OPEN Case Report

Simultaneous Intra-articular and Extra-articular Corrective Osteotomies Using a Patient-Matched Surgical Guide and Plate for Malunion After Distal Radius Fractures: A Report of Two Cases

Hiroki Kondo, MD
Ryoya Shiode, MD, PhD
Satoshi Miyamura, MD, PhD
Arisa Kazui, MD
Natsuki Yamamoto, MD
Tasuku Miyake, MD
Toru Iwahashi, MD, PhD
Hiroyuki Tanaka, MD, PhD
Tsuyoshi Murase, MD, PhD
Seiji Okada, MD, PhD
Kunihiro Oka, MD, PhD

ABSTRACT

Malunion after distal radial fractures with intra-articular and extra-articular deformities is difficult to treat. We report two cases of simultaneous intra-articular and extra-articular corrective osteotomies for malunion after distal radius fractures using a patient-matched surgical guide and plate (patient-matched instruments [PMIs]) created based on a preoperative computer simulation. Both patients experienced pain and limited range of motion in the wrist and forearm. Three-dimensional models were created using CT to simulate corrective osteotomy. Two types of PMIs were created to correct the extra-articular deformity and intra-articular step-off. Intra-articular and extra-articular corrective osteotomies were simultaneously performed using the PMIs. In postoperative imaging evaluations, the average step-offs were reduced from 4.5 to 0 mm and extra-articular deformities were anatomically corrected. The average visual analog scale score decreased from 55/100 to 12/100 mm, indicating substantial pain relief. In addition, there was a notable improvement in range of motion: flexion increased from 42.5° to 62.5°, extension from 57.5° to 75°, pronation from 67.5° to 85°, and supination from 47.5° to 82.5°. Simultaneous intra-articular and extra-articular corrective osteotomy using a patient-matched surgical guide and plate is a valuable technique for correcting complex deformities and ensuring precise osteotomy.

From the Department of Orthopaedic Surgery, Graduate School of Medicine, Osaka University, Japan (Dr. Kondo, Dr. Shiode, Dr. Miyamura, Dr. Kazui, Dr. Yamamoto, Dr. Miyake, Dr. Iwahashi, Dr. Tanaka, Dr. Murase, Dr. Okada, and Dr. Oka); the Department of Orthopaedic Surgery, Bellland General Hospital, Japan (Dr. Murase); and the Department of Orthopaedic Biomaterial Science, Graduate School of Medicine, Osaka University, Japan (Dr. Oka).

Correspondence to Dr. Oka: oka-kunihiro@ort.med.osaka-u.ac.jp

JAAOS Glob Res Rev 2025;9: e24.00328

DOI: 10.5435/JAAOSGlobal-D-24-00328

Malunion is a common complication of distal radius fractures.[1] Wrist dysfunction, including limited range of motion (ROM), pain, decreased grip strength, and delayed onset of median nerve neuropathy, occurs because of persistent deformity.[2-4] Corrective osteotomy resolves these complications by attaining normal wrist alignment.[5-7]

Recently, reports have shown favorable outcomes of corrective osteotomy for either intra-articular or extra-articular deformities using patient-matched surgical guides.[5,6] However, there are few reports on the simultaneous correction of intra-articular and extra-articular deformities.[2,8,9]

For corrective osteotomy in our institution, patient-matched plates and surgical guides (patient-matched instruments [PMIs]) are used to achieve accurate correction and sufficient fixation.[7] To our knowledge, no studies have reported the use of PMIs for corrective osteotomy in patients with malunion after distal radial fractures with intra-articular and extra-articular deformities. In this article, we report two cases of the application of PMIs in simultaneous corrective osteotomy for intra-articular and extra-articular radius malunions.

Case Report

Case 1

A 64-year-old woman had a left distal radial fracture (AO type C1). Initial conservative splint treatment resulted in malunion. She was referred to our hospital because of wrist pain and restricted ROM. Grip strength was reduced to 12 kg on the affected side (50% of the unaffected side). Radiography revealed a volar tilt (VT) of 38°, radial inclination (RI) of 12°, and ulnar variance (UV) of +5 mm. CT showed an intra-articular step-off of up to 5 mm and volar dislocation of the carpal bones (Figure 1).

