Genij Ortopedii. 2022. Vol. 28, no. 3. P. 322-327.

Original article

https://doi.org/10.18019/1028-4427-2022-28-3-322-327

Comparison between volar plating and external fixation augmented by Kirshner wires in comminuted distal radial fractures

Usama F. Attia✉, Mohamed A. El-Soufy, Tarek A.E. El-Hewala, Mohamed A. Abdelrazek

Orthopedic Surgery Department, Faculty of Medicine, Zagazig University, Egypt

Corresponding author: Usama F. Attia, usamafawzy19@yahoo.com

Abstract

Background Volar locking plate (VLP) has gained the most popularity in the treatment of distal radius fractures due to its superior biomechanical property. In contrast, external fixation (EF) is not so extensively used. The aim of this study was to find what procedure is better in the management and achieves favorable outcomes in patients with comminuted distal radial fractures. **Patient and methods** This study included 30 patients with distal radial fractures AO types A3, C2, C3 in which 15 ubjects were managed with open reduction and internal fixation by volar plate, and another 15 were managed with external fixation augmented by K-wires. The minimum duration of follow-up in our study was six months. **Results** Patients treated with external fixation augmented by K-wires had grip strength range 15-27, patients treated with volar plating had grip strength range 8-27. There was no significant statistical difference between 2 groups regarding extension. In Group A Mann-Whitney test revealed that Gartland-Werely score had negative correlation with affected hand. In Group B the correlation was positive with AO/OTA classification only and negative with affected hand and ulnar styloid fracture but also not statistically significant between Quick-DASH score with affected hand, AO/OTA classification and ulnar styloid fracture. **Conclusion** Both volar plating and external fixation augmented by K-wires are treatment choices for distal radius fractures. Whereas external fixation maintains a significant role in the treatment of distal radius fractures, ORIF with locked volar plating has changed the way many surgeons treat certain types of distal radius fractures.

Keywords: Volar Plating, External Fixation, Radial Fractures, DASH score

For citation: Attia U.F., El-Soufy, M.A.A., El-Hewala, T.A.E., Abdelrazek M.A. Comparison between volar plating and external fixation augmented by Kirschner wires in comminuted distal radial fractures. Genij Ortopedii, 2022, vol. 28, no 3, pp. 322-327. https://doi.org/10.18019/1028-4427-2022-28-3-322-327

INTRODUCTION

Distal radius fractures comprise 16 % of all fractures that are treated surgically. Despite the high prevalence of this kind of fracture, there is still no consensus concerning the preferred way to manage this type of fracture. Another issue of significant concern is that the approach to dealing with intra-articular fractures of the distal radius remains even more challenging to treat than unstable extra-articular fractures [1]. Distal radius fractures are of the most prevalent fractures in the middle-aged and elderly people [2, 3], so such fractures are an important concern. There has been an especially sharp increase in their incidence among women older than 40, and this brings into sharper focus the possible consequence of estrogen withdrawal and loss of bone density [4].

Unfortunately, such fractures are difficult to reduce and stabilize, so they are prone to malunion [5]. Also, they are prone to result in malfunctioning of the wrist and hand (which depends on radius alignment and the positioning of the carpal and ulnar joints) [6]. Such fractures can cause deterioration of the long-term functional outcome if they are not reduced well and in an anatomically correct manner [7, 8].

During the past 10 years, volar locking plate (VLP) has gained the most popularity in the treatment of distal radius fractures due to its superior biomechanical property [9, 10]. In contrast, external fixation (EF) is not so extensively used, but was preferred by a number of surgeons due to its easy application, improved reduction by ligamentotaxis, no need of a secondary procedure, and the acceptable results. However, the higher complication rate should be a concern, including pin-tract infection, loss of reduction, the sensory radial nerve injury, and complex regional pain syndrome [11, 12].

Randomized controlled trials (RCTs) or cohort studies have demonstrated the advantages of volar locked plating over external fixation for treatment of all types of distal radius fractures, especially at early postoperative period [13, 14]. As for AO type C2/C3 fractures, the reported results varied and were even contradictory, treated either by volar locked plating or external fixation alone, or combined. However, as far as we know, data on the direct comparison of clinical or radiographic outcomes for treatment of such fractures were favorable [15–17]. The aim of the present study is to find what procedure is better in their management and achieves favorable outcomes in patients with comminuted distal radial fractures.

