



골간단부가 심하게 분쇄된 원위 요골 골절에서 소형 금속판의 사용

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Use of Miniplate for Severe Comminuted Metadiaphyseal Fractures of the Distal Radius

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Purpose: This study investigated the clinical and radiological outcomes of patients undergoing provisional fixation in conjunction with locking plate fixation. Miniplates were used as the reduction plates for the surgical treatment of severe comminuted metadiaphyseal fractures with an intra-articular fracture of the distal radius.

Materials and Methods: The radial length, radial inclination, volar tilt, and radial intra-articular step-off were measured preoperatively, postoperatively, and at one year after surgery in 12 patients (eight males, four females, mean age 55.4 years old). The patients underwent volar locking plate fixation with miniplate as a reduction plate for severe comminuted metadiaphyseal fractures with an intra-articular fracture of the distal radius. Clinical evaluations were conducted using the modified Mayo wrist score (MMWS).

Results: Bone union was achieved in all cases. The mean MMWS was 81.8 points, including two excellent, three good, and seven fair cases. Radiological improvements were observed in the average radial length (preoperative, 6.4 mm; postoperative, 11.8 mm), average radial inclination (10.2° to 22.4°), average volar tilt (-4.5° to 10.6°), and average radial intra-articular step-off (4.8-0.8 mm) (all, $p < 0.05$). Radiographic measurements obtained immediately after surgery and at the final follow-up revealed insignificant decreases in radial length (0.6 mm), radial inclination (0.4°), and volar tilt (0.9°) (all, $p > 0.05$).

Conclusion: Miniplate fixation can be an effective treatment option as a reduction plate for the treatment of distal radial fractures, which is challenging to reduce and maintain due to severely comminuted metadiaphysis fractures with the intra-articular fracture.

Key Words: Distal radius fracture, Metadiaphyseal fracture, Comminuted fractures, Fracture reduction, Miniplate

Introduction

Distal radial fractures are some of the most common

fractures experienced by adults.¹⁾ More complicated fracture patterns and an increased incidence of unstable fractures (e.g., intra-articular or comminuted fractures) reflect the

increasing incidence of high-energy traumas, more advanced patient age, and more numerous industrial and traffic accidents.^{1,2} In cases involving unstable fractures, surgical treatment is preferred since a loss of reduction may occur due to secondary displacement during the fixation period, regardless of anatomic reduction.³

Among surgical treatments, internal fixation and open reduction using plates are widely used, as they enable more accurate anatomic reductions of articular facets that can be performed while the fracture site is directly visualized. Further, favorable outcomes after internal fixation, achieved using volar locking plates, have been reported in numerous studies.¹⁻⁴ However, in patients with open or severe comminuted metadiaphyseal fractures of the distal radius, the comminuted fragments are difficult to maintain in a reduced state until definitive plate fixation can occur. Additionally, the use of volar locking plates, alone, is usually insufficient to appropriately treat all fragments.²

Therefore, in this study, we investigated the clinical and radiological outcomes of patients undergoing volar locking plate fixation using miniplates (reduction plates), after provisional fixation, as a surgical treatment for severe comminuted fractures of the metadiaphysis associated with intra-articular fractures (AO classification, C2 or C3).

Materials and Methods

1. Patients

Among patients presenting with severe comminuted fractures of the metadiaphysis associated with intra-articular fractures, between March 2015 and March 2017 at Department of Orthopaedic Surgery in our hospital, a total of 12 underwent open reduction and plate fixation using volar locking compression plates and reduction plates using the anterior approaches. These patients were recruited for this

