ORIGINAL ARTICLE

Volar-locking plate versus external fixator in the management of distal radius fractures: An isokinetic study

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ABSTRACT

BACKGROUND: The aim of this study was to compare the clinical and isokinetic evaluation of distal radius fractures treated by volar locking plate (VLP) and external fixator.

METHODS: The study included fifty patients with distal radius fracture type C1/C2/C3. Twenty-seven patients (12 men, 15 women; mean age 49.5±4.42) underwent open reduction and VLP fixation, and 23 patients (10 men, 13 women; 52.1±4.6) underwent closed reduction and external fixation. The follow-up period was at least 12 months and the mean following time was 13.5±1.02 (12–15) months. The functional parameters measured were range of motion (ROM) and grip strength. Radiographic parameters (radial inclination, palmar tilt, and radial height) and isokinetic evaluation were measured at the 6 months and at the final follow-up after surgery. The isokinetic test was done at the speed of 60°/s. The non-fractured arm was tested first and all results were also expressed as a percentage of that on the normal side. Wrist scores according to the disability of the arm, shoulder, and hand (DASH) questionnaire were used.

RESULTS: The DASH scores, grip strength, and palmar flexion were better in VLP group at the 6 months ($p<0.05$). However, there were no differences between two groups at the one year ($p=0.79$). Isokinetıc evaluation of the VLP showed that peak pronatıon torque and total pronation work were better than external fıxatıon at the 6 month ($p<0.05$). At the final of follow-up was seen no significant differences between two groups ($p=0.11$).

CONCLUSION: We looked at external fixation and locked volar plates in a prospective study and we found an improved range of movement and isokinetic evaluation outcome at 6 months after locked plating, but there were no differences between two groups at the final of follow-up. Our study showed no evidence for the superiority of one treatment over the other at the final follow-up.

Keywords: Distal radius fracture; external fixation; isokinetic evaluation; volar plate.

INTRODUCTION

Distal radius fractures account for 44% of all kinds of the forearm and hand fractures, which is the most familiar kind of upper limb fractures and lead to a serious problem of public health.[1–3] AO type C2/C3 distal radius fracture is an unstable completely intra-articular fracture with metaphyseal simple or multifragmentary, which is typically indicated for surgical treatment. It was found that wrist functions return quickly within two years in patients with external fixator (EF) application and there is no difference between external fixation and volar plating application in long-term.[4,5] In one meta-analysis, a better functional outcome was observed in patients with unstable distal radius fractures treated with a volar locking plate (VLP) compared with external fixation at 3, 6, and 12 months follow-up.[6] The assessment of the force can be supported by use of isokinetic machines with an objective data on the functional recovery.[7] Costantino et al.[8] evalu-

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ated patients with proximal humeral fractures treated with a locking plate, and they used isokinetic test for analyzing the recovery of strength and its correlation with clinical and functional outcomes. They reported that, the isokinetic test can give objective data on strength recovery and could help the surgeon's clinical evaluation to assess the functional recovery of the operated shoulder over time. Daumillare et al.[9] ınvestigated the impact of a ulnar styloid process fracture on pronation and supination strength in isometric and isokinetic tests. Recent prospective randomized trials have reported rapid functional recovery after volar plate fixation compared with EF, but no functional advantages were demonstrated at 2 years.[10] Navarro et al.[11] randomized 140 patients aged 50–74 years with a dorsally displaced distal radius fractures to VLPs or external fixation. They reported that volar plating and external fixation with optional addition of K-wires are two equally suitable treatment options for dorsally displaced distal radius fractures.

This study was designed to compare the clinical and isokinetic evaluation of VLP and EF in the treatment of intra-articular distal radius fractures (AO type C).

MATERIALS AND METHODS

Fifty-four patients diagnosed with AO Type C distal radius fracture who were admitted to our hospital between December 2013 and November 2015 were evaluated prospectively. Approval of the Institutional Review Board (IRB) was taken before initiating the study and informed consent was obtained from all the study participants. Two of the patients stopped follow-up, one of them had distal radius fractures on the other side and one patient developed cerebrovascular disease during follow-up period. A total of 50 patients were included in the study. VLP was performed in 27 fractures and EF was performed on 23 fractures. The mean age of patients treated by VLP was 49.5 (18–73), of which 15 (55.5%) were female and 12 (45.5%) male. EF was performed in 23 patients and the mean age of this group was 52.1 (18–77) and 13 (56.4%) of these patients were female and 10 (44.6%) were male.