PATIENTS AND METHODS

A prospective comparative study was conducted involving 30 patients with distal radial fractures AO type A3,C2,C3 in which 15 subjects were treated with open reduction and internal fixation by volar plate and another 15 with external fixation augmented by K-wires. All patients fulfilled the inclusion criteria and completed at least a 6-month follow-up period. Participants were numbered from 1 to 30 and categorized into group A (volar plating) and group B (external fixation augmented by K-wires). Standard informed consents were taken from every patient.

Inclusion criteria

Patients with unilateral acute closed (> 14 days of occurance) comminuted extra-articular distal radius fractures type A3 according to AO/OTA classification; unilateral acute closed comminuted intra-articular distal radius fractures type C2 or C3 according to AO/OTA classification; surgically fit patients.

Exclusion criteria

Patients with old fractures, concomitant fracture at the same injured limb, systematic skeletal diseases (e.g. hyperparathyroidism) or local disorder (e.g. tumors, Paget disease, or rheumatoid arthritis); surgically unfit patients;

Patients with associated vascular injury, open fractures, contaminated fractures, pathological fractures and patients with compartmental syndrome.

I. Preoperative evaluation

Patients were evaluated by history taking, physical examination, investigations, consent taking and images. AO classification was used in this study. Standard examination of the hand was performed to assess skin condition, functions of muscles, tendons and nerves; and hand grip and fingers movement. Routine preoperativecomplete blood picture, liver and kidney functions were studied. Anteropsterior and lateral views of the affected wrist showed the site of fracture, articular extension, comminution, associated fractures (ulnar styloid, carpals, metacarpals), and disrupted distal radioulnar joint. Elbow X-ray was taken to detect higher level fractures or dislocation. To detect the site and degree of articular comminution (scaphoid and lunate fossae), CT was routinely ordered in all cases; however, twelve out of all cases could not do CT due to unavailabity of this service at the time of investigation.

II. Surgical Management

General or regional anaesthesia. The patient was positioned supine and the forearm placed on a hand table.

Group A: Volar plating, modified Henry approach

The modified Henry approach uses the plane between flexor carpi radialis tendon and the radial artery. Longitudinal incision is made over the flexor carpi radialis (FCR) tendon. The flexor pollicis longus muscle belly is bluntly swept to the ulnar side The pronator quadratus is mobilized by releasing its distal and lateral borders with an L-shaped incision then exposing the fracture site. After exposure and refreshing of the fracture site, the fracture was reduced and provisionally fixed under C-arm control using K-wires. In intra-articular fractures, large fragments were manipulated, reduced and preliminary fixed by wires. The plate should be positioned on the distal radius proximal to the Watershed line. A screw is inserted in the oval non-locking hole of the plate which permits fine adjustment of the plate position either proximally or distally (Fig. 1). The plate is applied to bone and a 3.5-mm cortical screw is inserted into the oblong hole in the shaft. Prior to fully seating the screw, the plate may be translated distally or proximally as needed. In polyaxial fixation, after achievement of the optimal plate position and insertion of a screw into the oblong hole of the plate in the shaft of the bone, the plate was fixed to bone distally beginning with the most ulnar screw using the funnel-shaped end of the VA-LCP drill sleeve at the desired angle.

Group B: External fixation

We used an external fixator with pinning by K-wires to retain the reduced position of the distal radius by adequate reduction of the distal radius fracture using traction to restore the radial height. Percutaneous K-wires were inserted (while an assistant maintaining the reduction). One or two wires inserted from the radial styloid directed proximally toward the opposite intact cortex. Another wire was added to maintain the distal radioulnar joint (DRUJ) and reduction of DRUJ was done by supination or pronation of the forearm depending on the direction of dislocation in case of associated distal radioulnar joint dislocation. The proximal fixator pin sites were exposed with a small incision made via a mini-open technique on the dorsal radial aspect of the radial shaft. The pins were placed in the radial shaft after predrilling and using a soft-tissue protector. The skin was then closed around the proximal pin sites. Application of the distal Schanz screw was done dorsoradially near the base of the metacarpal 40-60 degrees in reference to the horizontal plane (Fig. 2).

III. Follow-up

Radiological parameters of the distal radius on the operated side of both groups were followed up. The patients were advised to clean pin tracts with saline daily and encouraged to perform shoulder and elbow mobilization exercises.

