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Korean Type Distal Radius Anatomical Volar Plate System: A Preliminary Report

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Background: Distal radius fracture is the most common fracture of the upper extremity, and approximately 60,000 distal radius fractures occur annually in Korea. Internal fixation with an anatomical volar locking plate is widely used in the treatment of unstable distal radius fractures. However, most of the currently used distal radius anatomical plate systems were designed based on the anatomical characteristics of Western populations. Recently, the Korean-type distal radius anatomical volar plate (K-DRAVP) system was designed and developed based on the anatomical characteristics of the distal radius of Koreans. The purpose of this study was to evaluate the preliminary results of the new K-DRAVP system, and to compare its radiologic and functional results with those of the other systems.

Methods: From March 2012 to October 2012, 46 patients with acute distal radius fractures who were treated with the K-DRAVP system at three hospitals were enrolled in this study. Standard posteroanterior and lateral radiographs were obtained to assess fracture healing, and three radiographic parameters (volar tilt, radial inclination, and radial length) were assessed to evaluate radiographic outcomes. The range of motion and grip strength, the Gartland and Werley scoring system, and the disabilities of the arm, shoulder and hand (DASH) questionnaire were used to assess clinical and functional outcomes.

Results: All radiologic parameters were restored to normal values, and maintained without any loosening or collapse until the time of final follow-up. Grip strength was restored to 84% of the value for the unaffected side. The mean range of motion of the wrist at final follow-up was restored to 77%–95% of the value for the unaffected side. According to the Gartland and Werley scoring system, there were 16 excellent, 26 good, and 4 fair results. The mean DASH score was 8.4 points. There were no complications after surgery.

Conclusions: The newly developed K-DRAVP system could be used to restore and maintain good anatomical parameters, and provide good clinical outcomes with low complication rates. This system is a promising surgical option for the treatment of distal radius fractures in the Korean population.

Keywords: *Radius, Distal radius fracture, Volar locking plate, Anatomical plate*

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Distal radius fracture is the most common fracture of the upper extremity, with an annual incidence of 2 to 4 per 1,000 persons.[1] The annual incidence of distal radius fracture is increasing in elderly population, due to an increase in life expectancy, as well as in young population, due to sports activities. Approximately 60,000 distal radius fractures occur annually in Korea, and the residual lifetime risk is about 21.7% for women aged 50 years.[2]

Various treatment options are available for distal radius fractures. Stable distal radius fractures can be successfully treated by conservative methods, such as splinting or casting. However, some cases of unstable distal radius fractures and displaced intra-articular fractures require surgical treatment. Surgical options for the treatment of distal radius fractures include percutaneous pinning, internal fixation, and external fixation. Among these methods, the use of internal fixation using a volar locking plating system is the most common.[3,4] At present, volar locking plate is generally used in the treatment of unstable distal radius fracture because of its advantages and the advancements presented with plate fixation systems.

Various types of distal radius anatomical plates have been developed and are in widespread use. However, these anatomical plates were designed in Western countries, based on the anatomical characteristics of Western populations. Koreans have different anatomical features from those of the Western populations, such as a relatively small and short radius, especially in elderly women. And the angle of volar cortex is comparatively more acute than that of Western populations.[5] Therefore, the conventional anatomical plate systems specific for the Western populations do not always anatomically fit in Korean patients. In some patients, although the smallest conventional anatomical plate system was chosen, the plate size was too large for small radius of elderly Korean women. And in some patients, the precontoured plates do not appropriately contact the volar cortex. These mismatches of the anatomically precontoured plate system may cause complications, such as failure to achieve anatomic reduction, failure to achieve firm contact of the plate on the cortex, and tendon or nerve irritation.[6] Thus, Korean type of anatomical volar plate system was required to solve these problems. The Korean-type distal radius anatomical volar plate (K-DRAVP) system was designed and developed based on anatomical characteristics of distal radius of Koreans.[5]

The purpose of this study was to evaluate the preliminary results of the new K-DRAVP system, and to compare its radiologic and clinical results with those of the other systems.

