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ARTICLE

Refracture after plate removal following ulnar shortening osteotomy for ulnar impaction syndrome – a retrospective case–control study

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ABSTRACT

Refracture after plate removal following ulnar shortening osteotomy (USO) is a rare, but very distressing for both the patient and surgeon. This case–control study was performed to identify predictive factors for refracture incidence. A total of 245 patients, who had undergone USO between 2008 and 2018 were included in the study. We evaluated the basic demographic characteristics/clinical factors preoperatively. Radiological variables, such as dorsal subluxation of the ulna and pre/postoperative ulnar variance, and variables associated with operative conditions, such as triangular fibrocartilage complex degeneration classification, the use of a parallel double-blade saw, the type of plate, number of screws, and plate position, were investigated. Finally, the accuracy of osteotomy and any traces of incomplete healing after plate removal were evaluated. The no-refracture group consisted of 234 patients, whereas the refracture group consisted of eleven patients. The results of univariate analyses revealed that age, bone mineral density, accuracy of osteotomy, and presence of osteotomy traces were significantly associated with refracture. However, during multivariate analysis, low BMD was the only factor significantly associated with refracture. Nevertheless, the accuracy of osteotomy and absence of osteotomy traces were strongly associated with each other in the no-refracture group ($p < 0.001$, Cram's V coefficient $= 0.36$). Low BMD was sole independent predicting factor of refracture after plate removal in USO. Additionally, precise parallel osteotomy is critical for safety after plate removal following USO. Subsequent healing with no radiological traces of osteotomy after plate removal would be associated with absence of refracture.

Level of Evidence: Level III, case–control study.

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KEYWORDS
Ulnar shortening osteotomy; ulnar impaction; refracture; plate; independent variable

Introduction

Ulnar impaction syndrome is a complex of symptoms resulting from excessive compression of the ulnar head against the triangular fibrocartilage complex (TFCC) and the carpal bones. Some cases are due to apparent trauma, such as radius fractures [1]. Since it was first described by Milch [2], ulnar shortening osteotomy (USO) has become a widely accepted procedure for mechanical decompression at the ulnocarpal joint [3–9]. However, there have been few reports regarding plate removal if needed because of discomfort or for any other reason. Due to the location of the plate on the subcutaneous ulnar border of the forearm, pain may result when the arm comes into contact with a hard surface, such as a desk or tabletop. Furthermore, there is concern regarding plate retention in patients engaged in vigorous work or athletic activities [6,7,10,11].

Pomerance reported that 3.5-mm compression plates can be removed after 6–9 months, and that adequate bony union should be checked by the surgeon using simple radiography in multiple planes [12]. A postoperative period of at least 6 months is needed and plate removal should be performed only in patients with discomfort due to a plate that did not resolve over time. Plate removal after USO has been recognized as safe in other respects. That is, osteotomy represents a localized controlled injury to the bone, not trauma. The use of a plate during USO to fix a forearm represents a markedly different situation compared to long-bone fracture fixation.

However, we have encountered rare cases of refracture after plate removal between 2008 and 2018. All USOs were performed by a single surgeon and the plates were removed after critical inspection for proper union by at least two hand surgeons. Refracture after plate removal following USO is a very distressing condition for both the patient and surgeon, and there are no established guidelines for management, such as conservative options vs. osteosynthesis. To prevent such unexpected events after plate removal, this retrospective case–control study was performed to identify factors that can be used to predict cases of refracture.

Methods

Patient selection

Our Institutional Review Board approved this study, and all patients provided informed consent before participation. Prospectively collected data were analyzed retrospectively. Finally, a total of 245 patients were included in the investigation from among the 256 patients that fulfilled the inclusion/exclusion criteria drawn from an original cohort of 523 patients who had undergone USO performed by the senior author between March 2008

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and February 2018. Of the 256 patients, 11 were lost to follow-up. The following inclusion criteria were established for the present retrospective study: (1) patients with unilateral ulnar side wrist pain worsened by forearm pronation and ulnar deviation [13]; (2) positive ulnocarpal stress test [14]; (3) plain radiographs showing positive ulnar variance with or without cystic changes of the lunate; (4) arthroscopic findings showing degenerative changes (Class II) in the TFCC according to Palmer's classification [15]; (5) availability of complete medical records and radiological data; (6) postoperative follow-up period of at least 2 years; and finally (7) plate removal after USO with radiological findings of consolidation at least 1 year postoperatively.