Statistical analysis

Data were entered to the Statistical Package for Social Science (IBM SPSS) version 23. The comparison between groups regarding qualitative data was done by using Chi-square test and/or Fisher exact test .The comparison between two groups regarding quantitative data was done using Independent t-test while with non parametric distribution was done using Mann-Whitney test. One Way ANOVA test, Kruskall-Wallis test and Spearman correlation coefficients were used to assess the correlation between two quantitative

parameters in the same group. The confidence interval was set to 95 % and the margin of error accepted was set to 5 %. So, the p-value was considered significant as the following: p-value > 0.05: Non significant (NS), p-value < 0.05: Significant (S); p-value < 0.01: Highly Significant (HS).

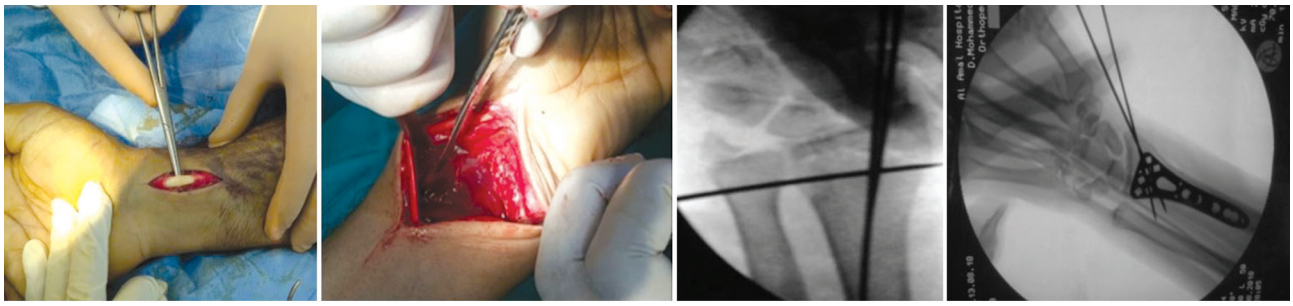

Fig. 1 Modified Henry approach showing: (a) identification of flexor carpi radialis tendon; (b) pronator quadratus exposed and an L-shaped incision is made to elevate it; (c) preliminary fixation of large articular fragments and (d) plate adjustment on the volar surface of lunate facet

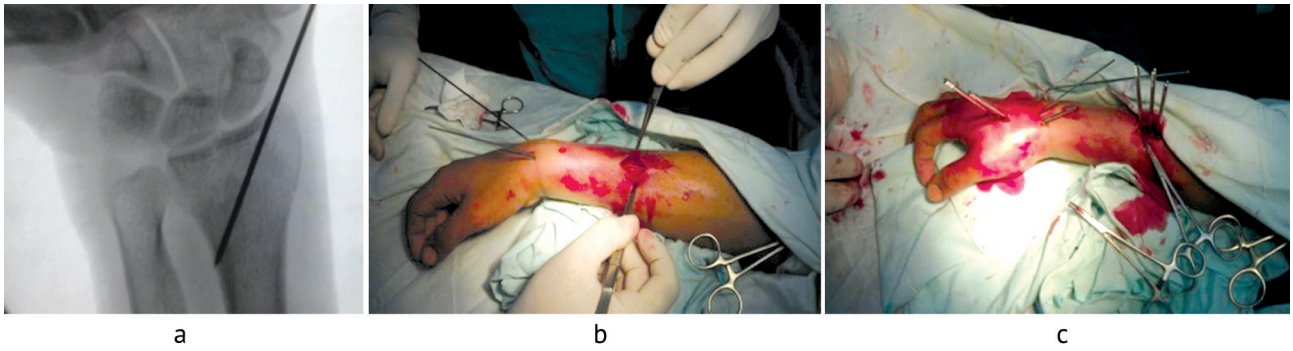

Fig. 2 External fixator with pinning by K-wires showing: (a) K-wire inserted from the radial styloid; (b) skin incision to introduce the proximal Schanz screw and (c) insertion of the distal Schanz screw

RESULTS

This study included 30 patients with a mean age of 40 years (range, 22-75 years) at the time of surgery. The group of patients included 22 males and 8 females. Twelve males and 3 females in Group A and ten males and five females for Group B. In Group A, 9 patients were smokers and 6 patients were non-smokers, while in Group A 8 patients were smokers and 7 patients were non-smokers. In Group A, there was 1 diabetic patient (6.7 %) and 2 hypertensive cardiac (13.3 %) patients; in Group B, there was 1 diabetic (6.7 %) and 4 hypertensive (26.7 %) patients. Fourteen patients had right-side fractures, 16 patients had left-side fractures, 29 patients with the right dominant hand and one with the left dominant hand (Table 1).