METHODS

Our Institutional Review Board approved this study, and all of the patients provided informed consent. From March 2012 to October 2012, 46 patients with acute distal radius fractures, who were treated with the K-DRAVP system at three hospitals, were enrolled in this study. Indications for surgical treatment of the distal radius fracture were as follows: (1) failure of initial closed reduction or maintenance in a cast; (2) an intra-articular step-off greater than 2 mm; and (3) need of surgical treatment to allow for early motion. Exclusion criteria were as follows: (1) inability to attend follow-up examinations for more than 6 months; (2) treatment with other surgical options, such as pinning and other plate systems; (3) presence of additional injuries in the affected upper limb; and (4) refusal to enroll in this study.

The participants included 16 men and 30 women with a mean age of 62 years (range, 28 to 90 years) at the time of injury. The mean period from injury to surgery was 4.6 days (range, 1 to 12 days). The mean follow-up time was 10.1 months (range, 6 to 14 months). The left wrist was affected in 25 patients, and the right wrist was affected in 21 patients. The fractures affected the dominant hand in 27 patients (59%). The most common cause of fracture was a simple slip down or fall onto an outstretched hand (39 cases, 85%). Other causes of fractures were a fall down from more than 2-m height (3 patients, 7%), a traffic accident (3 patients, 7%), and an injury caused by twisting (1 patient, 2%). All fractures were categorized and classified according to the Association for Osteosynthesis/Association for the Study of Internal Fixation (AO/ASIF) classification. All fractures were closed fractures, and there were 11 cases of A2, 9 of A3, 7 of C1, 4 of C2, and 15 of C3 classification. Three patients had other injuries in addition to the distal radius fracture: one patient had a traumatic intracranial hemorrhage with facial bone fractures; one patient had a femoral intertrochanteric fracture; and one patient had a liver laceration with rib and facial bone fractures.

Surgical Technique

Under general or regional anesthesia, a volar approach with an 8-cm zigzag skin incision along the radial side of the flexor carpi radialis (FCR) tendon was used. After splitting the forearm fascia, the FCR tendon, flexor tendons, and median nerve were retracted to the ulnar side, and the pronator quadratus muscle was detached from the radius. Reduction was performed under direct vision and confirmed with an image intensifier, and the bone was fixed temporarily with Kirschner wires. Then, the plate was inserted

and fixed using a 2.7-mm cortical screw in the gliding hole. Correct positioning was verified using an image intensifier. The distal portion of the plate was fixed to the radius using 2.4-mm locking screws, and the proximal portion was fixed to the radius using 2.7-mm locking screws. After placement of the plate, the detached pronator quadratus muscle was re-attached with absorbable sutures. After wound closure, a compressive dressing and a splint were applied. Postoperatively, the wrist was immobilized for 6 weeks with application of a long-arm cast for 3 weeks and application of a short-arm cast for 3 weeks. Range of motion exercises for the wrist were started at 6 weeks after surgery.

Plate System

The K-DRAVP system (BK Meditech, Hwaseong, Korea) was developed by the Department of Orthopedic Surgery of Seoul National University Hospital, and is patented in Korea (Patent No. 10-0784362). This system is fabricated from titanium alloy (Ti-6Al-4V ELI) that conforms to the standards of the American Society for Testing and Materials (ASTM) F136. This system has some advantages over other plate systems. First, this low-profile plate system is precontoured to provide the best position on the radius based on the anatomic characteristics of Koreans.[5] Second, the distal edge of the plate is specially contoured to follow the watershed line. Third, the plate has specially contoured thin and narrow end at the distal margin to minimize tendon or nerve irritations. The plate is of a single size and is available for the right and left wrists. The distal portion of the plate has threaded locking holes that can accept both locking and non-locking 2.4-mm screws. In addition, the plate system has a dynamic compression hole for 2.7-mm cortical screws at its shaft, and 3 threaded locking holes for both locking and non-locking 2.7-mm screws (Fig. 1).

Fig. 1. The Korean-type distal radius anatomical volar plate system.

