ORIGINAL ARTICLE

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

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ABSTRACT

BACKGROUND: The aim of this study was to compare the functional and radiological outcomes of K-wire-supported bridging external fixation (KW-EF) and volar locking plate (VLP) in the treatment of comminuted intra-articular distal radius fractures.

METHODS: Patients treated for complex intra-articular distal radius fractures between February 2010 and April 2013 were retrospectively investigated. A total of 114 patients (42 females and 72 males) with a mean age of 44.9±15.4 (range: 18–86) years were evaluated. Wrist ranges of motion were measured using a universal goniometer, and hand grip strength was determined using hand dynamometers. The results were evaluated with Gartland–Werley score. QuickDASH questionnaire was administered in subjective functional assessment. Radiological evaluations were performed, with wrist radiographs obtained on the 3rd month and 2nd year.

RESULTS: Wrist flexion, extension, pronation, and supination were all significantly better in the VLP group than in the KW-EF group at last control (p=0.001). Gartland–Werley, QuickDASH, and Visual Analog Scale were significantly better in the VLP than group than in the KW-EF group (p=0.003, p=0.003, and p=0.001, respectively). At the last follow-up, loss of grip strength compared with that on the uninjured side was 4% in the VLP group and 7% in the KW-EF group.

CONCLUSION: VLP is a safe method with low complication rates. It is superior to KW-EF as it facilitates early return to daily activities and shows better functional and radiological outcomes in the 2nd year of treatment.

Keywords: Bridging external fixation; functional outcomes; intra-articular distal radius fracture; volar locking plate,

INTRODUCTION

Distal radius fractures are the most common upper extremity injuries treated by trauma surgeons and constitute 17% of all fractures.[1] Intra-articular distal radius fractures represent one-sixth of all fractures treated in emergency departments.[2] In these types of fractures, the main aims of treatment are to provide and resume the anatomical restoration of joint surfaces, early mobilization, and better functional results; to avoid degenerative changes in future; and to provide stability allowing professional and other activities in all age groups.[3] However, the best treatment modality is still controversial.[4,5] Displaced intra-articular fractures are unstable, and in general, they are treated with some different methods such as external fixation (EF) and volar locking plate (VLP). Although EF may not always provide anatomical reduction and may cause residual instability and subsequent displacement, it is still in use in the traditional treatment of unstable intra-articular fractures.[6] Although this technique seems successful, some complications have been reported including stiffness in

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fingers, pin tract infections, loss of reduction, and radial sensory neuropathy.[7] In the last two decades, VLP has gained popularity in the anatomical restoration of the wrist joint as it results in high stability, early motion, and low complication rates in osteoporotic bones.[8] However, very small or comminuted distal articular parts may not allow open reduction internal fixation (ORIF). Moreover, this technique may also have some complications such as tendon irritation and rupture, superficial and deep infections, delays in wound healing, and loss of fixation in complex fractures.[9]

In this retrospective study, we aimed to compare the functional and radiological outcomes of K-wire-supported bridging EF (KW-EF) and VLP in the treatment of unstable intra-articular distal radius fractures. Our hypothesis is that VLP will have better functional and radiological outcomes than bridging EF in the treatment of unstable intra-articular distal radius fractures.