Age, gender, hand dominance, and fracture type according to AO/ASIF classification were recorded for each patient. There were no statistically significant differences between the two groups (Table 1). Radial height, radial inclination, palmar slope, and articular incompatibility were evaluated in X-ray before and after reduction. Considering the stability criteria set by Lafontaine and his friends,[12] surgical treatment for unstable fractures was decided. Exclusion criteria were open fractures, uncooperative patients to accomplish isokinetic testing such as dementia, Parkinson's disease, or psychiatric illness, previous injuries or surgeries in either side, bilateral fractures, and fractures treated with open reduction and plate that was not VLP fixation. Fractures type was classified according to the AO classification system. AO type C1, type C2, and type C3 fractures were included in the study. Fractures types in patients with volar plating; type C1 (n=7), type C2 (n=9), and type C3 (n=11). Fractures types in patients with EF; type C1 (n=8), type C2 (n=7), and type C3 (n=8) (Table 1).

Surgical Method

VLP: In the volar locked plating technique, a standard volar approach over the flexor carpi radialis (FCR) tendon was used with the interval of dissection between the FCR and the radial artery. The pronator quadratus was lifted from the radial border, and the muscle was retracted ulnarly. The volar aspect of the distal radius and the fracture was identified. Palmar fragments were often comminuted and impacted. Each fragment was identified and reduced. The titanium locking volar plate system used all the fractures. The C-arm was used to check for screw placement and reduction. Following surgery, a soft resting plaster wrist cast was used in the palmar locking plate group, that did not go beyond the metacarpophalangeal joint. Active finger exercises were started the day after surgery. Patients were evaluated clinically and radiographically at 2 and 4 weeks after surgery, the plaster was removed at week 2 and rehabilitation was started with active and passive exercises. At the end of 8 weeks, an exercise program for muscle strengthening was started depending on the level of union. All patients were followed for 6 months and 1 year after surgery and assessed for DASH scale, grip strength, pain, range of motion (ROM) activity, radiographic measurements, and isokinetic evaluations.

For objective functional assessment, joint ROM was measured with a goniometer. Grip strength was measured using a Jamar® hand dynamometer (Jamar, Preston, USA) and com-

Table 1. The demographic data of patients with distal radius fracture. There were no statistically significant differences between the two groups

	Volar plate	External fixator	p-value
Age	49.5±4.42	52.1±4.6	0.108
Gender (female/male)	15/12	13/10	0.744
Type C3/C2/C1 according to AO/ASIF classification	11/9/7	8/7/8	0.328
Hand dominance	23	18	0.734

pared with the healthy side. Isokinetic testing was done using a Biodex System 3 Pro isokinetic test device (Biodex Corp, Shirley, NY, USA).

External Fixation

External fixation was applied to fifteen patients under general and to eight patients with regional anesthesia. The EF system is wrist bridging and modular type (Orthofix, Bussolengo, Italy). Proximal and distal threaded pins were placed through a drill sleeve to the radial shaft and index metacarpal bone, respectively, with a stab incision. Closed reduction was done under fluoroscopy with flexion, ulnar deviation, and hyperpronation. EF was performed when the satisfactory reduction was achieved. Excessive flexion and ulnar deviation were avoided. We tried to achieve neutral values of palmar tilt. For additional stability, the fragments were reduced and fixed with 1.5 and 1.7 mm K-wire in ten patients. We did not apply any kind of graft in all patients.

All fixators were mobilized from the hinge point of the fixator at 3 weeks to allow wrist motion. The K-wires were removed at 6 weeks and the fixator was removed at 6–9 weeks according to the fracture healing state without anesthesia in the outpatient clinic. Active ROM of wrist exercises were encouraged after removal of the fixator and no cast or brace was applied.

Postoperative Management

All patients had similar follow-up protocols. In the EF group, physiotherapy of the elbow and shoulder joints began on the day after the surgical intervention. Active finger motion was encouraged after surgery. Wrist ROM exercises were started after mobilizing the hinge point of the EF after 3 weeks. In the palmar locking plate group, following surgery a soft resting plaster wrist cast was used, which did not go beyond the metacarpophalangeal joint. Active finger exercises were started the day after surgery. The plaster was removed at week 2 and rehabilitation was started with active and passive exercises. At the end of 8 weeks, an exercise program for muscle strengthening was started depending on the level of union.