Case 2

A 78-year-old woman presented with a left distal radial fracture (AO type C1). Initial conservative treatment was a cast, which resulted in malunion. Subsequently, she reported of wrist pain and restricted ROM and was referred to our institution for malunion treatment. Her grip strength had reduced to 5 kg on the affected side (30% of the unaffected side). Radiography revealed a VT of −30°, RI of 18°, and UV of +5 mm. CT revealed an intra-articular irregularity characterized by a 4-mm step-off and a 7-mm gap at the sigmoid notch (Figure 2).

Simulation and Surgery

For deformity evaluation and corrective osteotomy planning, three-dimensional (3D) bone models were created from CT images using software (BoneSimulator; Teijin Nakashima Medical). In Case 1, the extra-articular deformity, evaluated against a mirrored image of the unaffected side, showed radial flexion, 0.5°; palmar flexion, 19.2°; pronation, 8.9°; and intra-articular step-off, 5 mm (Figure 3). Corrective simulation was performed based on the mirrored image (Figure 4, A). A patient-matched plate (Accurio deformity correction system; Teijin Nakashima Medical) was designed to fit the volar bone surface after correction and provide sufficient fixation strength for the insertion of multiple screws, including into the intra-articular bone fragment. The extra-articular surgical guide was shaped to fit the bone surface and had an osteotomy slit and predrilled screw holes. The intra-articular surgical guide had multiple drilling sleeves to divide the malunited fragment using an extra-articular approach, thus eliminating intra-articular step-offs. To precisely define the placement of the guide, it was designed to fit both the volar bone surface and the osteotomy plane (Figure 4, B–D).

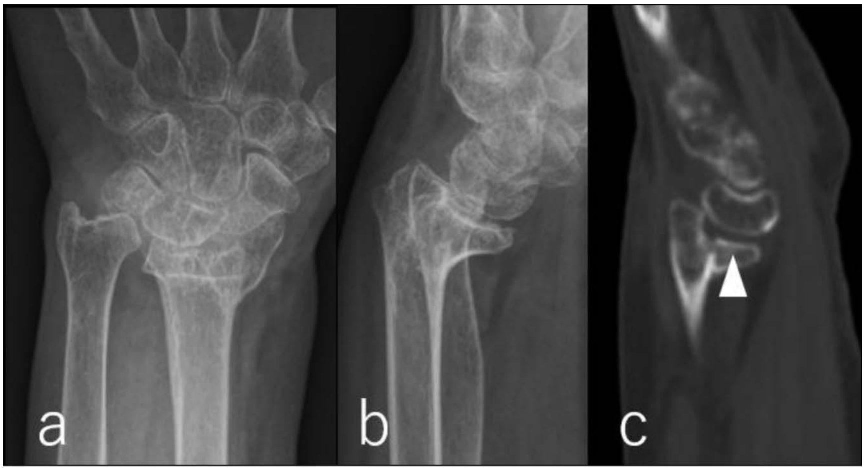
The corrective osteotomy was conducted 7 months after the initial injury. Extra-articular osteotomy was conducted first by setting the extra-articular surgical guide on the radius, predrilling screw holes for the patient-matched plate, and then cutting the bone using a slit (Figure 5, A). Subsequently, intra-articular osteotomy was conducted. An intra-articular surgical guide was fitted to the distal bone fragments, both the volar bone surface and the osteotomy plane. Multiple drill holes were made through the drill sleeves using a 1.2-mm diameter Kirschner wire, and the fragment was divided along the drill holes (Figure 5, B). The separated fragments were realigned using fluoroscopy and fixed with two double-threaded headless screws (Double Threaded Screw; MEIRA) to correct the intra-articular deformity. Finally, a patient-matched plate was placed by inserting screws into the predrilled holes, automatically completing the correction and fixation of the extra-articular deformity (Figure 5, C). The defect was grafted with an iliac bone and an artificial bone.