Radiologic Examination and Clinical Evaluation

All patients were assessed every other week until union was achieved. After fracture union, the patients were assessed at 3 months, 6 months, and 1 year after surgery. Standard posteroanterior and lateral radiographs of the wrist were obtained to assess fracture healing. Three radiographic parameters (volar tilt, radial inclination, and radial length) were measured: before surgery, immediately after surgery, and at the final follow-up evaluation. Two of the authors (JHK, HJL) evaluated radiographs of the wrist. Both these authors were orthopedic surgeons and blinded to other information regarding this study. We evaluated the intraobserver reliability by repeating all radiographic assessments after 2 weeks, and we evaluated the interobserver reliability by having the two examiners assess all radiographic parameters independently. The intra- and interobserver reliabilities of radiographic assessments were tested using interclass correlation coefficients (ICCs). ICC value of the intraobserver reliability of radiographic assessment was 0.922 (95% confidence interval), and that of the interobserver reliability was 0.889 (95% confidence interval). Thus we used the radiographic parameters measured by one of the authors in the analysis.

The range of motion of the affected wrist and the contralateral side was measured using a goniometer. Grip strength was measured using the Jamar dynamometer (Asimow Engineering, Los Angeles, CA, USA) with the elbow flexed at 90° and the forearm in neutral position. The disabilities of the arm, shoulder and hand (DASH) questionnaire was used to assess functional outcomes in activities of daily living. Final clinical and functional outcomes were assessed and graded using the scoring system of Gartland and Werley[7] modified by Sarmiento et al.[8] (Table 1).

Statistical Analysis

The paired *t*-test was used to compare each radiographic parameter. A $p < 0.05$ was considered statistically significant. The intra- and interobserver reliabilities of radiographic assessments were tested using ICCs. ICC values of > 0.8 were considered as excellent reliability. Statistical analyses were performed using IBM SPSS ver. 20.0 (IBM Co., Armonk, NY, USA).

RESULTS

Radiologic Outcomes

Bony union was achieved in all patients, and the mean time for union was 42 days (range, 37 to 50 days) (Fig. 2). None of the patients required an autologous or artificial

Table 1. Gartland and Werley Demerit Point System

Results	Point
Residual deformity (range, 0 to 3 points)	
Prominent ulnar styloid	1
Residual dorsal tilt	2
Radial deviation of hand	2 or 3
Subjective evaluation (range, 0 to 6 points)	
Excellent: no pain, disability, or limitation of motion	0
Good: occasional pain, slight limitation of motion, and no disability	2
Fair: occasional pain, some limitation of motion, feeling of weakness in wrist, no particular disability if careful, and activities slightly restricted	4
Poor: pain, limitation of motion, disability, and activities more or less markedly restricted	6
Objective evaluation* (range, 0 to 5 points)	
Loss of extension	5
Loss of ulnar deviation	3
Loss of supination	2
Loss of flexion	1
Loss of radial deviation	1
Loss of circumduction	1
Pain in distal radio-ulnar joint	1
Grip strength: 60% or less than on the opposite side†	1
Loss of pronation†	2
Complications (range, 0 to 5 points)	
Arthritic change	
Minimum	1
Minimum with pain	3
Moderate	2
Moderate with pain	4
Severe	3
Severe with pain	5
Nerve complications (median)	1–3
Poor finger function due to cast	1 or 2
Final results (ranges of points)	
Excellent	0–2
Good	3–8
Fair	9–20
Poor	≥ 21

*The objective evaluation is based on the following ranges of motions as being the minimum for normal function: extension (45°), flexion (30°), radial deviation (15°), ulnar deviation (15°), pronation (50°), and supination (50°). †Criteria added by Sarmiento et al.[8]