All patients were classified according AO classification as the following; group A: Type C2: 8 patients (53.3 %); Type C3: 7 patients (46.7 %); Type A3: 0 patients (0.0 %); and group B: Type C2: 7 patients (46.7 %); Type C3: 7 patients (46.7 %); Type A3: 1 patients (6.7 %) (Fig. 3).

Patients treated with external fixation augmented by K-wires had grip strength within the range of 15-27 kg. Patients treated with volar plating had grip strength within the range of 8-27 kg (Fig. 4). There was no significant statistical difference between 2 groups regarding extension (p = 0.209).

Table 1

Relation output of demographic results between two groups

		Volar Plate group	Ex- Fix group
		N = 15	N = 15
Age	Mean ± SD	37.33 ± 10.43	42.33 ± 16.60
	Range	23–54	22–75
Age groups	Young age	5 (33.3 %)	4 (26.7 %)
	Middle age	10 (66.7 %)	9 (60.0 %)
	Old age	0 (0.0 %)	2 (13.3 %)
Sex	Female	3 (20.0 %)	5 (33.3 %)
	Male	12 (80.0 %)	10 (66.7 %)
Occupation	Active	13 (86.7 %)	9 (60.0 %)
	Sedentary	2 (13.3 %)	6 (40.0 %)
Smoking	No	6 (40.0 %)	7 (46.7 %)
	Yes	9 (60.0 %)	8 (53.3 %)
Medical history	No	13 (86.7 %)	11 (73.3 %)
	Yes	2 (13.3 %)	4 (26.7 %)
DM	No	14 (93.3 %)	14 (93.3 %)
	Yes	1 (6.7 %)	1 (6.7 %)
HTN	No	13 (86.7 %)	11 (73.3 %)
	Yes	2 (13.3 %)	4 (26.7 %)
Previous operation	No	15 (100.0 %)	15 (100.0 %)
	Yes	0 (0.0 %)	0 (0.0 %)
Dominance	Right	15 (100.0 %)	14 (93.3 %)
	Left	0 (0.0 %)	1 (6.7 %)

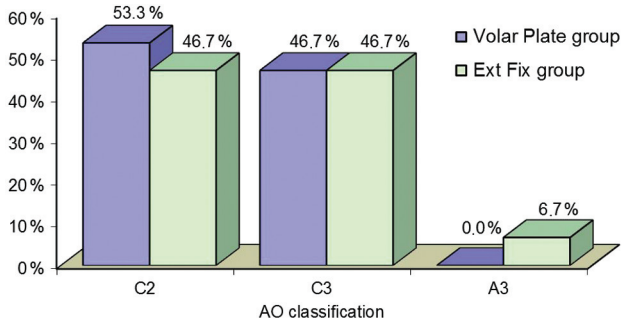

Fig. 3 Distribution of the patients regarding to AO classification

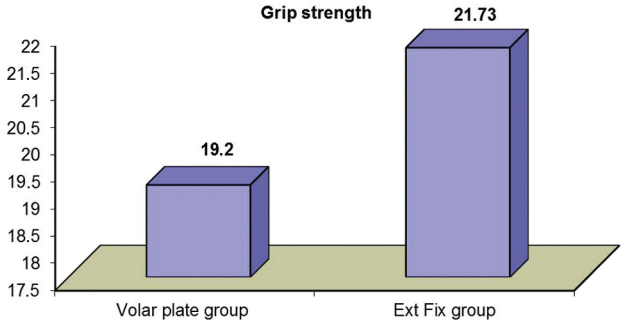

Fig. 4 Bar chart illustrating comparison of grip strength between two groups

In Group A, Mann-Whitney test revealed that Gartland-Werely score had negative correlation with the affected hand and AO/OTA classification with no statistical significance (Table 2). In Group B, the correlation was positive with AO/OTA classification only and negative with affected hand and ulnar styloid fracture but also not statistically significant between Quick-DASH score with affected hand, AO/OTA classification, and ulnar styloid fracture (Table 3).