Patients with the following characteristics were excluded: (1) concurrent distal radioulnar joint (DRUJ) instabilities requiring ligament reconstruction surgery; (2) acute traumatic TFCC tear; (3) incomplete recovery from trauma within 2 years around the wrist; (4) delayed union/nonunion after USO; (5) bilateral ulnar impaction syndrome; (6) arthritic changes at the DRUJ; (7) the presence of painful arthritic lesions in the elbow, wrist, or finger joints; (8) the presence of symptomatic neuropathy, including radiculopathy, confirmed by electromyography/nerve conduction velocity in the ipsilateral upper extremity; (9) impaction induced by congenital anomalies, such as Madelung deformity; and (10) retention of the plate for all reasons.

The no-refracture group consisted of 234 patients, whereas the refracture group consisted of eleven patients.

Demographic and clinical variables

We evaluated basic demographic factors, including age, sex, dominant/nondominant wrist, worker's compensation issues, smoking and diabetic mellitus status, and bone mineral density (BMD). The clinical variables included in the analysis were preoperative pain determined based on the visual analog scale (VAS) score, preoperative range of motion (ROM) in the wrist and forearm, preoperative grip strength, modified Mayo wrist score [8], symptom duration and aggravation period, and history of trauma.

Active smokers, defined as those who smoked within 4 weeks of surgery or smoked currently, were enrolled as 'smokers' for comparison with 'nonsmokers' [16].

BMD was measured at the last outpatient visit just before surgery using dual-energy X-ray absorptiometry (DEXA) with the Lunar Prodigy enCORE software (ver. 8.8; GE Medical Systems, Milwaukee, WI); the lowest T scores of the proximal femur and lumbar spine, except the value for the Ward area of the proximal femur, were recorded for each patient, and we used the mean scores measured from the hip and spine.

Radiological variables

The radiological features of each patient, such as the degree of dorsal subluxation of the ulna at the DRUJ and pre/postoperative ulnar variance were noted [17,18]. Dorsal subluxation of the DRUJ was quantified preoperatively by measuring the radioulnar distance on true lateral radiographs of the wrist, in which the pisoscaphoid distance was <3 mm [17]. Volar subluxation was described as a positive value regardless of the direction of subluxation. Perioperative ulnar variances were measured using the method of perpendiculars, whereby a line was drawn perpendicular to the longitudinal axis of the radius at its distal ulnar aspect, and the distance between it and the line at the end of the ulna was measured [18]. For accurate determination of ulnar variance, a posteroanterior radiograph of the wrist was obtained with the shoulder in 90° abduction, the elbow in 90° flexion, the forearm in neutral rotation, and the wrist in neutral alignment.

Operative variables

Variables associated with operative conditions, such as TFCC degeneration (assessed by Palmer's classification [15]) were investigated. Operative characteristics, such as the use of a parallel double-blade saw (Figure 1), the type of plate used for fixation, number of screws, and plate position of the volar or dorsal ulnar surface, were also evaluated. Some patients underwent treatment with width-specific parallel saw blades, which produce four different amounts of shortening from 2 to 5 mm (DePuy Synthes, West Chester, PA) and provide simple and accurate parallel osteotomy. Other patients were treated using a thin single-blade saw with a thickness of 0.4 mm (Linvatec, Largo, FL). Three types of plate were used: (1) a conventional 6-hole, 3.5-mm small bone plate for transverse osteotomy (Osteonics; Stryker, Mahwah, NJ); (2) an Acumed plate for oblique osteotomy (Acumed, Hillsboro, OR); and (3) an Acumed ulna plate for transverse ulna osteotomy (Acumed). Screw numbers ranged from six to eight. USO after transverse osteotomy was generally fixed with six screws, except in a few patients with osteoporotic bone in whom eight screws