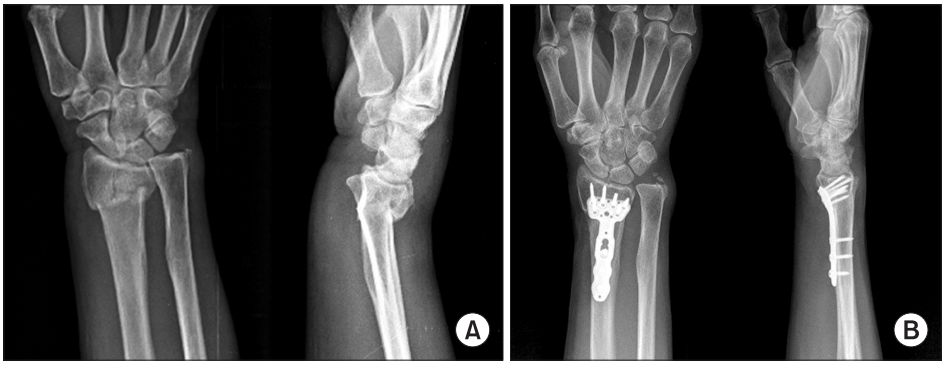

Fig. 2. (A) Initial radiograph of C1 fracture in a 73-year-old woman. (B) Radiograph taken at postoperative 6 months. Anatomical reduction was restored and well maintained.