MATERIALS AND METHODS

After approval was obtained from the local ethics committee, patients treated for complex intra-articular distal radius fractures between February 2010 and April 2013 were retrospectively investigated. Patients aged >18 years, with unilateral complete displaced intra-articular distal radius fractures, with closed fractures, treated in the first 2 weeks after injury, and followed up for at least 2 years, and who had no dysfunction before the injury were included in the study. Patients with bilateral fractures or accompanying other fractures on the injured extremity (except ulnar styloid process) or open fractures, treated with methods other than VLP or KW-EF, with a previous history of injury in fractured wrist, with fracture history more than 2 weeks ago, with medical contraindications, and with accompanying extremity fractures or head injuries were excluded. Only C1, C2, and C3 fractures according to the AO/ASIF classification system were included in the study.[10] Among 136 patients who met the inclusion criteria, 22 were excluded due to loss to follow-up, inaccessibility owing to address change, or non-attendance to the control. A total of 114 patients were evaluated in the study. Fifty-six patients treated with VLP and 58 patients treated with KW-EF were functionally and radiologically evaluated. All surgical procedures were performed by the same surgeon with the standard protocol under general or regional anesthesia. In the VLP group, the standard volar approach was performed with the longitudinal incision. Two different plates were preferred for fixation: 2.5-mm distal radius plates (TST, Istanbul, Turkey) and 2.4 LCP distal radius systems (Synthes, Oberdorf, Switzerland) (Figs. 1 and 2). All patients were splinted below the elbow for 2 weeks. Active finger exercises were started on postoperative day 1. Dressings and sutures were removed on postoperative day 15. The plaster splint was also removed, and another removable splint that allows active rehabilitation was inserted for 15 days. In the KW-EF group, alignment was achieved with manual traction in all patients, and the closed reduction was performed. Uni-planar bridging EF system (Tasarım-Med, Istanbul, Turkey) was used for the fixation. Pins and the connection rod were joined to each other and tightened while the wrist was ulnar deviated at 15° (Figs. 3 and 4). Additionally, one 1.5-mm subchondral K-wire was used for the fixation of the articular parts. Arthrotomy was not performed. All patients were splinted below the elbow for 1 week. Finger movements were allowed on postoperative day 1. In all patients, KW-EF was removed after 6–8 weeks (mean: 7.6 weeks) in the outpatient clinic. Wrist joint movements were started after the removal of the splint in the VLP group and after the removal of the fixator in the KW-EF group.

In last controls, all patients were clinical and functionally and radiologically evaluated. The objective functional evaluation was performed with the range of motion (ROM) and grip strength. Wrist ROMs of all patients were performed using

Figure 1. A 59-year-old female was admitted for falling while standing. **(a)** Displaced distal radius fracture seen in standard wrist radiographs. **(b)** Communited, intra-articular displaced distal radius fracture seen in axial, coronal, and sagittal CT scans.

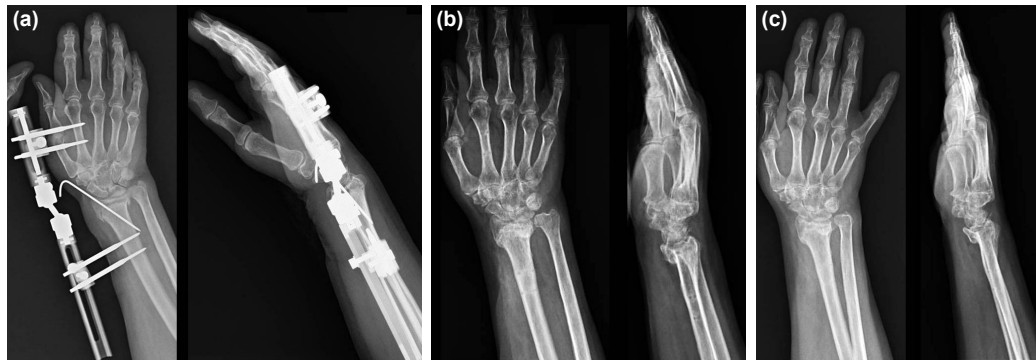

Figure 2. Radiological evaluation of the patient after the operation. **(a)** Two-planned radiographs obtained on the first day after closed reduction and external fixation supported with a K-wire. **(b)** Fracture healing on standard wrist radiographs obtained 3 months after operation. **(c)** Standard two-sided wrist radiographs obtained 2 years after treatment.