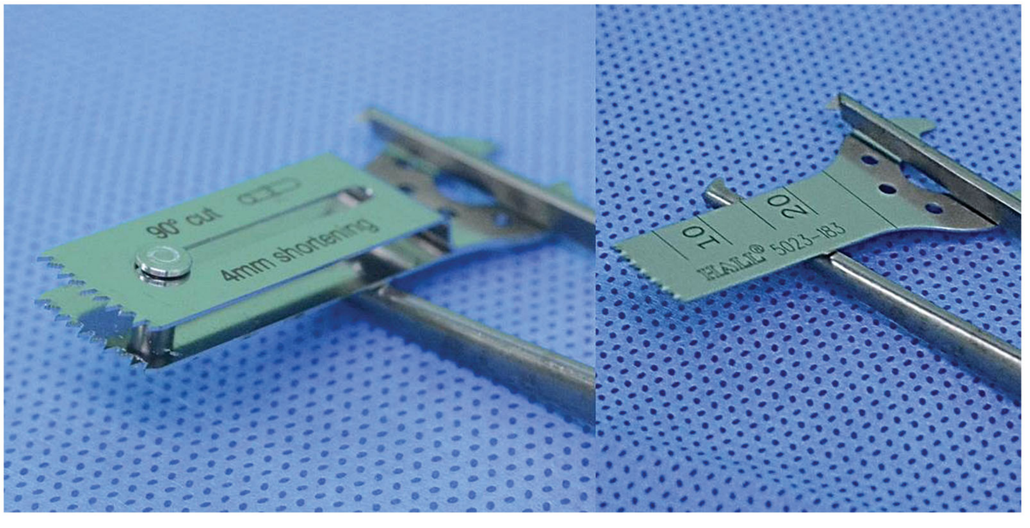

Figure 1. Two types of saw blade – double-blade and single-blade saws.

were used. The position of the volar or dorsal surface on the ulna was determined by the surgeon at the most anatomically accommodating position.

Surgical procedure and postoperative care

All operations were performed by the senior authors. Arthroscopic procedures were carried out according to the method described previously using a tourniquet with the patients under general anesthesia [8]. The lunotriquetral interosseous ligaments and TFCC were inspected thoroughly. The articular surfaces of the lunate and the triquetrum were also examined. In all patients, debridement of damaged TFCC tissue was performed using a small joint cutter (Arthrex, Naples, FL, USA) or an electrothermal small joint probe (Vulcan EAS; Smith and Nephew, Inc., Andover, MA, USA) to achieve a stable margin. After arthroscopic procedures, USO was performed. In 185 patients, conventional plate fixation after transverse osteotomy with a single-blade mini saw was performed according to the traditional method of Baek et al. [3]. Another 21 patients were treated using a specific USO system after oblique osteotomy through the guide attached to the plate, as recently reported by Clark and Geissler [9]. A third, ulnar locking plate after transverse osteotomy with width-specific parallel saw blades (double-blade saw), was used for 39 [5]. The arm was elevated for 24 h, and the patient was encouraged to move the fingers actively. The patient was discharged from the hospital on postoperative day 3, after the wound had been examined and the bandage changed to a light dressing. Two weeks later, the sutures were removed, and the patient – fitted with a removable long-arm splint that was usually worn for an additional 4 weeks – began ROM exercises of the elbow and wrist.

Accuracy of osteotomy

The accuracy of osteotomy according to postoperative radiographs was divided into the following three categories: 'Accurate', parallel lines with no gap (<1 mm) at osteotomy [19]; 'Parallel gap', gap >1 mm but osteotomy lines were parallel; 'Non-parallel gap', gap >1 mm and asymmetrical osteotomy (Figure 2).

Evaluation of bony consolidation

A bony union at the osteotomy site was defined as more than three regions of bone bridging among the radial, ulnar, dorsal, and volar cortical aspects of the distal part of the ulna, as seen on the anteroposterior, lateral, and both oblique views by two hand surgeons other than the operator in a blinded manner. Orthogonal radiographs were assessed for cortical bridging across the osteotomy site beginning at 10 weeks postoperatively, and monthly thereafter until bony union was achieved [20]. For patients with radiological union, physical examinations were performed by the senior author to confirm that the ulna was pain-free, particularly at the osteotomy area. Thus, final bony union was only considered to have occurred when both radiographic and clinical criteria had been met. If the patients complained of discomfort around the plate, we suggested removal, and the surgery was scheduled at least 1 year postoperatively. One or two weeks before plate removal, we finally checked four films of radiographs to determine whether the prior osteotomy line could no longer be seen. In addition, bone scans were performed for all patients scheduled for plate removal.

Traces of osteotomy are veiled by plate in radiographs

Just after plate removal, we confirmed the presence or absence of an osteotomy trace (any radiolucency at the osteotomy site) on plate-free multiplane radiographs. This was added as a variable for refracture with regard to incomplete healing.

Management after plate removal

After surgery, patients had to wear a short-arm ulnar gutter splint full-time for an average of 2 weeks (range, 1–3 weeks). After this time, the splint was worn during the day for protective purposes, but patients were allowed to take it off while sleeping or during sedentary activities. The patients were allowed to resume full work duties when the postoperative wound had healed, and the prior ulnar forearm tenderness had resolved, similar to the management procedure described by Pomerance [12].