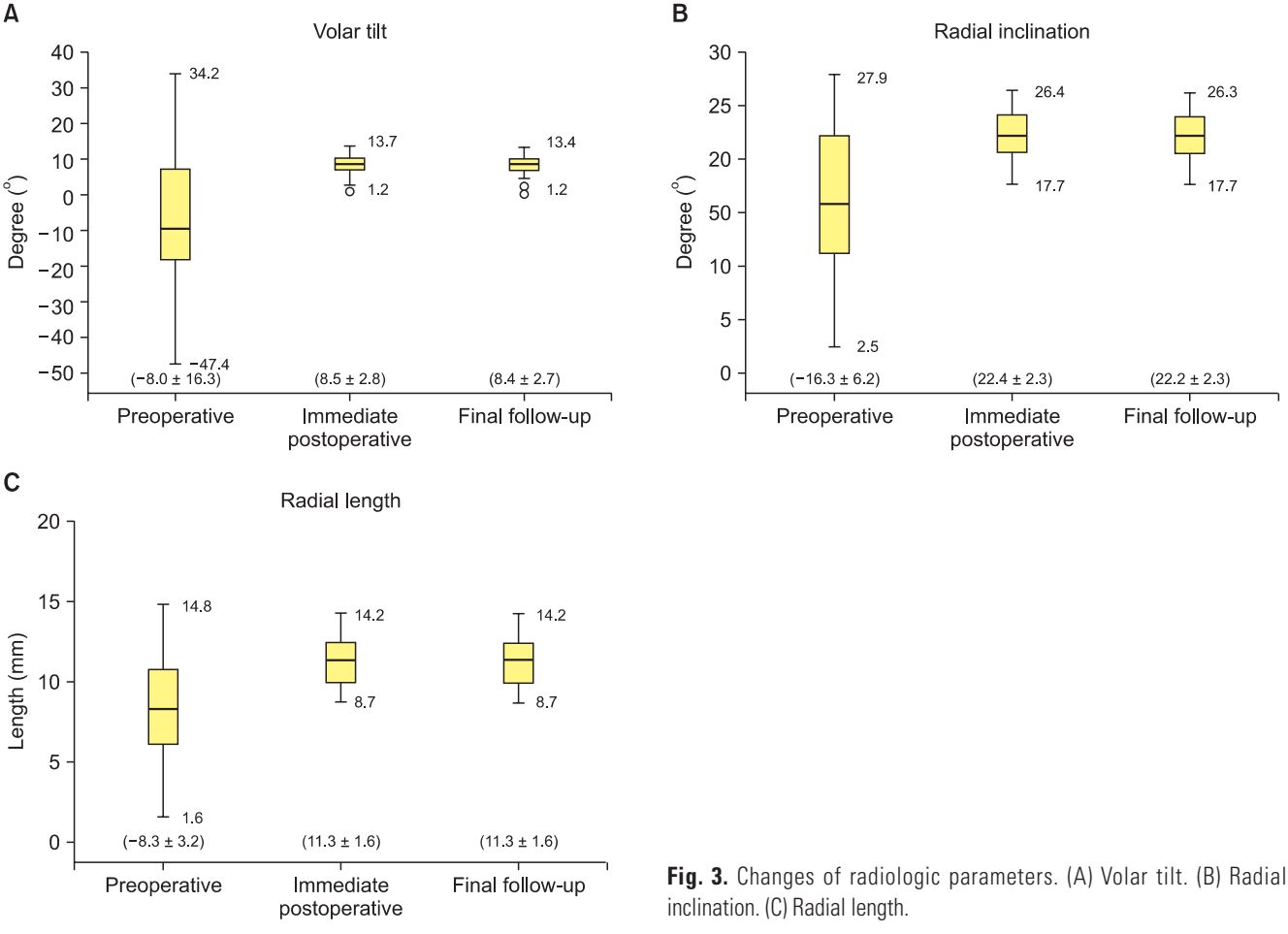

Fig. 3. Changes of radiologic parameters. (A) Volar tilt. (B) Radial inclination. (C) Radial length.

bone graft. The preoperative volar tilt was –8.0° ± 16.3° (range, –47.4° to 34.2°), the immediate postoperative volar tilt was 8.5° ± 2.8° (range, 1.2° to 13.7°), and the final follow-up volar tilt was 8.4° ± 2.7° (range, 1.2° to 13.4°). The preoperative radial inclination was 16.3° ± 6.2° (range, 2.5° to 27.9°), the immediate postoperative radial inclination was 22.4° ± 2.3° (range, 17.7° to 26.4°), and the final follow-up radial inclination was 22.2° ± 2.3° (range, 17.7° to 26.3°). Preoperative radial length was 8.3 ± 3.2 mm (range, 1.6 to 14.8 mm), the immediate postoperative radial length was 11.3 ± 1.6 mm (range, 8.7 to 14.2 mm), and the final follow-up radial length was 11.3 ± 1.6 mm (range, 8.7 to 14.2 mm). There was a significant difference in each parameter between the preoperative and the immediate postoperative values ($p < 0.001$). However, there was no statistically significant difference between each parameter immediately postoperative and the final follow-up evaluation (Fig. 3).

Clinical Outcomes

Grip strength was restored to 84% (range, 69% to 100%) of the value of the unaffected side at the final follow-up evaluation. The mean range of motion of the wrist at the final follow-up was 56.2° ± 13.2° of extension (range, 25° to 80°; 86% compared with the unaffected side), 51.3° ± 11.2° of flexion (range, 25° to 75°; 77% compared with the unaffected side), 15.6° ± 4.3° of radial deviation (range, 10° to 20°; 85% compared with the unaffected side), 25.9° ± 7.8° of ulnar deviation (range, 15° to 35°; 87% compared with the unaffected side), 81.0° ± 10.9° of pronation (range, 65° to 85°; 95% compared with the unaffected side), and 79.6° ± 11.7° of supination (range, 60° to 90°; 87% compared with the unaffected side). According to the Gartland and Werley scoring system, there were 16 excellent, 26 good, and 4 fair results. The mean follow-up time was the same for patients who showed excellent or good results (10.4 months; range, 7 to 14 months). The mean follow-up period for patients with fair results (7 months; range, 6 to 8 months) was relatively shorter compared with other patients with excellent or good results. The mean DASH score was 8.4 points (range, 0 to 20 points). All clinical outcomes are shown in Table 2.

Complications

One patient requested removal of the plate at 10 months after surgery. There were no cases of infection, complex regional pain syndrome, tendon rupture, nerve irritation, or implant failure.