Outcome Assessment

The outcome assessments were done at 6 months and 1 year after surgery. An independent physiotherapist who was not involved in this study performed the functional testing.

Physical Examination

Grip strength was measured using a Jamar® hand dynamometer (Therapeutic Equipment Corp, Clinton, NJ, USA) with the elbow flexed at 90° and neutral rotation. Results were recorded in kilograms.[13] Three trials were recorded for each hand and the mean value was calculated. The ROMs of the both wrist were determined with a goniometer.

Disability

The functional outcome was evaluated with the 'disabilities of the arm, shoulder and hand' (DASH) questionnaire that yields a score that can range from 0 (no disability) to 100 (worst possible disability).[14]

Radiographic Evaluation

Standard antero-posterior and lateral radiographies were taken in the follow-up period. Radial height, radial inclination, and volar tilt were measured using the hospital's PACS system from post-reduction radiographies and 1 year after the fracture follow-up and recorded. These measurements were compared with either of these treatment methods and all of the patients. Fracture healing was assessed with the osseous bridging across the fracture site on the antero-posterior and lateral radiographs.

The grip strength, ROM of the wrist, and radiographic results were recorded as the percentage of the unaffected side.

Isokinetic Evaluation

Isokinetic testing was done using a Biodex System 3 Pro isokinetic test device (Biodex Corp, Shirley, NY, USA). The measurements were made in a seated position and the patient's elbow flexed at 90° and strapped from his/her chest to stabilize the patient. The isokinetic testing was done by a rehabilitation medicine specialist. The test was done at the speed of 60°/s. The non-fractured arm was tested first and all results were also expressed as a percentage of that on the normal side. Patients performed ten isokinetic effort trials for each condition. Peak torque (Nm) was defined as the highest torque measured and total work (J) was defined as the greatest amount of work performed during ten repetitive isokinetic tests.

Statistical Analysis

Statistical analysis was performed using a computer program (SPSS 15.0 for Windows, SPSS Inc.). Chi-square test, paired sample t-test, and independent sample t-tests were used in evaluating the significance of the differences where appropriate and $p<0.05$ were considered as significant.

Sample Size Estimations (Prioripower) and Power Analysis (Post hoc Power)

The sample size was calculated for the independent sample t-tests, which was used to test the primary hypothesis of our study. As a result of the sample size analysis conducted using Cohen's effect size value of 0.85, it was found that a minimum of 46 (VLP group: 23 and EF group: 23) individuals should be included in the study to reveal significant differences between the groups with minimum 80% power ($1-\beta=0.80$) and $\alpha=0.05$ error (95% confidence interval). Post hoc power analysis was performed to determine the power of the study with a type 1 error value of 0.05 for the primary hypotheses

Table 2. Radiographic results were recorded as the percentage of the unaffected side and there were no statistically significant difference between EF group and VLP group at 6 month and one year

Radiographic outcomes	Volar plate	External fixator	p-value
Volar tilt at 6 month	37.16±25.61	30.71±24.22	0.47
Volar tilt at 1 year	35.25±18.64	31.26±18.69	0.14
Radial inclination 6. m	85.24±9.02	80.06±8.7	0.12
Radial inclination 1. year	78.26±8.78	65.22±6.8	0.75
Radial height at 6 m	80.98±15.17	77.81±17.18	0.64
Radial height at 1 year	74.54±10.25	68.23±11.24	0.58

EF: External fixator; VLP: volar locking plate.

that were found to be statistically significant. The G*power (version 3.1.9.7) package (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) was used for priori and post hoc power analysis.

RESULTS

The mean following time was 13.5 (12–15) month. The radiographic evaluation showed no significant difference between the two treatment groups (Table 2). The comparison of mean ROM of the wrist, grip strength and DASH score as percentages of the normal side between VLP and EF at 6 month and 1 year are given in Table 3. The DASH score was better in VLP group at 6 month ($p<0.05$), but no difference was found at one year ($p=0.79$). Grip strength of the wrist was also better in the VLP group at 6 month ($p<0.05$) but showed no significant difference at one year ($p=0.28$). Palmar flexion was better in the VLP group at 6 month ($p<0.05$) but no significant difference at one year ($p=0.18$). There was no statistically significant difference in palmar flexion, dorsal flexion, and ulnar flexion between EF group and VLP groups at 6 month and 1 year.