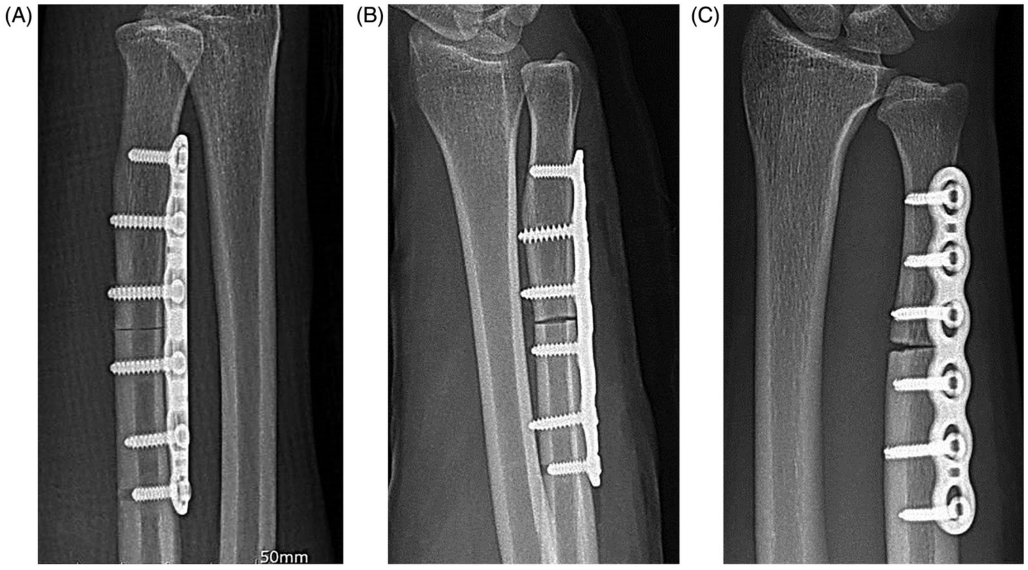

Figure 2. (A) The ideal osteotomy outcome –no gaps and parallel osteotomy lines – obtained through precise osteotomy and proper compression. (B) A gap (>1 mm) with parallel osteotomy lines from adequate osteotomy but insufficient compression. (C) A gap (>1 mm) with asymmetric osteotomy lines from inappropriate osteotomy and insufficient compression.

Table 1. Univariable analysis for all factors including demographic, clinical, radiological, and operative factors.

Variable	Group 1 (no-refracture, $n = 234$)	Group 2 (refracture, $n = 11$)	p Value
Age, yr	40 ± 12	51 ± 7	<0.001
Sex, n			
Male	127	3	0.12
Female	107	8	
Hand dominance, *n*			
Dominant	146	8	0.75
Nondominant	88	3	
Worker's compensation			
Yes	16	0	0.99
No	218	11	
Smoking			
Yes	70	2	0.52
No	164	9	
Diabetic mellitus			
Yes	60	4	0.49
No	174	7	
Bone mineral density	0.5 ± 1.4	−1.0 ± 1.4	<0.001
Preoperative visual analogue scale pain score	3.3 ± 0.5	3.6 ± 0.5	0.11
Preoperative wrist motion, ° (Flexion-extension arc)	120.4 ± 4.7	120.0 ± 5.9	0.78
Preoperative wrist motion, ° (Pronation-supination arc)	144.6 ± 5.9	145.0 ± 3.2	0.83
Preoperative grip strength, % (compared with unaffected side)	82.3 ± 4.3	82.6 ± 4.3	0.86
Preoperative modified Mayo wrist score	62.9 ± 7.0	62 ± 6.0	0.58
Symptom duration, months	28.5 ± 7.3	28.5 ± 5.1	0.98
Symptom aggravation, months	2.7 ± 1.1	2.6 ± 1.1	0.73
History of trauma			
Yes	20	0	0.61
No	214	11	
Distal radioulnar joint subluxation, mm	1.6 ± 1.4	0.4 ± 2.7	0.37
Preoperative ulnar variance, mm	4.0 ± 1.2	4.6 ± 0.9	0.07
Postoperative ulnar variance, mm	0.4 ± 0.9	0.5 ± 0.5	0.63
Triangular fibrocartilage complex tear type			
IB	2	0	0.82
IIA	1	0	
IIB	95	3	
IIC	129	8	
IID	7	0	
Double-blade saw			
Yes	51	2	0.99
No	183	9	
Plate type			
Small bone plate	176	9	0.58
Acumed® plate for oblique osteotomy	21	0	
Acumed® ulna plate for transverse ulna osteotomy	37	2	
Number of screw	6.1 ± 0.3	6.0 ± 0.1	0.63
Gap			
Accurate, no gap	220	0	<0.001
Parallel gap	11	5	
Non-parallel gap	3	6	
Plate position			
Volar	27	2	0.63
Dorsal	207	9	
Trace of osteotomy			
Yes	3	11	<0.001
No	231	0	
Time of plate removal, months (from index surgery)	13.4 ± 1.5	13.6 ± 0.9	0.55