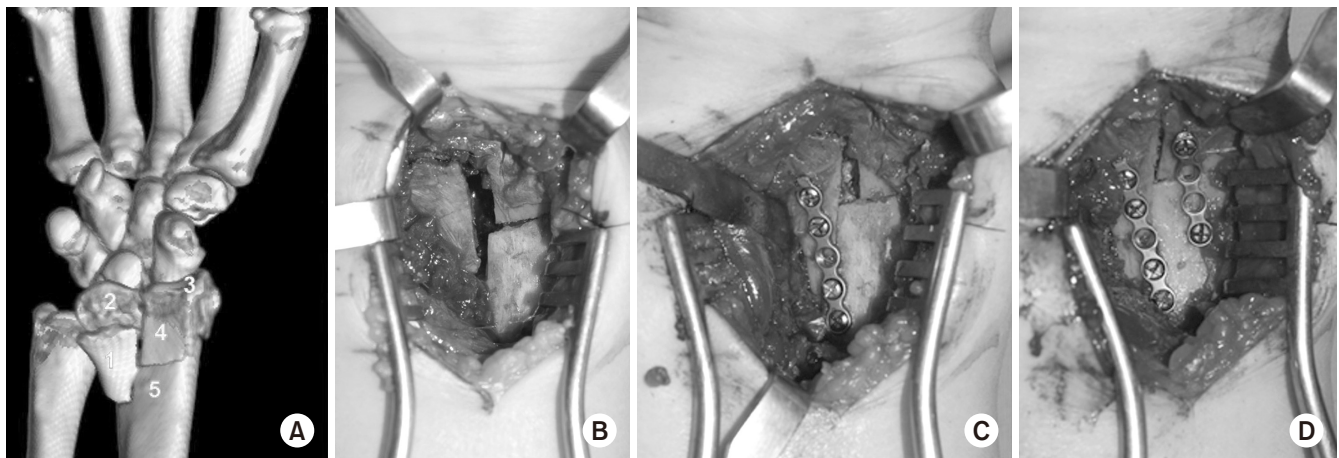


Fig. 1. A 55-year-old male (patient No. 8) visited the emergency room with a distal radial fracture due to a 2-m fall. (A) Preoperative computed tomography allowed the numbering of each fragment. (B) Following the anterior Henry approach, (C) fragments 1 and 5 were reduced using 1.5-mm miniplates for radial height restoration, and (D) fragments 4 and 5 were reduced using 2.0-mm miniplates.

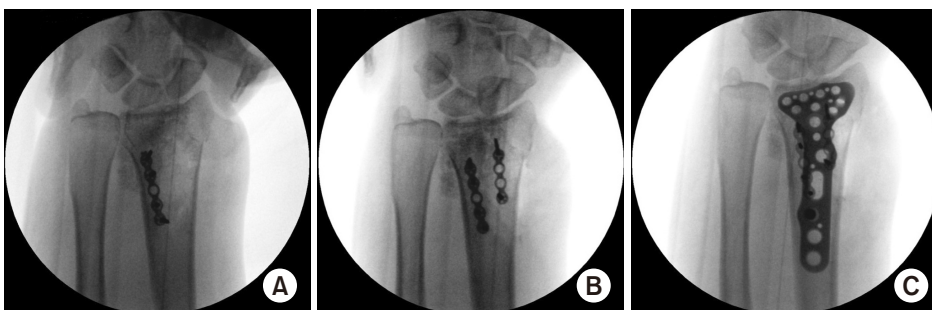


Fig. 2. Intraoperative image obtained using an image intensifier. (A, B) Miniplate was used as a reduction plate. (C) Volar locking plate was used as a definitive fixation plate.

study and were followed up for ≥ 1 year. The participants included 8 male and 4 female patients having a mean age of 55.4 years (range, 28–77 years). The injury causes included falls (6 patients), slips (3 patients), and crush injuries (3 patients); 7 presented with open fractures. The AO classification of fracture type and site revealed that 5 cases were C2 and 7 were C3. Ten cases required the use of 1.5-mm miniplates, 3 cases required 2.0-mm plates, and 1 case required both sizes of miniplates. The study design and data collection were approved by the institutional review board of the Human Experimental and Ethics Committee of Gachon University Gil Medical Center (IRB No: GCIRB2019–186). The patients and/or their families were informed that data from their case would be submitted for publication, and gave their consent.