Table 2. Clinical Outcomes

Variable	Mean ± SD	Range	Restoration (%)*
Range of motion (°)			
Extension	56.2 ± 13.2	25–80	86
Flexion	51.3 ± 11.2	25–75	77
Radial deviation	15.6 ± 4.3	10–20	85
Ulnar deviation	25.9 ± 7.8	15–35	87
Pronation	81.0 ± 10.9	65–85	95
Supination	79.6 ± 11.7	60–90	87
Grip power (%)		69–100	84
DASH score (point)	8.4	0–20	

Gartland and Werley scoring system: excellent (16), good (26), fair (4).
DASH: disabilities of the arm, shoulder and hand.
*Compared with the unaffected side.

DISCUSSION

In this study, the K-DRAVP system appropriately fit the anatomy of the distal radius of Korean patients. The system provided good maintenance of radiologic alignment after reduction of the fracture, and most patients (91%) achieved excellent or good results according to the Gartland and Werley scoring system. There was no statistically significant deterioration in any of the radiologic parameters, such as volar tilt, radial inclination, and radial length. Grip strength and range of motion at the final follow-up were restored to approximately 85% of the values of the unaffected side. The mean DASH score (8.4 points) indicated little discomfort in the activities of daily living.

Volar plating with a locking screw system has the advantages of an easy surgical procedure, relatively low risk of complications, and early functional mobilization. Several authors have reported good outcomes for various types of volar plates used for treatment of distal radius fractures. Drobetz and Kutscha-Lissberg[9] reported the results from 50 patients treated with a locking plate system (Mathys, Salzburg, Austria). According to the Gartland and Werley scoring system, 26 patients showed excellent results, 20 patients showed good results, 3 patients showed fair results, and 1 patient showed a poor result after a mean follow-up of 26 months. Kamano et al.[10] reported the results from 40 patients with distal radius fractures treated with palmar plates (Biotechini Co., Ciotat, France). They reported that 12 patients showed excellent results and 28 patients showed good results after a mean follow-up of 12 months, according to the Gartland and Werley scoring system. Wong et al.[11] reported the results from 35 patients with dorsally displaced distal radius fractures treated using the Stryker plating system with SmartLock locking screws after a mean follow-up of 10 months. The mean Mayo Clinic wrist score was 90 points and 20 patients achieved an excellent result. Figl et al.[12] reported the results from 80 patients with unstable distal radius fractures treated using the APTUS plate (Medartis AG, Basel, Switzerland) after a mean follow-up of 7 months. The mean DASH score was 25 points, and according to the Castaing score, 30 patients showed perfect results, 49 patients showed good results, and 1 patient showed an adequate result. Minegishi et al.[13] reported the results from 15 patients with unstable distal radius fractures treated using the Acu-Loc distal radius plate (Acumed, Hillsboro, OR, USA) after a mean follow-up of 15.5 months. In their study, according to the Cooney's clinical scoring chart, 5 patients showed excellent results, 7 patients showed good results, and 3 patients showed fair results. Lattmann et al.[14] reported a relatively

Table 3. Results of Recent Studies on Volar Locking Plate Systems

Study	Case no.	Plate system	Mean follow-up period (mo)	Result
Drobetz and Kutscha-Lissberg (2003)[9]	50	Mathys plate system (Salzburg, Austria)	26	Excellent (26), good (20), fair (3), poor (1)*
Kamano et al. (2005)[10]	40	Palmar plate (Biotechini Co., Ciotat, France)	12	Excellent (12), good (28)*
Wong et al. (2009)[11]	35	SmartLock (Stryker, Kalamazoo, MI, USA)	10	Excellent (20), good (12), fair (2), poor (1)†
Figl et al. (2009)[12]	80	APTUS (Medartis AG, Basel, Switzerland)	7	DASH 25 points: perfect (30), good (49), adequate (1)‡
Minegishi et al. (2011)[13]	15	Acu-Loc (Acumed, Hillsboro, OR, USA)	15.5	Excellent (5), good (7), fair (3)§
Matschke et al. (2011)[17]	117	3.5 mm LCP-DR (Synthes, Bettlach, Switzerland)	24	DASH 11.2 points: excellent (59), good (37), fair/poor (12)*
Lattmann et al. (2011)[14]	228	LC-T plates (Synthes)	12	Grip strength 91%: PRWE 8 points
Osada et al. (2008)[15]	49	DRV Locking Plate (Mizuho Ikakogyo Co., Tokyo, Japan)	12	DASH 6.1 points: excellent (47), good (2)*
Current study	46	Korean type distal radius anatomical volar plate (BK Meditech, Hwaseong, Korea)	10.1	DASH 8.4 points: excellent (16), good (26), fair (4)*