Inter- and intra-observer reliability of radiological measurements

Two experienced orthopedic surgeons evaluated all radiographs and re-evaluated them on the following day. Intraclass correlations (ICCs) of continuous variables were used as indices of inter- and intra-observer repeatability [21]. Kappa values were calculated for categorical variables such as classification type [22]. Fleiss and Cohen considered kappa values >0.75 as excellent, between 0.40 and 0.75 as good, and <0.40 as poor.

Statistical analysis

The sample size was calculated considering the ratio of 'no-refracture' to 'refracture' (10:1), in accordance with a recent study [23]. We determined that the effective odds ratio (OR) between the two groups was 1.6 for logistic regression analysis. For this condition to be met, a minimum of 187 patients were required for proper statistical comparison between the two groups (power of 80% and 20% maximum follow-up due to loss of patients). For univariate analyses, Student's t test was used for the analysis of continuous variables, and the Chi-square test or Fisher's exact test was used for categorical variables. For multivariate analysis, logistic regression using a forward selection method with a likelihood ratio was performed for factors that were statistically significant in the univariate analyses, to investigate the OR with a 95% confidence interval (CI). Any correlations between variables were clarified using Pearson's or Cramer's V correlation coefficient. Calculation of the sample size was performed using the G*Power program (ver. 3.1.9.2; Franz Faul, Universität Kiel,

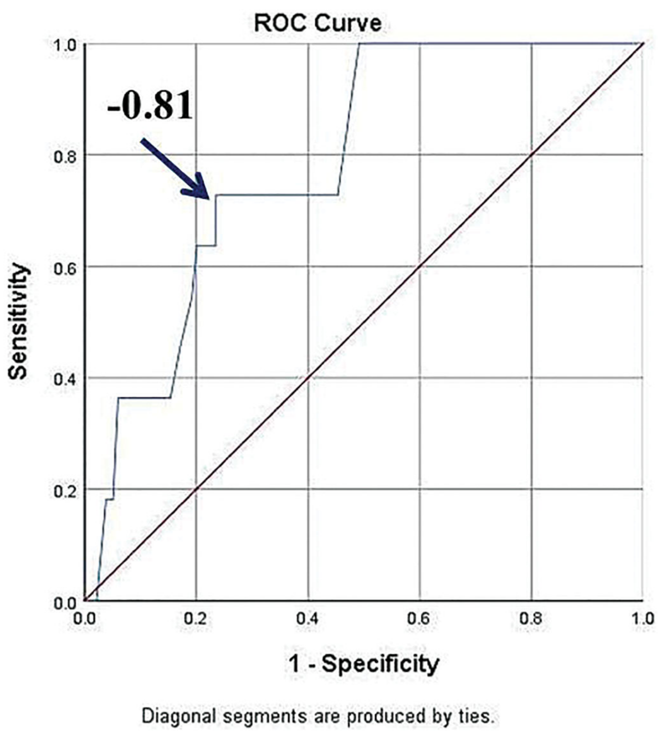

Figure 3. Receiver operating characteristic curves to determine the predictive cutoff value for the lowest BMD (mean of hip and spine measurements) The BMD cutoff value was −0.81.

Germany). Data were analyzed using SPSS for Windows (ver. 22.0; SPSS Inc., Chicago, IL). In all analyses, $p < 0.05$ was taken to indicate statistical significance.