Postoperative radiography showed that the extra-articular deformity was corrected to a VT of 14°, RI of 25°, and UV of 0 mm (Figure 6, A and B). On postoperative CT, the intra-articular step-off was reduced

None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Kondo, Dr. Shiode, Dr. Miyamura, Dr. Kazui, Dr. Yamamoto, Dr. Miyake, Dr. Iwahashi, Dr. Tanaka, Dr. Murase, Dr. Okada, and Dr. Oka.

Ethics declarations: This study was approved by the Institutional Review Board of Osaka University Hospital (approval no. 19247) and was conducted in accordance with the Declaration of Helsinki. Consent to participate: Written informed consent was obtained from all participants. Consent to publish: Written informed consent was obtained from all participants.

Figure 1



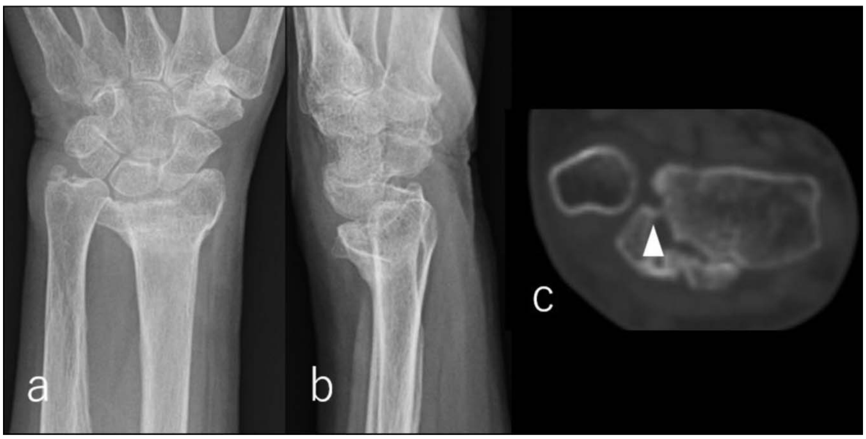
Preoperative plain radiographs of case 1: (**A**) anterior-posterior view; (**B**) lateral view. (**C**) CT in the sagittal plane reveals an intra-articular step-off and volar dislocation of the carpal bones (arrowhead).

from 5 to 0 mm, with correction of the volar displacement of the carpal bones (Figure 6, C). Bone fusion was confirmed without corrective loss 4 months postoperatively. At the latest follow-up, 1 year postoperatively, ROM had improved from 60° to 75° for flexion, 40° to 70° for extension, 80° to 90° for pronation, and 40° to 80° for supination (Figure 7). Activity-related pain was reduced from a visual analog scale score of 30/100 to 14/100 mm, and grip strength was increased to 80% of the unaffected side strength. The patient resumed normal activities without impairment.

The same procedures were performed for Case 2. A 3D CT scan revealed an extra-articular deformity with 26° of radial flexion, 49° of dorsal flexion, and 14° of pronation and an intra-articular deformity with a 4-mm step-off and a 7-mm gap (Figure 8). Given the dorsal location of the intra-articular deformity, an intra-articular osteotomy guide was specifically designed for dorsal application. Corrective osteotomy was conducted 6 months after the initial injury. An approach from the volar side was first used to perform the extra-articular osteotomy. Subsequently, extra-articular reduction was performed using a patient-matched plate, and iliac and artificial bone were grafted at the defect. The dorsal side was exposed, and osteotomy was performed using an intra-articular cutting guide. The bone fragment was reduced with pressure against the articular surface and fixed using double-threaded headless screws.

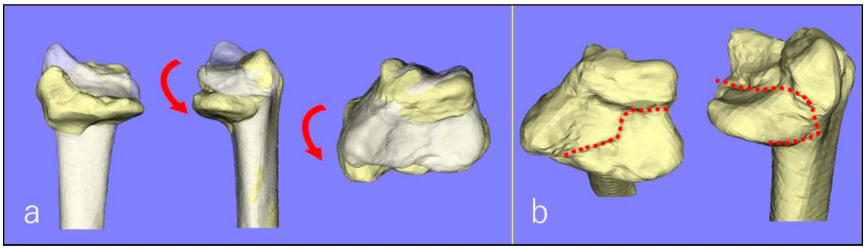
Postoperative radiography showed a VT of 18°, RI of 20°, and UV of +1 mm, indicating improvement (Figure 9,

Figure 2



Preoperative plain radiographs of case 2: (**A**) anterior-posterior view; (**B**) lateral view. (**C**) CT in the axial plane reveals a step-off at a sigmoid notch (arrowhead).