Table 2

Correlation of Gartland-Werley score with affected hand, AO/OTA classification, and ulnar styloid fracture in group A

		Gartland-Werley		Test value	P-value
		Median (IQR)	Range		
Affected side	Right	3 (2–5)	0–6	-0.295	0.768
	Left	2 (1.5–4.5)	1–9		
AO	C2	2 (1.5–2.5)	0–5	-1.714	0.087
	C3	4 (2–6)	1–9		
Ulnar styloid fracture	No	3 (2–5)	1–9	-1.359	0.174
	Yes	2 (1.5–3)	0–6		

Table 3

Correlation of Gartland-Werley score with affected hand, AO/OTA classification, and ulnar styloid fracture in group B

		Gartland-Werley		Test value	P-value
		Median (IQR)	Range		
Affected side	Right	5 (2–5)	2–9	-0.896	0.370
	Left	3.5 (2–4.5)	2–6		
AO	C2	4 (2–5)	2–9	1.430	0.489
	C3	4 (2–5)	2–6		
Ulnar styloid fracture	No	2 (2–2)	2–2	-0.358	0.720
	Yes	4 (2–5)	2–5		

Spearman's test revealed that Gartland-Werley score had positive correlation with age, operative time and injury to treatment interval in group A. This correlation was statistically significant with age only (p = 0.019) (Table 4). This correlation was not statistically significant but the correlation between Gartland-Werley score and injury to treatment interval was negative in group B (Table 5).

Mann Whitney U test revealed that mean union time had negative correlation with postoperative complications in groups A and B. This negative correlation was statistically significant with pin-tract infection (p = 0.01) (Table 6, 7).

Table 4

Correlation of Gartland-Werley score with age, mean operative time , injury to treatment interval and articular stepoff in group A

	Gartland-Werley	
	Correlation coefficient (r)	P-value
Age	0.594*	0.019
Mean operative time (min.)	0.332	0.226
Injury to treatment interval (days)	0.230	0.410
Articular stepoff (mm)	0.166	0.555

Table 5

Correlation of Gartland-Werley score with mean operative time, injury to treatment interval and articular step-off in group B

	Gartland-Werley	
	Correlation coefficient (r)	P-value
Mean operative time (min)	0.137	0.627
Injury to treatment interval (days)	-0.321	0.243
Articular stepoff (mm)	-0.303	0.273

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant. r = Spearman correlation coefficient

Table 6

Correlation of mean union time with postoperative complications in group A

		Union (weeks)		Test value	P-value
		Mean ± SD	Range		
Complications	Not complicated	6.75 ± 1.16	5–8	0.064•	0.950
	Complicated	6.71 ± 0.95	6–8		
Stiffness	No	6.71 ± 1.07	5–8	-0.258•	0.800
	Yes	7 ± 0	7–7		
Carpal Tunnel Syndrome + screw perforation	No	6.69 ± 1.03	5–8	-0.380•	0.710
	Yes	7 ± 1.41	6–8		
Tendon rupture	No	6.79 ± 1.05	5–8	0.722•	0.483
	Yes	6 ± 0	6–6		
Scar hypertrophy	No	6.79 ± 1.05	5–8	0.722•	0.483
	Yes	6 ± 0	6–6		
Inflammation of surgical wound	No	6.79 ± 1.05	5–8	0.722•	0.483
	Yes	6 ± 0	6–6		
Delayed healing	No	6.64 ± 1.01	5–8	-1.300•	0.216
	Yes	8 ± 0	8–8		

P-value > 0.05 – Non significant; P-value < 0.05 – Significant; P-value < 0.01 – Highly significant; • – Independent t-test

Table 7

Correlation of mean union time with postoperative complications in group B

		Union (weeks)		Test value	P-value
		Mean ± SD	Range		
Complications	Not complicated	6.5 ± 1.07	5–8	-2.228•	0.044
	Complicated	8 ± 1.53	6–10		
Stiffness	No	6.92 ± 1.32	5–10	-2.059•	0.060
	Yes	9 ± 1.41	8–10		
Pin-tract infection	No	6.67 ± 0.98	5–8	-4.079•	0.001
	Yes	9.33 ± 1.15	8–10		
Tendon rupture	No	7.21 ± 1.53	5–10	0.135•	0.894
	Yes	7 ± 0	7–7		
Complex regional pain syndrome (CRPS)	No	7.15 ± 1.57	5–10	-0.299•	0.770
	Yes	7.5 ± 0.71	7–8		
Nerve injury	No	7.29 ± 1.49	5–10	0.834•	0.420
	Yes	6 ± 0	6–6		

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant •: Independent t-testt

DISCUSSION

Current treatment goals for fractures of the distal radius are centered on restoration of bony anatomy of the distal radius (radial inclination, radial length and volar tilt) with specific attention to the restoration of articular surfaces of the radiocarpal and radioulnar joints [20].