Results

The no-refracture group consisted of 234 patients, whereas the refracture group consisted of eleven patients. Refracture occurred at a mean of 7.1 months after plate removal. Univariate analyses of basic demographic and clinical characteristics revealed that age and BMD were significantly different between the two groups (all, $p < 0.001$, Table 1). In addition, radiological and operative variables were not significantly different between the two groups ($p > 0.05$, Table 1). However, the accuracy of osteotomy was shown to be an important variable for safety after plate removal ($p < 0.001$, Table 1). Also, osteotomy traces were observed at a significantly higher rate in the refracture group than in the no-refracture group ($p < 0.001$, Table 1). However, during multivariate analysis, low BMD was the only factor significantly associated with refracture ($p = 0.001$, OR = 0.86, CI = 0.61–1.36; Figure 3). Nevertheless, the accuracy of osteotomy and the presence of osteotomy traces strongly correlated, in the no-refracture group. Namely, the rate of USO with no gap followed by bony healing without traces of osteotomy was significantly higher in the no-refracture group than in the refracture group ($p < 0.001$, Cram's V coefficient = 0.36, Table 2). All refractured ulnas (i.e. the refracture group) showed a gap in the osteotomized area after the index procedure and healed with radiological traces of osteotomy. However, there was no significant correlation between gap incidence and traces of osteotomy in the refracture group.

All refractures achieved bony healing with conservative treatment. Complete bony unions were seen at a mean of 4.6 months after refracture (Figures 4 and 5). In terms of radiological measurement or classifications, the inter- and intra-observer mean repeatability coefficients were all satisfactory (>0.75).

Discussion

Low BMD was previously suggested as a factor responsible for delayed union and nonunion after USO (cutoff value: −1.75) [19]. Although BMD measured with DEXA scans could not accurately reflect the status of ulnar diaphysis, Park and Kim [24] reported correlations of general BMD with BMDs of other areas of the extremities; this indicated that the overall BMD of the area of the USO did not differ markedly from the general BMD. Qualitative and quantitative alterations that occur at the cellular level during osteoporosis may explain the incomplete healing of bone tissue, despite an interval of >1 year [25]. Thus, when USO is performed in patients with low BMD, caution should be exercised during plate removal.

The incidence of plate removal in the present study was 49% (256 of 523 patients), which was similar to that reported by Rajgopal et al. [23]. In addition, refracture rates following plate removal have been reported to range from 2.5% to 11.4% [12,23,26]. In the present study, refracture occurred in eleven patients (4.5%). Plate removal was performed at a mean of 13.2 months after index surgery, and refracture occurred at a mean of 7.5 months after the second surgery. Other reports of refracture after plate removal indicated heterogeneous etiologies, including forearm fractures [11,26,27]. Forearm fractures caused by trauma represent a different mechanism compared to elective osteotomy. Strong forces must be applied to the diaphysis of the radius or ulna for a fracture to occur. This is often accompanied by fracture comminution, periosteal stripping, open injuries, and soft-tissue loss. All of these factors may delay or prevent fracture healing. In addition, if the plates are removed before complete union has occurred, there is a significant risk of refracture. Therefore, we emphasize that refracture after only USO plate removal should be differentially assessed, similar to recommendations by Pomerance [12] and Rajgopal et al. [23]. Pomerance suggested that plate removal should be performed after 6–9 months to have a low risk of refracture [12]. However, we removed the plates after at least 12 months in all 256 patients with critical inspections for complete union. However, the timing of plate removal seems to have no effect on refracture rate, as plate removal was performed at least 12 months after USO in our study.

All refractures occurred at the osteotomy site without a definitive trauma event, not at screw holes or other areas. Six patients complained of a vague feeling of discomfort commencing after a few days and five patients complained just after slight slippage during daily activities. In our institute, plate removal, especially in the forearm, requires caution due to discouraging results such as refracture. Thus, whole-body bone imaging scans are additionally checked for any occult lesions of delayed union/nonunion or loosening, or any subclinical infection around plate despite cortical and trabecular continuity across the osteotomy. However, all refracture patients in this study exhibited normal findings on imaging scans. Furthermore, it was nearly impossible to identify traces of osteotomy intraoperatively. Only a single plane of healed periosteum –thickened muscle fascia just beneath the plate – could be seen, and the other surface of the ulna could not be seen without iatrogenic dissection during exploration. A retrospective review of refracture cases revealed radiolucent lines just after plate removal, and these most likely could be explained by impaired vascularity or incomplete bone healing [11,26,27]. Finally, refracture after plate removal following USO has been

Table 2. Correlation of the accuracy of osteotomy and the trace of osteotomy after plate removal in each group.