2. Methods

The surgical plans were based on the initial simple radiographs that indicated whether fracture comminution was severe enough to require reduction plates, and on 3-dimensional computed tomography (CT) to verify the fracture pattern. While planning the surgery, each fragment was numbered; the reduction sequence, method, and volar locking and reduction plate locations were determined (Fig. 1). A modified anterior Henry approach was used with the patient under general anesthesia. The flexor carpi radialis was palpated, the skin over it was incised approximately 5 to 8 cm, and a vertical incision of the fascia was carefully created, inferior to the flexor carpi radialis, to prevent damage to the radial artery and the median nerve palmar branch. Traction of the flexor pollicis longus toward the ulna was performed, the pronator quadratus was longitudinally incised from the radial side, the fracture site was dissected according to the CT findings, and the reductions were completed (Fig. 1, 2). In open fracture cases, the plate was not initially fixed and an external fixator was temporarily used after thorough debridement and irrigation. Plate fixation was attempted within 2 weeks after the injury, when the wound had healed without evidence of infection (Fig. 3, 4).

Per the individual preoperative plan, the metadiaphysis was fixed using 1.5- or 2.0-mm miniplate reduction plates (DePuy Synthes, Paoli, PA, USA); pointed reduction forceps for fragments or K-wires were used after reduction. In cases involving very small fragments or the cortical bone only, direct reduction plate fixation was performed using a Hohmann retractor and manual traction to minimize soft tissue damage. Among the various fragments, those that were essential for radial length recovery were reduced first (Fig. 1C, fragments 1 and 5); the remaining fragments were reduced and fixed according to the surgical plan (Fig. 1D, fragments 4 and 5). During the reduction, as much of the periosteum as possible was left attached to the fragments; the overall reduction state was investigated, using an image intensifier, since a minimal incision was created to minimize soft tissue dissection (Fig. 2A, B). Following this provisional fixation, a volar locking plate was fixed to the appropriate location over the reduction plate (Fig. 2C). Allogenic bone grafts were used in 3 cases involving severe bony defects. Each fracture site was splinted using a short-arm cast for 2 weeks after the surgical treatment, and each patient wore an orthosis for 2 weeks and performed active joint motion 2 to 3 times daily, with a gradually increasing range of joint motion.

3. Treatment outcome evaluation

Radiographs, anteroposterior and lateral views, of the wrist joint were obtained before and after surgery and at the final follow-up. These were used to determine the radial length, radial inclination, volar tilt, and radial distal intra-articular step-off. To evaluate the clinical outcomes, pain, ability to return to work, range of joint motion, and muscular strength were measured; comprehensive evaluations were also performed using the modified Mayo wrist score (MMWS).

The Wilcoxon signed rank test was performed as a non-parametric test of the radiological results, preoperatively, postoperatively, and at the final follow-up; a p -value < 0.05 was considered significant (IBM SPSS Statistics ver. 20.0; IBM Corp., Armonk, NY, USA).



Fig. 3. (A) Anteroposterior and (B) lateral radiographs, (C) clinical image, and (D) computed tomography image of the wrist of a 59-year-old male (patient No. 11) with a metadiaphyseal comminuted distal radial open fracture (Gustilo–Anderson classification IIIA) due to a crush injury. The associated injuries include metacarpal fractures 3, 4, and 5 and an ulnar styloid process fracture.