Most of the patients in our study were males. The percentage of males were 66.7 % in the external fixator group and 80 % in the volar plate group. This is similar to Duramaz et al. [21] reporting the percentage of males in the external fixator and volar plate groups 65.5 % and 60.7 %, respectively, and also to the study of Yu et al. [22] in which the percentage of males in the external fixator and volar plate groups were 56.5 % and 59.0 %, respectively. But this is different than the study of Rizzo et al. [23] in which most of patients were females, the ratios of females to males for the external fixator and volar plate groups were 8/6 and 25/6, respectively.

In this study, the mean age of the external fixator group was 42.33 years while of the volar plate group was 37.33. The age distribution between the two groups was not different. This is similar to Kreder et al. [11] study, in which the mean age in the external fixator group was 39 years and in the volar plate group was 40, and Xu et al. [24] study, in which the mean ages in the external fixator and volar plate groups were 41.8 years and 45.3, respectively. Generally, neither age nor gender distribution made a significant difference between the two groups, an observation that was similar to the results of Phandis et al. [25].

In this study, volar plate group patients had better functional outcomes in Quick DASH score (6.8 vs 9.1) when compared to external fixation group patients. And also Gartland-Werley score has better results in volar plate group (53.3 % excellent and 40 % good) than external fixation group (33.3 % excellent and 60 % good) but that did not differ significantly ($p > 0.05$) as mentioned by Richard et al. [26] in a retrospective cohort of 115 patients with AO type C2/C3 fractures demonstrated a better DASH score and more improved pronation/supination arc in VLP group at 12 postoperative months. Williksen et al. [27] compared volar plating (52 patients) and external fixation (59 patients) and reported that patients with volar locked plates had a higher Mayo wrist score (90 vs 85) and better supination (89° vs 85°) at 52 weeks compared to external fixation group.

In our study, volar plating group had an overall decreased incidence of complications compared with external fixation. Thus, seven cases had complications out of 15 patients treated by volar plating in comparison to nine cases treated by external fixation. These results are in concordance with most of the prior studies, which have tended to show less complications in patients treated with ORIF as in Abramo et al. [28] study who reported 14 complications in 26 patients treated with ORIF and 20 complications in 24 patients treated with external fixation. Grewal et al. [29] reported 7 complications in 29 patients treated with ORIF and 8 complications in 33 patients treated with external fixation. Karantana et al. [30] reported 16 complications in 66 patients treated with ORIF and 27 complications in 64 patients treated with external fixation. On the other hand, some studies showed higher incidence of complications in ORIF patients than in external fixation patients, which is different than the results of the current study, as in Mellstrand et al. [31] study which reported 35 complications in 69 patients treated with ORIF and 29 complications in 65 patients treated with external fixation.

CONCLUSION

Both volar plating and external fixation augmented by K-wires are treatment choices for distal radius fractures. Whereas external fixation maintains a significant role in the treatment of distal radius fractures, ORIF with locked volar plating has changed the way many surgeons treat certain types of distal radius fractures. Volar plating had better performance in initiating early wrist motion and some radiological outcomes like maintaining the radial head height and improving articular congurance.