Figure 3



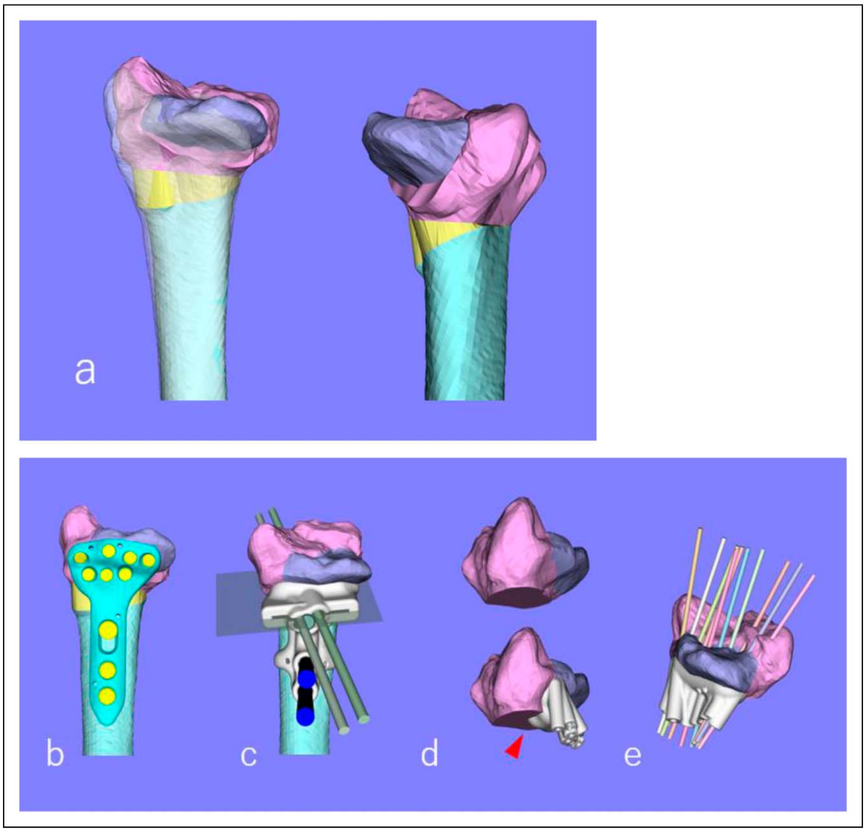
Three-dimensional CT scan using a mirrored overlay of the unaffected side to assess deformities. (**A**) Extra-articular deformities include palmar flexion and pronation. (**B**) Intra-articular deformity showing a bone fragment with a step-off on the volar side of the lunate fossa (dotted lines represent the fracture lines).

A and B). The intra-articular deformity was reduced from a 4-mm step-off and 7-mm gap to 0 mm for both (Figure 9, C). Bone fusion was confirmed without corrective loss 6 months postoperatively. The ROM improved from 25° to 60° for flexion, 75° to 80° for extension, 55° to 80° for pronation, and 55° to 85° for supination. Activity-related pain reduced from a visual analog scale score of 80/100 to 10/100 mm, and grip strength increased to 75% of the unaffected side strength.

Discussion

Malunion after distal radial fractures is a notable complication in approximately 5.3% of cases.[10] The malunion rate after conservative treatment is particularly

Figure 4



Scan demonstrating (**A**) corrective simulation performed using the mirrored image of the unaffected side as a reference; (**B**) a plate designed to fit the surface of the bone after reduction and allow the insertion of multiple screws into the intra-articular bone fragment; (**C**) an extra-articular osteotomy guide featuring sleeves for creating screw holes and cutting slits; and (**D** and **E**) an intra-articular osteotomy guide designed to fit both the original bone surface and the osteotomy plane (arrowhead), enabling multiple perforations for osteotomy using an extra-articular approach.