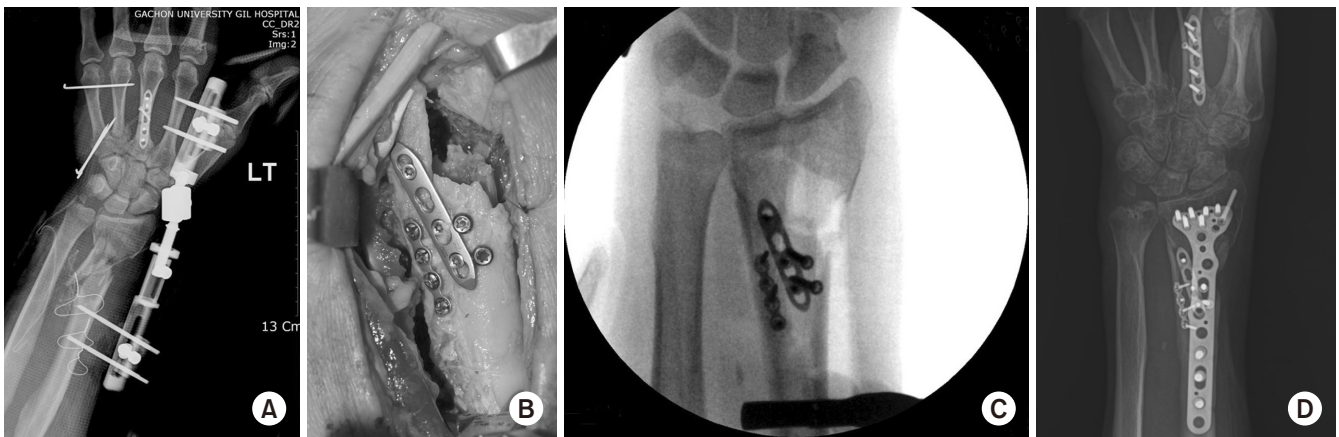


Fig. 4. Meticulous debridement and irrigation were performed on the day of admission, and an external fixator was applied to the fracture site. (A) Two weeks later, definitive surgery was performed when the soft tissue was healed and infection is not evident. (B) Secure surgical fixation of the small metadiaphyseal comminuted fragments involves the use of a miniplate, (C) image intensifier confirmation, and (D) fixation using a definitive plate.

Results

1. Radiological outcomes

The average follow-up period was 14.9 months, with complication-free bone union being achieved in all 12 cases at a mean of 6.8 months. The average radial length, radial inclination, and volar tilt increased from their preoperative values to their postoperative values, then remained relatively constant over the duration of the follow-up. Similarly, the average radial distal intra-articular step-off improved from its preoperative value to its postoperative value, and also remained relatively constant throughout the follow-up period.

The differences between the postoperative and final follow-up values for radial length, radial inclination, volar tilt, and radial distal intra-articular step-off were not statistically significant (Table 1).

2. Clinical outcomes

At the last follow-up visit, the patients had an average MMWS of 81.8 points, with the majority of patients (7) having fair scores (Table 2). The 7 patients with fair scores included 3 for whom accurate reductions were difficult to achieve due to severe bony defects, 3 with severe invasions of the fractures on the articular facet, and 1 requiring long-

Table 1. Radiological Data for Distal Radial Fractures Treated Using Volar Locking Plates and Reduction Plates

	Before surgery	After surgery	p-value	At final follow-up	p-value
Radial length (mm)	6.4 (2.3-9.6)	11.8 (9.5-14.9)	0.01	11.2 (9.2-14.3)	0.54
Radial inclination (°)	10.2 (6.4-25.5)	22.4 (17.3-28.8)	0.01	22.0 (16.9-27.5)	0.81
Volar tilt (°)	-4.5 (-16.1-22.8)	10.6 (2.3-16.8)	0.01	9.7 (1.3-15.8)	0.49
Intra articular step-off (mm)	4.8 (2.1-8.3)	0.8 (0.1-1.2)	0.02	0.9 (0.1-1.4)	0.39

Table 2. Demographics, Injury Types, and Treatment Information of the 12 Patients