REFERENCES

1. Cooney W.P. 3rd, Linscheid R.L., Dobyns J.H. External pin fixation for unstable Colles' fractures. *J. Bone Joint Surg. Am*., 1979, vol. 61, no. 6A, pp. 840-845.
2. Arora R., Lutz M., Deml C., Krappinger D., Haug L., Gabl M. A prospective randomized trial comparing nonoperative treatment with volar locking plate fixation for displaced and unstable distal radial fractures in patients sixty-five years of age and older. *J. Bone Joint Surg. Am*., 2011, vol. 93, no. 23, pp. 2146-2153. DOI: 10.2106/JBJS.J.01597.
3. Arora R., Gabl M., Erhart S., Schmidle G., Dallapozza C., Lutz M. Aspects of Current Management of Distal Radius Fractures in the Elderly Individuals. *Geriatr. Orthop. Surg. Rehabil*., 2011, vol. 2, no. 5-6, pp. 187-194. DOI: 10.1177/2151458511426874.
4. Plate J.F., Gaffney D.L., Emory C.L., Mannava S., Smith B.P., Koman L.A., Wiesler E.R., Li Z. Randomized comparison of volar locking plates and intramedullary nails for unstable distal radius fractures. *J. Hand Surg. Am*., 2015, vol. 40, no. 6, pp. 1095- 1101. DOI: 10.1016/j.jhsa.2015.02.014.
5. Xia S., Lu Y., Wang H., Wu Z., Wang Z. Open reduction and internal fixation with conventional plate via L-shaped lateral approach versus internal fixation with percutaneous plate via a sinus tarsi approach for calcaneal fractures – a randomized controlled trial. *Int. J. Surg*., 2014, vol. 12, no. 5, pp. 475-480. DOI: 10.1016/j.ijsu.2014.03.001.
6. 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, vol. 33, no. 5, pp. 691-700. DOI: 10.1016/j.jhsa.2008.01.024.
7. DeNoble P.H., Marshall A.C., Barron O.A., Catalano L.W. 3rd, Glickel S.Z. Malpractice in distal radius fracture management: an analysis of closed claims. *J. Hand Surg. Am*., 2014, vol. 39, no. 8, pp. 1480-1488. DOI: 10.1016/j.jhsa.2014.02.019.
8. Chung K.C., Shauver M.J., Birkmeyer J.D. Trends in the United States in the treatment of distal radial fractures in the elderly. *J. Bone Joint Surg. Am*., 2009, vol. 91, no. 8, pp. 1868-1873. DOI: 10.2106/JBJS.H.01297.
9. Bentohami A., de Burlet K., de Korte N., van den Bekerom M.P., Goslings J.C., Schep N.W. Complications following volar locking plate fixation for distal radial fractures: a systematic review. *J. Hand Surg. Eur*. Vol. 2014, vol. 39, no. 7, pp. 745-754. DOI: .10.1177/1753193413511936
10. Disseldorp D.J., Hannemann P.F., Poeze M., Brink P.R. Dorsal or Volar Plate Fixation of the Distal Radius: Does the Complication Rate Help Us to Choose? *J. Wrist Surg*., 2016, vol. 5, no. 3, pp. 202-210. DOI: 10.1055/s-0036-1571842
11. Kreder H.J., Hanel D.P., Agel J., McKee M., Schemitsch E.H., Trumble T.E., Stephen D. Indirect reduction and percutaneous fixation versus open reduction and internal fixation for displaced intra-articular fractures of the distal radius: a randomised, controlled trial. *J. Bone Joint Surg. Br*., 2005, vol. 87, no. 6, pp. 829-836. DOI: 10.1302/0301-620X.87B6.15539.
12. Reynolds P.R., Beredjiklian P.K. External fixation of distal radius fractures: do benefits outweigh complications? Curr. Opin. Orthop., 2001, vol. 12, no. 4, pp. 286-289. DOI: 10.1097/00001433-200108000-00004.
13. Fu Q., Zhu L., Yang P., Chen A. Volar Locking Plate versus External Fixation for Distal Radius Fractures: A Meta-analysis of Randomized Controlled Trials. *Indian J .Orthop*., 2018, vol. 52, no. 6, pp. 602-610. DOI: 10.4103/ortho.IJOrtho_601_16.
14. Walenkamp M.M., Bentohami A., Beerekamp M.S., Peters R.W., van der Heiden R., Goslings J.C., Schep N.W. Functional outcome in patients with unstable distal radius fractures, volar locking plate versus external fixation: a meta-analysis. *Strategies Trauma Limb Reconstr*., 2013, vol. 8, no. 2, pp. 67-75. DOI: 10.1007/s11751-013-0169-4.
15. Rein S., Schikore H., Schneiders W., Amlang M., Zwipp H. Results of dorsal or volar plate fixation of AO type C3 distal radius fractures: a retrospective study. *J. Hand Surg. Am*., 2007, vol. 32, no. 7, pp. 954-961. DOI: 10.1016/j.jhsa.2007.05.008.
16. Chou Y.C., Chen A.C., Chen C.Y., Hsu Y.H., Wu C.C. Dorsal and volar 2.4-mm titanium locking plate fixation for AO type C3 dorsally comminuted distal radius fractures. *J. Hand Surg. Am*., 2011, vol. 36, no. 6, pp. 974-981. DOI: 10.1016/j.jhsa.2011.02.024.