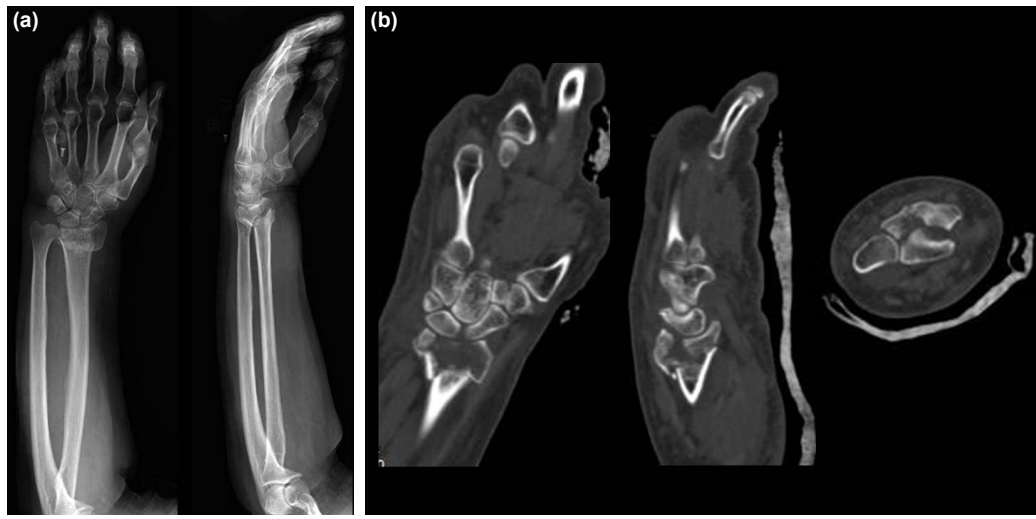

Figure 3. A 56-year-old male patient was admitted for falling from the stairs. **(a)** Distal radius displaced fracture extending toward distal radioulnar joint seen on standard wrist radiographs. **(b)** Metaphyseal impaction and comminuted, intra-articular displaced distal radius fracture seen in axial, coronal, and sagittal computed tomographic scans.

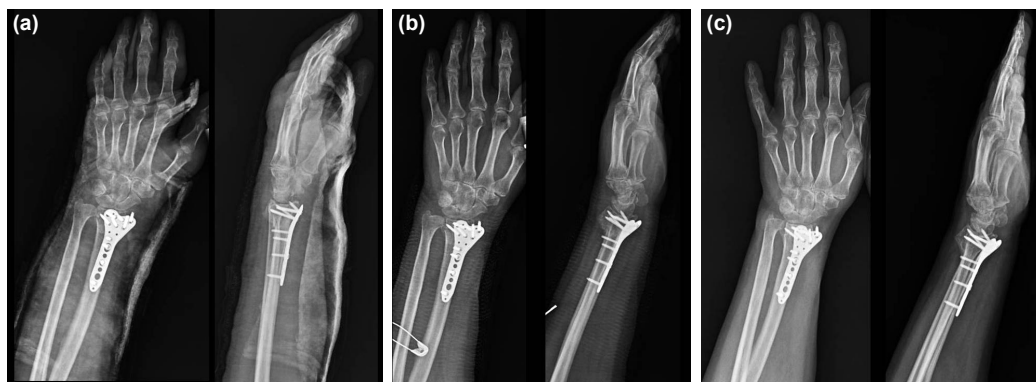

Figure 4. Radiological evaluation of the patient after the operation. **(a)** Two-planned radiographs obtained on the first day after open reduction and internal fixation with volar locking plate. **(b)** Fracture healing on standard wrist radiographs obtained 3 months after the operation. **(c)** Two-planned radiographs obtained 2 years after treatment.

a universal goniometer. Hand grip strength was measured using Jamar dynamometers (Jamar, Preston, USA) while the elbow was at 90° flexion and forearm was on neutral rotation. Grip strength was compared between the injured and uninjured side, and the difference was defined as a percentage. The subjective functional evaluation was performed with Gartland–Werley score of 20 points (excellent: 0–2, good: 3–8, fair: 9–20, and poor: >20), Visual Analog Scale (VAS)

of 10 points for pain (0: no pain, 10: widespread pain), and summarized disabilities of the arm, shoulder, and hand questionnaire (QuickDASH) Turkish version.[11] For radiological evaluations, radial height, palmar tilt, radial inclination, ulnar variance, and articular step-off were measured with the standard anteroposterior and lateral radiographs. The presence of arthritic changes was evaluated with Jupiter criteria on last radiographs.[12] Patients were evaluated for postoperative complications such as infection, loss of reduction, tendon injuries, neuropathy, implant failure, and complex regional pain syndrome (CRPS) in all controls. The follow-up period was at least 2 years with a mean of 34.3±9.6 months (range: 24–58 months).