Patient No.	Age (yr)	Sex	Injury mechanism	AO/OTA classification	G-A classification	Combine orthopedic injury	Miniplate (mm)	Time to union (mo)	MMWS
1	50	M	Crushing injury	23C2	IIIA	Ulnar styloid process fracture	1.5	6	Good
2	44	M	Crushing injury	23C3	IIIA	Scaphoid fracture	1.5	6	Fair
3	28	F	Fall down	23C2	II	Humerus shaft fracture	1.5	6	Good
4	54	M	Fall down	23C2	Close	Ulnar head fracture, TFCC injury	1.5	8	Excellent
5	41	M	Fall down	23C3	II	Distal ulnar neck fracture Humerus surgical neck fracture, olecranon fracture	1.5	8	Fair
6	62	M	Fall down	23C3	II	Ulnar head fracture	1.5	8	Fair
7	77	F	Slip down	23C3	II	Galeazzi fracture	2.0	6	Fair
8	55	M	Fall down	23C3	Close	None	1.5	5	Excellent
9	76	F	Slip down	23C2	Close	Ulnar styloid process fracture	1.5	6	Good
10	55	F	Slip down	23C3	Close	Ulnar styloid process fracture	1.5	6	Fair
11	59	M	Crushing injury	23C2	IIIA	Ulnar styloid process fracture 3,4,5 metacarpal fracture	1.5, 2.0	7	Fair
12	64	M	Fall down	23C3	Close	Ulnar head fracture	2.0	10	Fair

M: male, F: female, AO/OTA: Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association, G-A: Gustilo-Anderson, MMWS: modified Mayo wrist score, TFCC: triangular fibrocartilage complex.

term fixation due to an associated scaphoid fracture. Furthermore, 5 of those cases involved open fractures with associated poor soft tissue condition; 2 cases had lower scores due the injuries being crush injuries.

Symptoms of postoperative median nerve compression were observed in 2 patients. One of the patients experienced improvement of the complication over time whereas the other experienced spontaneous regression. Carpal pain was reported in 3 cases, and finger flexor tenosynovitis was present in 2 patients; nevertheless, all patients recovered. Flexor stimulation or rupture, malunion, nonunion, or screw loosening were not noted in any patient.

Discussion

This study showed that provisional fixation of miniplate and the fixation of the Volar locking plate were effective for

the reduction and maintenance of fractures in the surgical treatment of severe comminuted metadiaphyseal fractures of distal radius fractures.

Numerous methods, including cast fixation after manual reduction, external fixative devices, K-wiring, open reduction, and plate fixation, are used to treat distal radial fractures.¹⁻⁴⁾ Among them, the volar locking plate is currently the most popular method owing to its fixation strength and promotion of early active joint motion.^{5,6)} However, in cases of comminuted metadiaphyseal fractures, a definitive plate is often difficult to locate in the correct position, using K-wires or pointed reduction forceps. Moreover, the definitive plate may be fixed in the wrong direction to avoid interrupting the K-wire that was temporarily used for the reduction, regardless of the reduction being conducted after soft tissue dissection. Furthermore, a single definitive plate is sometimes insufficient to fix numerous comminuted bone

fragments.

When comminuted metadiaphyseal fractures are fixed using miniplates, fixation of the definitive plates becomes easy, allowing intra-articular fractures to be stably fixed. Cho et al.⁷⁾ designed and reported a pronator-preserving approach in which the pronator quadratus is conserved and a plate is inserted under it by adopting a minimally invasive plate osteosynthesis method. This procedure was used to treat comminuted metadiaphyseal fractures of the distal radius. However, the approach can only be used when the pronator quadratus is intact; thus, we used reduction plates for fractures involving damaged pronator quadratus muscles.