Figure 5

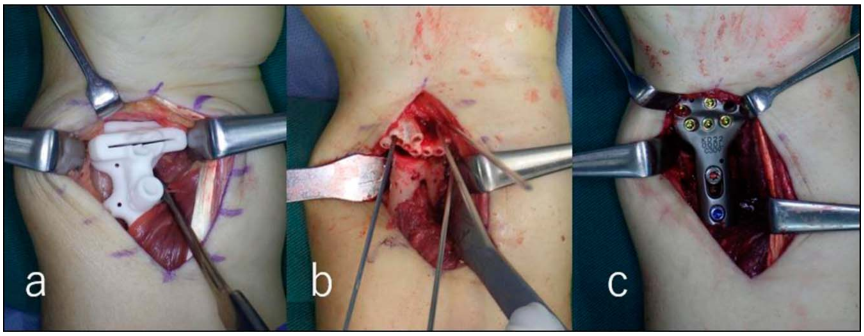


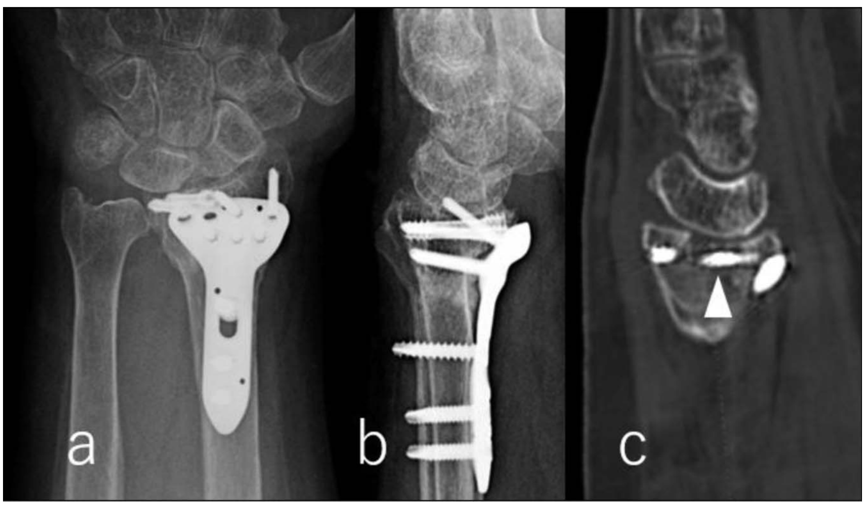
Image demonstrating (**A**) screw hole creation and extra-articular osteotomy, (**B**) intra-articular osteotomy, and (**C**) plate placement.

high (15.6% to 37.5%).[11,12] Malunion has a substantial effect on clinical outcomes, with extra-articular deformities of >10° dorsal tilt and shortening of >3 mm, contributing to wrist dysfunction.[13] Intra-articular deformities with a step-off >2 mm contribute to osteoarthritic changes.[13] For symptomatic malunion, corrective osteotomy is performed to restore normal anatomy.[2,14]

Various reports have described this corrective osteotomy method for malunion after distal radial fractures. Patient-matched surgical guides from preoperative 3D CT have been introduced to achieve accurate osteotomy correction. Regarding treatment outcomes, extra-articular deformities can be corrected with an accuracy of 1 mm and 1°,[7] and for intra-articular deformities, step-offs can be reduced to approximately 1 mm.[2,6,15]

However, when corrective osteotomy is required for both intra-articular and extra-articular deformities, treatment becomes challenging. Few studies report the simultaneous correction of both intra-articular and extra-articular deformities[2,8,9] because the simultaneous procedure is associated with a risk of necrosis of the intra-articular bone fragments, particularly with the addition of osteotomy sites. The use of patient-matched surgical guides allows osteotomies to be performed from outside the joint without damaging the joint capsule, resulting in the preservation of soft tissue attached to the bone fragments.[6] Furthermore, the simultaneous fixation of multiple bone fragments is complex. Meticulous attention is needed for plate placement and fixation between bone fragments to secure multiple bone pieces. The patient-matched surgical guides enable osteotomy and screw hole creation as planned preoperatively. In addition, by using a patient-matched plate, screws can be positioned at any location according to the preoperative plan, and the plate can be shaped to fit the bone

Figure 6



Postoperative plain radiographs: (**A**) anterior-posterior view; (**B**) lateral view. **(C)** CT in the sagittal plane reveals the disappearance of the step-off and reduction of the carpal bones (arrowhead).