Statistical Analysis

Statistical analyses were performed with Number Cruncher Statistical System (NCSS) 2007 (Kaysville, Utah, USA) program. In the evaluation of data, together with the descriptive statistical methods (mean, standard deviation, median, frequency, ratio, and minimum, maximum); in comparison of quantitative data between two groups with normal distribution Student's t-test and in comparison of parameters between two groups with abnormal distribution Mann–Whitney U test were performed. In a comparison of qualitative data, Pearson's chi-squared test, Fisher–Freeman–Halton test and Yates' Continuity Correction test (Yates corrected chi-square) were performed. A p-value of <0.05 was considered significant. Some parameters were statistically significant at an advanced level. A p-value of <0.001 was used to demonstrate advanced statistical significance.

RESULTS

Forty-two patients (36.8%) were female, and 72 (63.2%) were male with a mean age of 44.9±15.4 (range: 18–86) years. There was no statistically significant difference between the VLP and KW-EF groups regarding age, sex, preoperative period, and follow-up periods (p>0.05). There was no statistically significant difference between groups regarding fracture side, dominant side fracture ratio, trauma mechanism, and fracture type (p>0.05) (Table 1). In functional evaluation at last control, flexion, extension, pronation, and supination were all significantly better in the VLP group than in the KW-EF group (p=0.001, p=0.001, p=0.001, and p=0.001, respectively) while ulnar deviation was significantly lower and radial deviation was significantly higher (p=0.001 and p=0.001, respectively). Palmar tilt, radial height, and radial inclination were determined as significantly lower in the VLP group than in the KW-EF group in radiological evaluation at postoperative month 3 (p=0.001, p=0.001, and p=0.001, respectively). However, there was not any significant difference between groups regarding ulnar variance (p=0.798; p>0.05). On the last follow-up, radial height and radial inclination were significantly lower in the VLP group than in the KW-EF group (p=0.001 and p=0.001, respectively). However, there was no significant difference between the two groups regarding palmar tilt and ulnar variance (p=0.294 and p=0.075; p>0.05, respectively). It was taking attention that ulnar variance measurements were higher in the VLP group than in the KW-EF group. Ulnar variance alterations were significantly lower in the VLP group than in the KW-EF group (p=0.001; p<0.01) (Table 2).

There was a statistically significant difference between the groups regarding Gartland–Werley scores (p=0.037; p<0.05). Good score in the KW-EF group and excellent score in the VLP group were statistically significant. Gartland–Werley, QuickDASH, and VAS scores were all significantly better in the VLP group than in the KW-EF group (p=0.003, p=0.003, and p=0.001, respectively; p<0.01). At the last follow-up, loss of grip strength compared with the uninjured side was 4% in the VLP group and 7% in the KW-EF group. All patients underwent preoperative computed tomographic scan and intraoperative stress radiography under fluoroscopy for wrist instability after the fixation of the fracture. Two patients in the VLP group and three patients in the KW-EF group had midcarpal instability. Furthermore, one patient in the VLP group and one in the KW-EF group had distal radioulnar instability. All patients with wrist instability were treated with two or three KW as an early treatment. KWs were removed after 6–8 weeks (mean: 7.6 weeks) in the outpatient clinic for all patients. However, as a result of wrist instability, three patients in the VLP group and four patients in the KW-EF group had stage I osteoarthritis according to the Jupiter Osteoarthritis Criteria, at the last follow-up. Although there was not any significant difference regarding joint mismatch (>1 mm) between the groups, the complication rate was significantly higher in the KW-EF group than in the VLP group (p=0.149 and p=0.005, respectively; p>0.05). In this study, there were two patients with median nerve neuropathy, three with stage-I CRPS, and two with tendon irritations in the VLP group, while there was one patient with median nerve neuropathy, six with pin tract infections, two with superficial radial nerve neuropathy, and 12 with stage-I CRPS in the KW-EF group. Median nerve compression was required in none of our patients. Patients with pin tract infection were treated with antibiotics. All patients with CRPS recovered with hand rehabilitation.