The reduction plate concept was first proposed by Mast et al.⁸⁾; thereafter, Benirschke et al.⁹⁾ and Lang et al.¹⁰⁾ conducted studies on the treatment of proximal tibial fractures using reduction plates prior to the insertion of intramedullary nails. Archdeacon and Wyrick¹¹⁾ reported cases in which reduction plates were used in the humerus and ankle joints. Additionally, Yun et al.¹²⁾ reported the use of reduction plates to treat pertrochanteric fractures and the use of reduction plates for fractures in other body areas. However, the use of reduction plates for the treatment of distal radial fractures has not been previously reported.

Corrosion and interference between metals may occur when fixing plates on top of the miniplates used in the metadiaphysis. Although previous studies typically used one-third plates, the miniplate used in this study was available in 1.5 mm or 2.0 mm lengths.⁸⁻¹²⁾ These miniplates were used according to the contour of the bone, prior to fixation, and fixed to the bone as tightly as possible; the locking plate was then inserted on top of it. Further, the screw heads of the 1.5-mm and 2.0-mm miniplates are small and flat. Neither interference nor corrosion occurred since both types of miniplates were composed of titanium. Even though the miniplates demonstrated weak fixation and a narrow range of distal radius fixation, sufficient clinical efficacy was achieved to provide temporary fixation of comminuted metadiaphyseal fractures.

The clinical outcomes reported in this study were poor. This was probably because only severely comminuted

fractures, beyond the degree of comminution that can be treated using only volar locking plates, were included (Fig. 3, 4). In other words, the treatment method was only used for comminuted fractures with severe bony defects and severely damaged articular facets; in some cases, this method has also been associated with severe tendon injuries. For the same reason, the time to bone union was longer, using this method, than is typical for general distal radial fractures.

The limitations of this study include the small number of included patients, absence of a control group, and lack of consideration of patient compliance. In addition, the follow-up period was relatively short; hence, the determination of the late clinical outcomes, including traumatic arthritis occurring after unstable fractures, was limited. This was a retrospective study in which the reduction plate efficacy was determined on the basis of clinical outcomes; future prospective and biomechanical studies are needed.

Conclusion

A miniplate can play pivotal roles for severe comminuted metadiaphyseal fracture with intraarticular fracture of the distal radius as it was beneficial for the reduction and maintenance of the fragments and was able to provide adequate fixation of the fragments, which were unable to be fixed by a volar locking plate alone.

요 약

목적: 관절내 골절을 동반한 골간단부의 심한 분쇄상 원위 요골 골절에서 소형금속판을 정복용 금속판으로 사용 후 수장측 장김금속판으로 고정한 환자들에 대한 수술 치료 결과를 알아보고자 한다.

대상 및 방법: 골간단부의 분쇄상 원위 요골 골절 환자들 12예를 대상으로 하였다. 방사선학적으로 수술 전, 수술 후, 그리고 술 후 1년째 방사선 검사상 요골 길이, 요골 경사, 수장측 경사, 요골 관절면의 층형성을 측정하였으며, 임상적으로 modified Mayo wrist score (MMWS)를 이용한 평가를 시행하였다.

결과: 전 예에서 골유합을 얻었으며 임상적으로 평균 MMWS는 81.8점이며, 우수 2예, 양호 3예, 보통 7예였다. 방

사선학적으로 요골 길이는 수술 전 평균 6.4 mm에서 수술 후 평균 11.8 mm로, 요골 경사는 평균 10.2°에서 22.4°로, 수장측 경사는 평균 -4.5°에서 10.6°로, 요골 관절면의 층형성은 평균 4.8 mm에서 0.8 mm로 향상되었다($p < 0.05$). 수술 직후와 최종 추시 방사선 사진을 계측 비교한 바 통계적 유의성은 없었다($p > 0.05$).

결론: 소형 금속판을 골 간단부가 분쇄되어 정복 및 유지가 힘든 원위 요골 관절내 골절의 치료에서 정복용 금속판으로 사용하여 만족스러운 결과를 얻을 수 있었다.

색인 단어: 원위 요골 골절, 골간단부 골절, 분쇄 골절, 골절 정복, 소형 금속판

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