17. Earp B.E., Foster B., Blazar P.E. The use of a single volar locking plate for AO C3-type distal radius fractures. *Hand* (N Y), 2015, vol. 10, no. 4, pp. 649-653. DOI: 10.1007/s11552-015-9757-8.
18. Deng Y.S., Zhang Q.L., Wang Q.G., Ji F., Cai X.B., Tang H., Wu J.H., Wang F., Tang X.R., Xie Y., Guan Z.M., Yang C.W., Wang Q. [Combination of volar buttress plate with external fixatior for the distal radial fractures of type C3 caused by high-energy injuries]. *Zhongguo Gu Shang*., 2009, vol. 22, no. 7, pp. 543-546. (in Chinese)
19. Cao J., Shen G., Lu J., et al. Volar locking compression plate combined with external fixation for treatment of AO type C3 distal radius fractures. *Clin. Med. China*, 2013, vol. 29, pp. 118-120.
20. Gliatis J.D., Plessas S.J., Davis T.R. Outcome of distal radial fractures in young adults. *Hand Surg. Br*., 2000, vol. 25, no. 6, pp. 535-543. DOI: 10.1054/jhsb.2000.0373.
21. Duramaz A., Bilgili M.G., Karaali E., Bayram B., Ziroğlu N., Kural C. Volar locking plate versus K-wire-supported external fixation in the treatment of AO/ASIF type C distal radius fractures: a comparison of functional and radiological outcomes. *Ulus. Travma Acil. Cerrahi Derg*., 2018, vol. 24, no. 3, pp. 255-262. DOI: 10.5505/tjtes.2017.35837.
22. Yu X., Yu Y., Shao X., Bai Y., Zhou T. Volar locking plate versus external fixation with optional additional K-wire for treatment of AO type C2/C3 fractures: a retrospective comparative study. *J. Orthop. Surg. Res*., 2019, vol. 14, no. 1, pp. 271. DOI: 10.1186/s13018-019-1309-4.
23. Rizzo M., Katt B.A., Carothers J.T. Comparison of locked volar plating versus pinning and external fixation in the treatment of unstable intraarticular distal radius fractures. *Hand* (N Y), 2008, vol. 3, no. 2, pp. 111-117. DOI: 10.1007/s11552-007-9080-0.
24. Xu G.G., Chan S.P., Puhaindran M.E., Chew W.Y. Prospective randomised study of intra-articular fractures of the distal radius: comparison between external fixation and plate fixation. *Ann. Acad. Med. Singap*., 2009, vol. 38, no. 7, pp. 600-606.
25. Phadnis J., Trompeter A., Gallagher K., Bradshaw L., Elliott D.S., Newman K.J. Mid-term functional outcome after the internal fixation of distal radius fractures. *J. Orthop. Surg. Res*., 2012, vol. 7, pp. 4. DOI: 10.1186/1749-799X-7-4.
26. Richard M.J., Wartinbee D.A., Riboh J., Miller M., Leversedge F.J., Ruch D.S. Analysis of the complications of palmar plating versus external fixation for fractures of the distal radius. *J. Hand Surg. Am*., 2011, vol. 36, no. 10, pp. 1614-1620. DOI: 10.1016/j.jhsa.2011.06.030.
27. Williksen J.H., Frihagen F., Hellund J.C., Kvernmo H.D., Husby T. Volar locking plates versus external fixation and adjuvant pin fixation in unstable distal radius fractures: a randomized, controlled study. *J. Hand Surg. Am*., 2013, vol. 38, no. 8, pp. 1469-1476. DOI: 10.1016/j.jhsa.2013.04.039.
28. Abramo A., Kopylov P., Geijer M., Tägil M. Open reduction and internal fixation compared to closed reduction and external fixation in distal radial fractures: a randomized study of 50 patients. *Acta Orthop*., 2009, vol. 80, no. 4, pp. 478-485. DOI: 10.3109/17453670903171875.
29. Grewal R., Perey B., Wilmink M., Stothers K. A randomized prospective study on the treatment of intra-articular distal radius fractures: open reduction and internal fixation with dorsal plating versus mini open reduction, percutaneous fixation, and external fixation. *J. Hand Surg. Am*., 2005, vol. 30, no. 4, pp. 764-772. DOI: 10.1016/j.jhsa.2005.04.019.
30. Karantana A., Downing N.D., Forward D.P., Hatton M., Taylor A.M., Scammell B.E., Moran C.G., Davis T.R. Surgical treatment of distal radial fractures with a volar locking plate versus conventional percutaneous methods: a randomized controlled trial. *J. Bone Joint Surg. Am*., 2013, vol. 95, no. 19, pp. 1737-1744. DOI: 10.2106/JBJS.L.00232.
31. Mellstrand Navarro C., Ahrengart L., Törnqvist H., Ponzer S. Volar Locking Plate or External Fixation with Optional Addition of K-Wires for Dorsally Displaced Distal Radius Fractures: A Randomized Controlled Study. *J. Orthop. Trauma*, 2016, vol. 30, no. 4, pp. 217-224. DOI: 10.1097/BOT.0000000000000519.

No conflict of interest.