DASH: disabilities of the arm, shoulder and hand, PRWE: Patient-Rated Wrist Evaluation.
*By Gartland and Werley score. †By Mayo wrist score. ‡By Castaing score. §By Cooney's clinical scoring chart.

large series of 228 patients with distal radius fractures treated with LC-T plates (Synthes, Bettlach, Switzerland). Grip strength was 91% of that on the contralateral side, and the assessed Patient-Rated Wrist Evaluation score was 8 points. Few studies have evaluated the results of Asian-type distal radius volar plates. Osada et al.[15] reported the results of 49 patients with distal radius fractures treated with a distal radius volar locking plate (DRV-LP, Mizuho Ikakogyo Co., Tokyo, Japan). After 1 year of follow-up, the mean DASH score was 6.1 points (range, 0 to 30 points) and all patients showed excellent or good results according to the Gartland and Werley scoring system. Yasuda and Ando[16] also reported good outcomes with a new variable angle distal screw locking volar plate system (Nakashima Propeller Co., Okayama, Japan).

Our radiologic and clinical results are similar to those of other studies using different types of distal radius volar plates (Table 3).[9-15,17] Furthermore, in our study, there were no mechanical complications such as irritations of flexor tendons or the median nerve. Some studies have reported on mechanical irritations after volar plate fixation.[18-20] Kim et al.[18] reported 2 cases of multiple flexor tendon ruptures after volar plate (LC-T, plate; Synthes) fixation for distal radius fractures. They reported that the prominent distal portion of the volar plate could cause damage to the flexor tendons. Lee et al.[19] reported 2 complications of mechanical irritations after volar plate (Acu-Loc System; Acumed) fixation for distal radius fractures. Lee et al.[20] reported mechanical irritation of the median nerve after volar plate fixation for distal radius fractures. In this case, there were no mechanical complications because the K-DRAVP system was initially designed as a low-profile system with a specially contoured thin and narrow end of the distal margin in order to minimize these mechanical complications, such as tendon or nerve irritations.

This study has some limitations. First, this was not a randomized controlled study, and we did not compare our results with patients who were treated with other types of distal radius plates. Therefore, we compared our data with those of previous reports. Further prospective randomized controlled studies are needed. Second, we had a relatively short follow-up period because this was a preliminary report. Patients who showed fair results according to the Gartland and Werley scoring system had relatively shorter follow-up periods (mean, 7 months; range, 6 to 8 months) than those of patients who showed excellent or good results (mean, 10.4 months; range 7 to 14 months). This finding suggests that more favorable outcomes can be achieved after a longer follow-up period. Third, the K-DRAVP plate system had some problems. On the basis

of our experience with the K-DRAVP system, we recommended some improvements in the plate design. First, the drilling guides for the screws were small and separated, and management of these guides was difficult and time-consuming. Second, plates of variable sizes and lengths need to be designed. One female patient could not be treated with the K-DRAVP system because the diameter of her radius was smaller than that of this plate. Third, another plate design for juxta-articular type distal radius fractures is needed for fixation of small distal juxta-articular fragments. After we reported our suggestions to the manufacturer, a revised version of the K-DRAVP system has been developed and is currently being used. We will report the results of the revised version of the plate in due course.

Although this study was only a preliminary report of the newly developed K-DRAVP system, we found that this plate system could be used to restore and maintain the anatomical parameters, and it provided good clinical outcomes with low complication rates because it is the first anatomical distal radius volar plate designed based on the anatomical characteristics of Koreans. The K-DRAVP system is a promising surgical option for treatment of distal radius fractures in the Korean population.