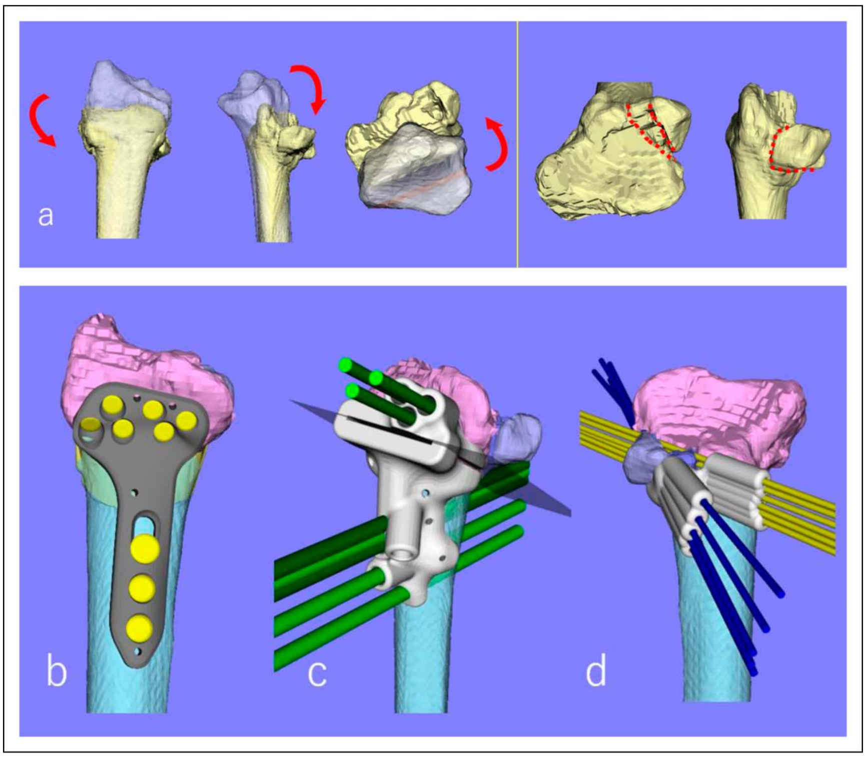
Figure 7

(**A**) Preoperative and (**B**) postoperative patient images. An improved range of motion was observed (*affected side).

surface after reduction, thereby simplifying the complexity of the reduction.[16] Patient-matched plates closely fitted to the bone surface also minimize damage to soft tissues and interference with the flexor tendons.