	Trace of osteotomy		Chi-square test	Cramer's V	
Group	Yes	No	*p* Value	Coefficeint	*p* Value
Group 1 (no-refracture, $n=234$)					
Accurate, no gap	1	219	<0.001	0.36	<0.001
Parallel gap	1	10			
Non-parallel gap	1	2			
Group 2 (refracture, $n=11$)					
Accurate, no gap	0	0	0.99		
Parallel gap	5	0			
Non-parallel gap	6	0			

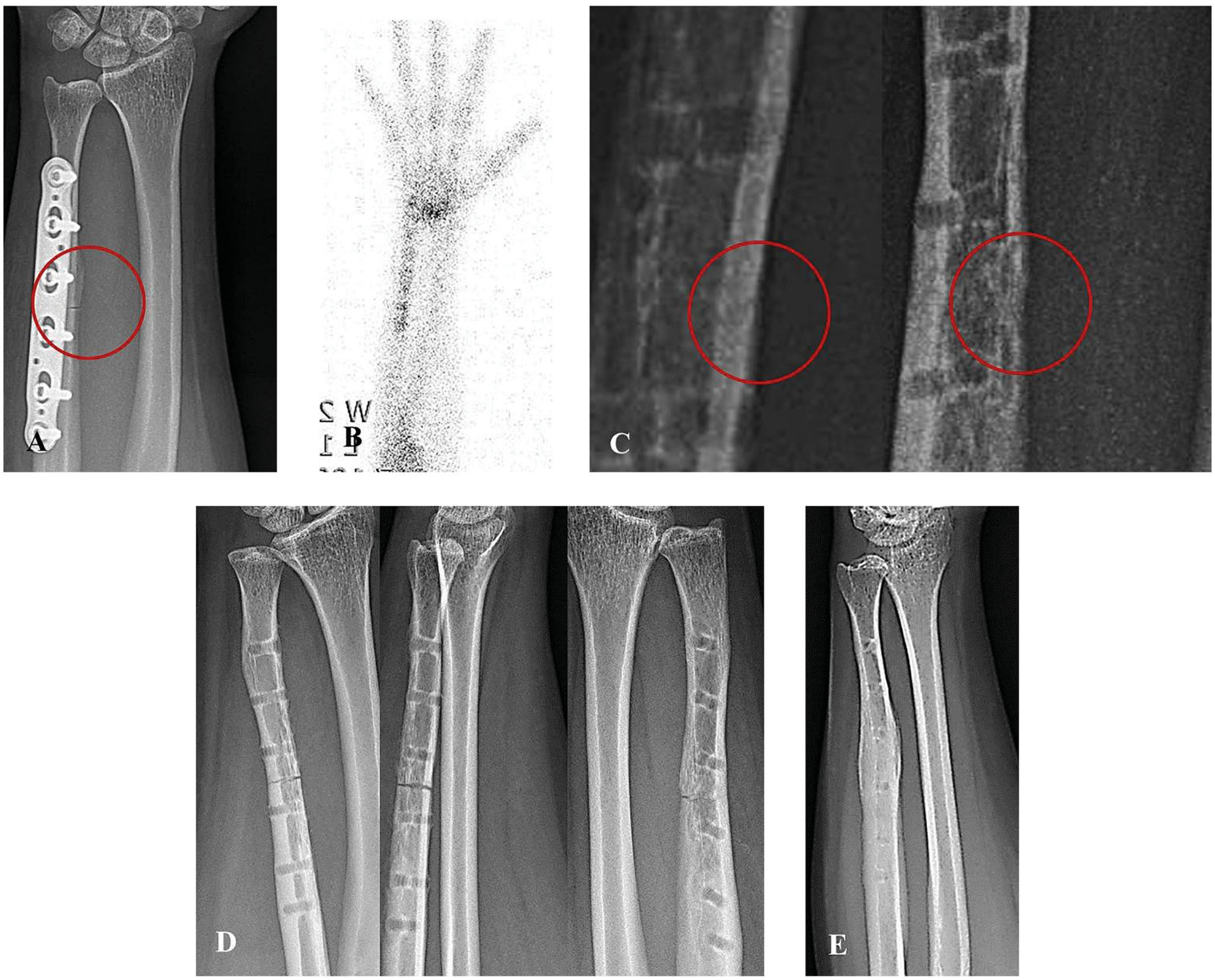

Figure 4. (A) A 36-year-old woman exhibited an asymmetric gap (>1 mm) on postoperative radiographs. (B) Before plate removal, the bone scan revealed no specific positive findings around the osteotomy area. (C) After plate removal, a very subtle radiolucent lesion was observed, thus we confirmed this lesion as a trace of osteotomy. (D) Four months after plate removal, refracture occurred at the location of osteotomy during daily activities. (E) Five months after refracture, complete bony union was achieved with the typical secondary bone healing pattern.

shown to be originated from premature healing, including in the present study. In addition, premature healing, even after elective and controlled procedures as opposed to unexpected trauma, was associated with surgical factors in this study. Precise osteotomy and proper compression during plating were critically important for primary bone healing [28].