DISCUSSION

Regarding the anatomy of the distal radius and effects of the forces in various directions, different types of fractures may be observed. It is mostly not possible to achieve success with the same approaches and materials in various fracture types. Mechanical features are important in the selection of surgical technique, while strategic insertion of the selected material may be more important than the features of material in especially intra-articular fractures.[13] In the treatment of unstable intra-articular distal radius fractures, many different surgical techniques may be performed includ-

Table 1. Descriptive features of patients

	External fixation (n=58)			Volar locking plate (n=56)			p
	n	%	Mean±SD	n	%	Mean±SD	
Age (years)			42.90±15.99			47.02±14.64	[a]0.154
Time to surgery (days); (median)			7.97±4.04 (6)			8.18±4.11 (7)	[b]0.842
Duration of follow-up (months); (median)			34.97±8.78 (32)			33.73±10.53 (29)	[b]0.122
Sex							
Male	38	65.5		34	60.7		[c]0.595
Female	20	34.5		22	39.3		
Handedness							
Right	30	51.7		25	44.6		[c]0.449
Left	28	48.3		31	55.4		
Wrist fractured							
Dominant	34	58.6		34	60.7		[c]0.820
Nondominant	24	41.4		22	39.3		
Mechanism of trauma							
Bike accident	4	6.9		6	10.7		[d]0.189
Motor vehicle accident	6	10.3		1	1.8		
Fall from standing	30	51.7		37	66.1		
Fall from height	16	27.6		10	17.9		
Fall stairs	2	3.4		2	3.6		
Fracture Classification (AO-ASIF)							
C1	20	34.5		16	28.6		[d]0.750
C2	16	27.6		18	32.1		
C3	22	37.9		22	39.3		
Complications							
Median nerve neuropathy	1	3.4		2	1.8		[e]0.005**
Pin tract infection	6	10.3		0	0		
Complex regional pain syndrome	12	20.7		3	5.4		
Tendon irritation	0	0		2	3.6		
Superficial radial neuropathy	2	3.4		0	0		
Gartland-Werley Score							
Fair	14	24.1		5	8.9		[a]0.037*
Good	26	44.8		23	41.1		
Excellent	18	31		28	50		
Articular Step-off (≥1 mm)							
No	34	58.6		41	73.2		[e]0.149
Yes	24	41.4		15	26.8		

[a]Student's t-test; [b]Mann-Whitney U Test; [c]Pearson's chi-square test; [d]Fisher-Freeman-Halton Test; [e]Yates' Continuity Correction Test; **p<0.01; *p<0.05.

ing arthroscopy-assisted surgery, fragment-specific fixation methods, EF, and locked or unlocked palmar plates. Direct view of the joint and reduction, diagnosis and treatment of related ligament injuries, removal of intra-articular cartilage debris are advantages of arthroscopy-assisted surgery. However, the necessity of imaging with fluoroscopy, because of the long and difficult procedure, cost increase, and excessive resource utilization are the disadvantages of arthroscopy. Fragment-specific fixation has some advantages such as secure fixation of comminuted fracture, complete anatomical correction, and prevention of tendon problems due to low-profile plates. EF and VLP have been compared in many previous studies in the treatment of intra-articular distal radius fractures.[6,7,11] The main advantages of EF are relatively easy

Table 2. Comparison of radiological outcomes and functional scores between volar locking plate and external fixation at the end of 2 years of follow-up

		External fixation (n=58)	Volar locking plate (n=56)	p
		Mean±SD (median)	Mean±SD (median)	
Range of motion (°)				
Flexion		56.17±7.24	68.71±3.42	[a]0.001*
Extension		56.48±3.87	64.39±3.45	[a]0.001*
Pronation		67.48±4.95	72.59±2.96	[a]0.001*
Supination		61.21±6.55	71.89±3.81	[a]0.001*
Ulnar deviation		30.55±2.52	26.77±2.18	[a]0.001*
Radial deviation		12.14±2.08	16.54±2.20	[a]0.001*
Radiographic data				
Palmar tilt (°)	3rd month	7.94±4.83 (9.8)	6.67±3.13 (7)	[b]0.001*
	2nd year	4.15±5.14 (5.4)	5.60±3.32 (5.9)	[b]0.294
	Alteration	3.79±1.83 (4)	1.58±1.28 (1.1)	[b]0.001*
Radial length (mm)	3rd month	11.76±1.24	10.82±1.03	[a]0.001*
	2nd year	10.73±1.01	10.13±0.59	[a]0.001*
	Alteration	1.03±0.57 (1)	0.72±0.74 (0.3)	[b]0.001*
Radial inclination (°)	3rd month	20.09±1.03	19.08±1.13	[a]0.001*
	2nd year	18.85±1.14	17.95±1.16	[a]0.001*
	Alteration	1.24±0.71 (1.4)	1.11±0.79 (0.9)	[b]0.268
Ulnar variance (mm)	3rd month	0.75±1.17 (1.2)	0.78±0.88 (0.9)	[b]0.798
	2nd year	0.29±1.20 (0.6)	0.75±0.67 (0.9)	[b]0.075
	Alteration	0.52±0.41 (0.5)	0.38±0.22 (0.3)	[b]0.001*
Functional scores				
Gartland-Werley Score		4.86±3.40 (4)	3.02±2.79 (2.5)	[b]0.003*
QuickDASH Score		5.96±5.23 (4.5)	3.33±3.58 (2.3)	[b]0.003*
Visual Analog Score		2.35±2.09 (2)	1.02±1.15 (1)	[b]0.001*