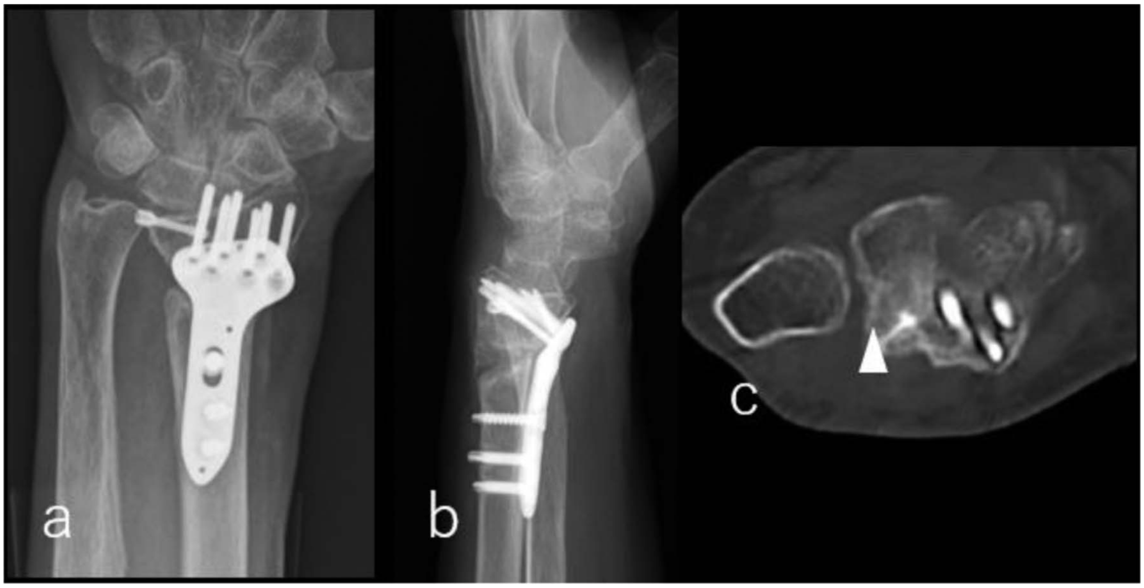
In our cases, satisfactory correction angles were achieved for extra-articular deformities and intra-articular deformities were also reduced to <1 mm. These results suggest that performing both intra-articular and extra-articular corrective osteotomies simultaneously using PMIs may achieve a level of precision comparable with that achieved with these procedures separately. In addition, improvements were observed in both postoperative ROM and pain relief, and bone fusion was achieved within 6 months postoperatively, without bone fragment necrosis. Consequently, we believe that simultaneous corrective osteotomy using PMIs for both intra-articular

Figure 8



Three-dimensional CT scans for deformity assessment: (**A**) extra-articular deformities included radial flexion, extension, and pronation. Intra-articular deformity with a bone fragment exhibiting a step-off on the dorsal side of the lunate fossa. (**B–D**) Similar to case 1, a plate and osteotomy guide were designed. The intra-articular osteotomy guide was designed to be positioned from the dorsal side of the radius.

Figure 9



Postoperative plain radiographs: (**A**) anterior-posterior view; (**B**) lateral view. (**C**) CT in the axial plane reveals the disappearance of the step-off (arrowhead).

and extra-articular deformities after distal radius fractures is a highly effective treatment method.

This study had some limitations. First, the relatively short follow-up period limited the assessment of long-term outcomes. Second, even if an osteotomy is performed from outside a joint without damaging the joint capsule, multiple drilling into small bone fragments could lead to osteonecrosis, especially in patients with osteoporosis. In cases with fairly small bone fragments or osteoporosis, it is crucial to determine the number of screws considering stability and the risk of osteonecrosis. Furthermore, osteoporotic patients are at risk of collapse even if they do not develop osteonecrosis. Therefore, it is essential to design plates that offer robust support to the volar surface of intra-articular fragments and provide subchondral support with screws. Concurrently, the use of anabolic agents, such as teriparatide, is recommended for the treatment of osteoporosis. Moreover, PMI creation requires notable time and cost, which may not be feasible in clinical settings. Approximately 2 weeks are needed to manufacture the instruments, with the patient-matched surgical guide and plate costing approximately 600 and 2000 USD, respectively.[15,17] However, because corrective osteotomies for both intra-articular and extra-articular deformities are inherently complex procedures, our method seems a viable option for patients with severely impaired wrist function after intra-articular and extra-articular fractures, who may require salvage surgery such as arthrodesis. We believe that as this technology becomes more affordable and widely adopted, its range of applications will expand markedly.

Conclusion

Simultaneous corrective osteotomy using PMIs was conducted for intra-articular and extra-articular malunions after distal radial fractures. Both patients achieved satisfactory outcomes, suggesting that PMIs are useful surgical options for corrective intra-articular and extra-articular osteotomy.

Acknowledgments

The study was supported by a national grant from the Japan Society for the Promotion of Science (JSPS KAKENHI, Grant No. JP 23K24458).