In our study, there were no significant factors for predicting refracture based on multivariate analysis, except low BMD. However, precise osteotomy/proper compression and subsequent absence of traces of osteotomy guaranteed 'safety' after plate removal. Furthermore, traces of osteotomy were observed on radiographs for all refractures just after plate removal, and all USOs were performed inappropriately. On the other hand, there have been no reports on the conditions after plate removal in oblique osteotomy. Biomechanical studies have shown that the structural stiffness in torsion is clearly greater with an oblique osteotomy [29,30]. In addition, oblique osteotomies have faster healing and lower nonunion rates than transverse osteotomies [20,29,30]. Rayhack et al. [30] reported a faster healing time with oblique osteotomy due to the 40% greater bone surface area.

Figure 5. (A) A 42-year-old woman exhibited a parallel gap (>1 mm) on postoperative radiographs. (B) Before plate removal, the bone scan revealed no specific positive findings around the osteotomy area. (C) After plate removal, a radiolucent lesion was observed, which was not recognized before plate removal. After plate removal, an additional wearable splint was applied for protective purposes for 2 weeks. (D) Three months after plate removal, refracture occurred at the location of osteotomy during daily activities. (E) Complete bony union was achieved with the typical secondary bone healing pattern, at six months after refracture.

Other studies also reported 100% bony union after oblique osteotomy [9,20,31]. Although 'not a significant factor', the oblique osteotomy also did not result in refracture in the current study. Furthermore, Clark and Geissler emphasized the benefits of the volar plate position for minimising the need for plate removal and 100% union after oblique osteotomy [20]. In our series, nine of 11 refractures had the plate located in the dorsum. If there was no discomfort or irritation due to the dorsal position, these patients would not demand plate removal and refractures may not occur. However, the number of cases was relatively small (11 patients) for determining the statistical significance of these potential factors.

A previous study of delayed union/nonunion after USO indicated that smoking, low BMD, a stiff wrist, and the use of a double-blade saw were potential factors, and the features of delayed union appeared to be secondary bone healing with abundant calluses around the osteotomy [19,28]. This previous study was performed in patients with maintained plates, unlike in the current study. These prognostic factors for delayed union/nonunion were not important in the present study due to the exclusion of delayed union/nonunion from the analysis.

Conservative treatment was attempted in all refractured ulnas with at least 4 weeks of long arm splinting, and proper union in these cases was finally achieved. There have been no reports of guidelines for revision surgery. Pomerance [12] achieved union through conservative treatment and Rajgopal et al. [23] performed revision surgery with iliac bone grafts for two final cases of nonunion among four refractures. In this study, all eleven patients with refractures finally achieved union through conservative treatment, but the features of union were somewhat different from the original intention of primary bone healing based on osteotomy. Most refractures were not associated with definitive displacement or angulation but exhibited at least a fracture line. In addition, sufficient stability established during the plating period, including well-healed soft tissue such as the fascia and interosseous membrane, would help in achieving proper union even with a splint or cast. Furthermore, revision surgery just after refracture would not be easily accepted by the patients. Interestingly, Chan et al. [32] emphasized that plate removal itself was one of the morbidities associated with USO, and surgeons should counsel patients appropriately when offering USO.

This study had several limitations. First, attempting to identify predictive factors for refracture after USO was not easy as it is a rare complication. In addition, there are no guidelines for revision surgery (prompt internal fixation or delayed osteosynthesis with bone graft). Checking simple radiographs for traces of osteotomy would have low inter- and intra-observer consistency. At least four radiographs of each ulna were checked by two orthopedic surgeons in our study. However, examination by more than two observers would be beneficial for increasing the accuracy of detection.

Conclusively, low BMD was the sole factor independently associated with increased rate of refracture after plate removal in USO. Additionally, precise parallel osteotomy is critical for safety after plate removal following USO. Subsequent healing without radiological traces of osteotomy after plate removal may be associated with a reduced rate of refracture. Further investigations with larger sample sizes are needed to confirm factors associated with the risk of refracture.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Disclosure statement

The authors declare that they have no conflict of interest.

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