[a]Student's t-test; [b]Mann-Whitney U Test. *p<0.01.

application, less surgical trauma, preservation of height and alignment, minimal surgical exposure, and achievement and maintenance of reduction under fluoroscopy with ligamentotaxis.[14] However, ligamentotaxis in EF is not successful enough to accomplish the anatomical restoration of the joint surface. Percutaneous pins support EF stability. However, EF has some potential complications in the treatment of distal radius fractures such as pin tract infections, over-distraction, joint stiffness, restriction in finger movements, loss of grip strength, superficial radial nerve injury, and CRPS. Management of these complications reported between 6% and 60% is difficult, and they negatively affect the functional results.[15] On the other hand, VLP has some advantages including direct view and intervention of fracture parts with ORIF, maintenance of stable and rigid fixation, subchondral support, anatomical restoration of joint surface, and early mobilization and preservation of upper extremity functions in the postoperative period. However, FPL tendon ruptures were reported to be as high as 12% in recent studies. The possible causes of tendon ruptures were thought to be distal localization of VLP and sharp corners of the screws.[16] Moreover, carpal tunnel syndrome (CTS) may develop following VLP. In some studies, CTS ratios were determined to decrease with the release of transverse carpal ligament.[17] Egol et al.[18] reported that wrist ROM results were initially better in patients in the VLP group, but only pronation could be maintained better during the follow-ups. In our study, when wrist ROM results of the VLP and KW-EF groups were compared for all parameters, there were significant differences in favor of VLP at the end of the follow-up. Richard et al.[19] determined that VLP was superior to EF in early return to daily activities and functional results and on the 12th month of treatment in EF, and wrist ROM decreased while QuickDASH and VAS scores were higher. However, Williksen et al.[20] did not determine any significant difference between VLP and EF regarding QuickDASH scores at the end of 12 months of follow-up. In our study, in functional evaluations, wrist ROM, Gartland–Werley, VAS, and QuickDASH

scores were significantly better in the 24th month in the VLP treatment. Motion superiority determined in the VLP group was associated with the patients' being able to start wrist movements earlier due to the rigid fixation. Kumbaracı et al. reported that despite the early start of wrist ROM in the VLP group, there was no significant difference between the two groups regarding grip strength at the end of at least 12 months of evaluation.[9] In our study, loss of grip strength was determined to be lesser in the VLP group. All KW-EFs were passing through the joint and were dynamized. For that reason, until the removal of the fixator, the wrist was immobilized. This condition may explain the greater movement loss and diminished grip strength in EF.