References

1. Mulders MA, d'Ailly PN, Cleffken BI, Schep NW: Corrective osteotomy is an effective method of treating distal radius malunions with good long-term functional results. *Injury* 2017;48:731-737.

2. Roner S, Schweizer A, Da Silva Y, Carrillo F, Nagy L, Fürnstahl P: Accuracy and early clinical outcome after 3-dimensional correction of distal radius intra-articular malunions using patient-specific instruments. *J Hand Surg Am* 2020;45:918-923.

3. Tarallo L, Mugnai R, Adani R, Catani F: Malunited extra-articular distal radius fractures: Corrective osteotomies using volar locking plate. *J Orthop Traumatol* 2014;15:285-290.

4. Megerle K, Baumgarten A, Schmitt R, van Schoonhoven J, Prommersberger KJ: Median neuropathy in malunited fractures of the distal radius. *Arch Orthop Trauma Surg* 2013;133:1321-1327.

5. Roner S, Carrillo F, Vlachopoulos L, Schweizer A, Nagy L, Fuernstahl P: Improving accuracy of opening-wedge osteotomies of distal radius using a

patient-specific ramp-guide technique. *BMC Musculoskelet Disord* 2018; 19:374.

6. Oka K, Shigi A, Tanaka H, Moritomo H, Arimitsu S, Murase T: Intra-articular corrective osteotomy for intra-articular malunion of distal radius fracture using three-dimensional surgical computer simulation and patient-matched instrument. *J Orthop Sci* 2020;25:847-853.

7. Oka K, Tanaka H, Okada K, et al: Three-dimensional corrective osteotomy for malunited fractures of the upper extremity using patient-matched instruments: A prospective, multicenter, open-label, single-arm trial. *J Bone Joint Surg Am* 2019;101:710-721.

8. Zhang H, Zhu Y, Fu F, et al: Corrective osteotomy with volar and dorsal fixation for malunion of intra-articular fracture of the distal radius: A retrospective study. *Orthop Surg* 2022;14:1751-1758.

9. Buijze GA, Prommersberger KJ, González Del Pino J, Fernandez DL, Jupiter JB: Corrective osteotomy for combined intra- and extra-articular distal radius malunion. *J Hand Surg Am* 2012;37:2041-2049.

10. Turner RG, Faber KJ, Athwal GS: Complications of distal radius fractures. *Hand Clin* 2010;26:85-96.

11. Kilic A, Ozkaya U, Kabukcuoglu Y, Sokucu S, Basilgan S: The results of non-surgical treatment for unstable distal radius fractures in elderly patients. *Acta Orthop Traumatol Turc* 2009;43:229-234.

12. Sharma H, Khare GN, Singh S, Ramaswamy AG, Kumaraswamy V, Singh AK: Outcomes and complications of fractures of distal radius (AO type B and C): Volar plating versus nonoperative treatment. *J Orthop Sci* 2014;19:537-544.

13. Kamal RN, Shapiro LM: American Academy of Orthopaedic Surgeons/American Society for Surgery of the hand clinical practice guideline summary management of distal radius fractures. *J Am Acad Orthop Surg* 2022;30:e480-e486.

14. Andreasson I, Kjellby-Wendt G, Fagevik-Olsén M, Aurell Y, Ullman M, Karlsson J: Long-term outcomes of corrective osteotomy for malunited fractures of the distal radius. *J Plast Surg Hand Surg* 2020;54:94-100.

15. Oka K, Miyamura S, Shiode R, et al: Intra-articular corrective osteotomy for distal radial intra-articular malunion using patient-matched instruments: A prospective, multicenter, open-label, single-arm trial. *JB JS Open Access* 2024;9:e24.00026.

16. Omori S, Murase T, Kataoka T, et al: Three-dimensional corrective osteotomy using a patient-specific osteotomy guide and bone plate based on a computer simulation system: Accuracy analysis in a cadaver study. *Int J Med Robot* 2014;10:196-202.

17. Miyamura S, Tanaka H, Oka K, et al: Physeal bar resection using a patient-specific guide with intramedullary endoscopic assistance for partial physeal arrest of the distal radius. *Arch Orthop Trauma Surg* 2018;138:1179-1188.