osteotomy with paralleled osteotomy and minimal osteotomy reduction gap. a The immediate postoperative radiograph showed that the lag screw could enhance compression and stability of the osteotomy. b After 2 months, the osteotomy was united. c At 10 months, complete osteotomy consolidation was achieved.

Figure 1

The second metacarpal cortical percentage (2MCP) for assessment of bone quality. 2MCP was calculated by the formula [(A - B) / A] X 100 (A: Outer diameter of the second metacarpal isthmus, B: Inner diameter of the second metacarpal isthmus).

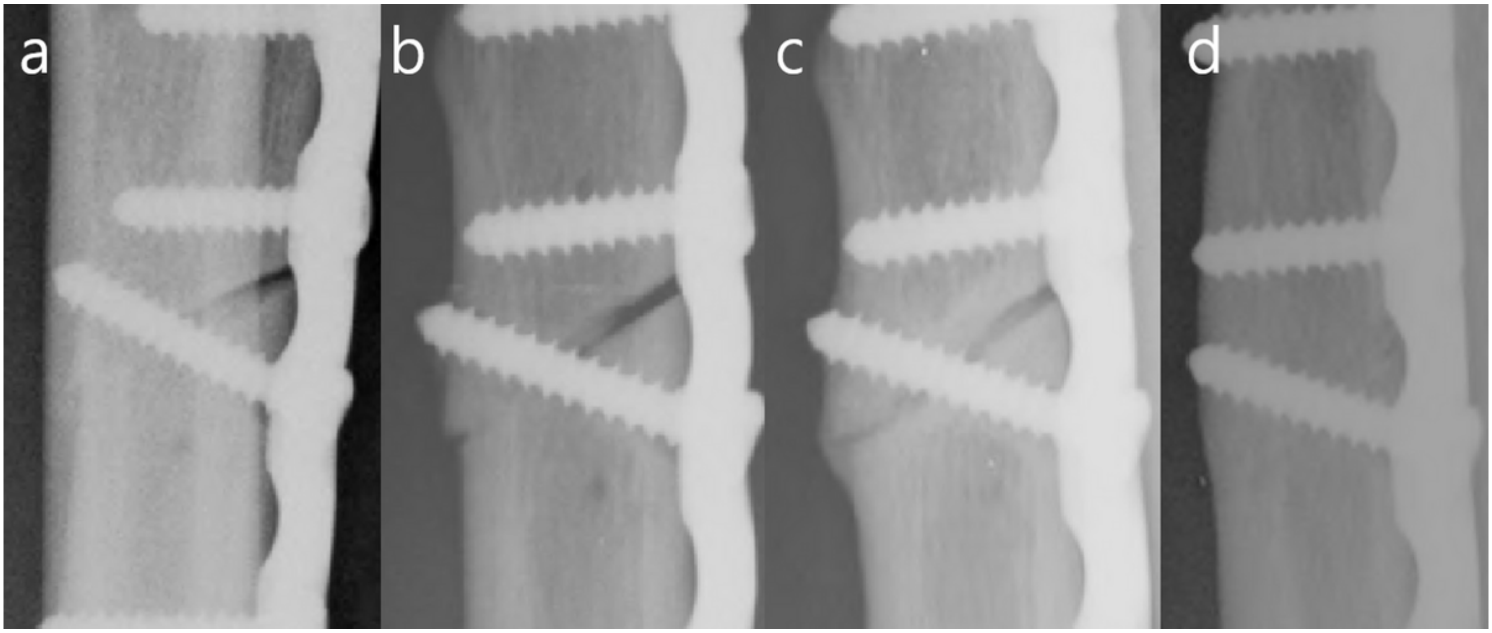

Figure 1

Serial radiographs of a freehand osteotomy with unparallel osteotomy surfaces and a long osteotomy reduction gap. a The immediate postoperative radiograph showed that the lag screw could not compress a long osteotomy reduction gap. b After 2 months, bone defect still existed. c At 6 months, the osteotomy was united. d The complete osteotomy consolidation was achieved at 22 months.

Figure 1

Radiograph of the case with a osteotomy trace (solid arrow) and b refracture after plate removal (dot arrow).

Supplementary Files

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- ulnarshorteningosteotomydatasetJOSRlast.xlsx