CONFLICT OF INTEREST

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

REFERENCES

1. Thompson PW, Taylor J, Dawson A. The annual incidence and seasonal variation of fractures of the distal radius in men and women over 25 years in Dorset, UK. Injury. 2004;35(5):462-6.
2. Park C, Ha YC, Jang S, Jang S, Yoon HK, Lee YK. The incidence and residual lifetime risk of osteoporosis-related fractures in Korea. J Bone Miner Metab. 2011;29(6):744-51.
3. Orbay JL. The treatment of unstable distal radius fractures with volar fixation. Hand Surg. 2000;5(2):103-12.
4. Chung KC, Shauver MJ, Birkmeyer JD. Trends in the United States in the treatment of distal radial fractures in the elderly. J Bone Joint Surg Am. 2009;91(8):1868-73.
5. Lim ST, Yeom JS, Lee CH, Lee YH, Chang CB, Baek GH. Development of anatomical plating system for treatment of distal radius fractures. J Korean Soc Surg Hand. 2007;12(3):95-104.
6. Arora R, Lutz M, Hennerbichler A, Krappinger D, Espen D, Gabl M. Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate. J Orthop Trauma. 2007;21(5):316-22.
7. Gartland JJ Jr, Werley CW. Evaluation of healed Colles' fractures. J Bone Joint Surg Am. 1951;33(4):895-907.
8. Sarmiento A, Pratt GW, Berry NC, Sinclair WF. Colles' fractures: functional bracing in supination. J Bone Joint Surg Am. 1975;57(3):311-7.
9. Drobetz H, Kutscha-Lissberg E. Osteosynthesis of distal radial fractures with a volar locking screw plate system. Int Orthop. 2003;27(1):1-6.
10. Kamano M, Koshimune M, Toyama M, Kazuki K. Palmar plating system for Colles' fractures: a preliminary report. J Hand Surg Am. 2005;30(4):750-5.
11. Wong TC, Yeung CC, Chiu Y, Yeung SH, Ip FK. Palmar fixation of dorsally displaced distal radius fractures using locking plates with Smartlock locking screws. J Hand Surg Eur Vol. 2009;34(2):173-8.
12. Figl M, Weninger P, Liska M, Hofbauer M, Leixnering M. Volar fixed-angle plate osteosynthesis of unstable distal radius fractures: 12 months results. Arch Orthop Trauma Surg. 2009;129(5):661-9.
13. Minegishi H, Dohi O, An S, Sato H. Treatment of unstable distal radius fractures with the volar locking plate. Ups J Med Sci. 2011;116(4):280-4.
14. Lattmann T, Meier C, Dietrich M, Forberger J, Platz A. Results of volar locking plate osteosynthesis for distal radial fractures. J Trauma. 2011;70(6):1510-8.
15. Osada D, Kamei S, Masuzaki K, Takai M, Kameda M, Tamai K. Prospective study of distal radius fractures treated with a volar locking plate system. J Hand Surg Am. 2008;33(5):691-700.
16. Yasuda M, Ando Y. A new variable angled locking volar plate system for Colles' fracture: outcome study and time-course improvement of objective clinical variables. Hand Surg. 2009;14(2-3):93-8.
17. Matschke S, Marent-Huber M, Audige L, Wentzensen A; LCP Study Group. The surgical treatment of unstable distal radius fractures by angle stable implants: a multicenter prospective study. J Orthop Trauma. 2011;25(5):312-7.
18. Kim JY, Kang HJ, Yi Y. Multiple flexor tendon injuries after

volar plate fixation for distal radius fracture: two cases report. J Korean Soc Surg Hand. 2012;17(1):47-51.

19. Lee SJ, Bae JY, Cho HJ, Suh KT. Short term results of AO type C fractures of the distal radius treated with volar locking plating system. J Korean Soc Surg Hand. 2011;16(4): 191-7.

20. Lee SU, Park IJ, Kim HM, Lee JY, Yoo HH, Jeong C. K-wire fixation supplemented with external fixator versus volar locked plating for unstable fractures of the distal radius. J Korean Soc Surg Hand. 2010;15(4):157-63.