Roh et al.[6] reported that VLP had better radiological outcomes regarding ulnar variance but these radiological results did not affect the functional outcomes on the 12th month. In this study, when radiological results were compared, radial length and radial inclination were better corrected with EF. However, these results were observed not to have any effect on functional outcomes during the 2 years of follow-up. Especially in very distally located comminuted fractures that do not allow the placement of screws, K-wire supported EF may have successful outcomes. On the other hand, EF may not resist the collapse of the fracture since it could not stabilize the fracture as rigid as VLP and since it should be removed after a period. Moreover, loss of palmar angulation may continue in the EF group in the long term, even after the removal of the fixator. Since ORIF may be directly and visually performed, the palmar tilt may be corrected better with VLP. Subchondral inserted distal screws of VLP maintain support against palmar angulation loss and also prevent the collapse of fracture in the long term.[21] In this study, there were no significant differences observed between groups regarding palmar tilt at the end of follow-ups. However, in both groups, but especially in EF, loss of wrist flexion and supination was determined in patients who were restored with shortness and palmar angulation loss. A study by Juedy et al. evaluating articular step-off radiologically, there were no significant differences between the groups.[22] In the present study, there were no significant differences between the groups regarding articular step-off at the last follow-up. Shukla et al. reported that EF was superior to VLP at the end of the 1st year, and also the results were better in patients aged <50 years if treated with EF.[21] In our study, patient satisfaction was determined to be significantly higher in the VLP group regarding objective and subjective functional evaluations. Moreover, all parameters except ulnar variance and palmar tilt were radiologically better in the VLP group. Additionally, the complication rate in the KW-EF group was significantly higher than that in the VLP group, consistent with previous studies.[6,11] The present study is taking attention with its follow-up period of at least 2 years. On the other hand, its retrospective design, lack of randomization, and absence of functional monitoring data between the 3rd month and 2nd year are the main limitations of this study.

Conclusions

This study results indicate that VLP is a safe method with low complication rates. Patients' preference is an increasingly prominent factor in the choice of treatment method. However, VLP is a better option in young and active patients with the expectation of high functional achievements. On the other hand, KW-EF may be successful in older patients with low activity levels and in very distal and comminuted fractures that contraindicate the use of VLP, but the complications should be kept in mind. We believe that VLP is superior to KW-EF for early return to normal daily activities as well as functional and radiological outcomes in the 2nd year of treatment.

Conflict of interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZET*

AO/ASIF tip C distal radius kırıklarının tedavisinde volar kilitli plak mı? K-teli destekli eksternal fiksatör mü? Fonksiyonel ve radyolojik sonuçların karşılaştırılması

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AMAÇ: Eklem içi ve parçalı distal radius kırıklarının tedavisinde volar kilitli plak uygulaması ile K teli destekli eksternal fiksatör uygulamasının fonksiyonel ve radyolojik sonuçlarının karşılaştırılması amaçlandı.

GEREÇ VE YÖNTEM: Şubat 2010–Nisan 2013 tarihleri arasında kompleks intraartiküler distal radius kırığı için tedavi edilmiş hastalar geriye dönük olarak tarandı. Dâhil edilme kriterlerini karşılayan 18 ile 86 yaş arasında (ortalama yaş, 44.9±15.4) 114 hasta değerlendirildi. Hastaların fonksiyonel değerlendirmelerinde gonyometre ile eklem hareket açıklıkları ve el dinamometresi ile kavrama güçleri ölçüldü. Sonuçlar Gartland–Werley ölçeği ile değerlendirildi. Subjektif fonksiyonel değerlendirmede Quick DASH ölçeği kullanıldı. Radyolojik değerlendirme hastaların ameliyat sonrası üçüncü ay ve ikinci yılda el bileği grafileri ile yapıldı.

BULGULAR: Son kontroldeki fonksiyonel değerlendirmede volar kilitli plakta (VLP) fleksiyon, ekstansiyon, pronasyon ve supinasyon eksternal fiksatörden (EF) anlamlı düzeyde yüksekti (p=0.001). Volar kilitli plağın Gartland-Werley skoru, QuickDASH skoru ve vizüel analog skoru (VAS), EF'den iyiydi (p=0.003, p=0.003 ve p=0.001, sırasıyla). VLP'de ameliyat sonrası son kontrolde sağlam tarafa göre kavrama gücü kaybı ortalama %4, EF'de ise %7 oranındaydı.

TARTIŞMA: Volar kilitli plağın güvenli ve komplikasyondan uzak bir yöntem olduğu görülmüştür. Volar kilitli plak günlük yaşam aktivitelerine erken dönüş, fonksiyonel ve radyolojik sonuçlar açısından tedavinin ikinci yılında eksternal fiksatörden daha üstün bir yöntemdir.

Anahtar sözcükler: Fonksiyonel sonuçlar; intraartiküler distal radius kırığı; köprü eksternal fiksatör; volar kilitli plak.

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