In the isokinetic evaluation of the wrist, the peak torque and total work values for pronation in VLP was better than in EF at 6 month ($p<0.05$), but no difference was found at one year ($p=0.11$ and $p=0.29$, respectively). Peak torque and total work values for supination, flexion and extension were not significantly different between EF and VLP group at 6 month and 1 year after fracture (Table 4). Swelling and superficial pin infections were observed in two patients in the EF group that controlled with antibiothreapy. There were no complications in the palmar locking plate group.

DISCUSSION

The importance of restoring the anatomical alignment and articular congruity is well-recognized in the fixation of distal

Table 3. Comparison of the DASH Score, grip strengt, hand range of motion of the wrist between VLP and EF after the management of distal radius fractures. DASH Score, Grip strengt hand palmar flexion were better at 6 month in VLP group, but no difference were found at one year

	After 6 months			After 1 year		
	Volar plate treatment	Eksternal fixator treatment	p-value	Volar plate treatment	Eksternal fixator treatment	p-value
DASH Score	23.59±4.94	27.87±3.09	<0.05			
PA=95%	20.07±3.63	21.70±2.54	0.79			
Grip strength	70.52±5.63	66.43±4.143	<0.05			
PA=82%	88.78±2.46	87.96±2.88	0.28			
Palmar flexion	80.33±2.18	77.09±4.670	<0.05			
PA=87%	88.48±3.73	86.83±4.90	0.18			
Dorsal flexion	88.85±3.50	87.30±6.02	0.26	89.92±3.41	88.70±3.183	0.20
Radial deviation	87.48±3.63	84.22±7.97	0.62	89.31±4.01	87.61±4.66	0.17
Ulnar deviation	86.48±4.25	84.83±4.54	0.19	89.70±3.49	87.61±4.57	0.73

DASH: Disabilities of the arm, shoulder and hand; EF: External fixator; VLP: volar locking plate; PA: Power analysis.

Table 4. Comparison of the isokinetic muscle strength of the wrist between volar locking plate and external fixation after the management of distal radius fractures. In the isokinetic evaluation of the wrist, the both peak torque and total work values for pronation in VLP was better than in EF at 6 month ($p<0.05$). At one year after fracture, both peak torque and total work values were not significantly different between EF and VLP group for pronation ($p=0.11$, $p=0.29$ respectiveliy)

	After 6 months			After 1 year		
Isokinetic musclestrength	**Volar plate treatment**	**Eksternal fixator treatment**	**p-value**	**Volar plate treatment**	**Eksternal fixator treatment**	**p-value**
Flexor						
Peaktorque (Nm)	78.81±8.13	74.90±11.97	0.10	80.06±7.30	76.50±12.24	0.21
Total work (Joule)	76.40±13.73	70.81±10.88	0.12	82.74±10.20	81.28±7.158	0.56
Extansor						
Peaktorque (Nm)	78.50±7.35	76.43±5.39	0.26	83.10±7.87	81.98±4.65	0.55
Total work (Joule)	75.99±11.72	79.17±3.80	0.22	87.40±7.69	85.58±5.13	0.34
Pronator						
Peaktorque (Nm)	84.05±6.322	79.38±5.01	<0.05 PA=81%	87.37±6.68	84.83±3.66	0.11
Total work (Joule)	81.01±5.96	76.93±6.84	<0.05 PA=88%	86.63±6.23	84.55±5.01	0.29
Supinator						
Peaktorque (Nm)	79.87±5.59	76.55±6.91	0.66	85.10±8.02	82.75±6.71	0.27
Total work (Joule)	85.50±4.34	81.38±7.13	0.32	88.7±8.12	86.82±6.67	0.38

EF: External fixator; VLP: volar locking plate.

radial fractures. These fractures are among the most common extremity fractures affecting both young and elderly individuals.[15] Restoration of the wrist function to pre-injury levels is of primary concern for the orthopedic surgeons due to the involvement of the joint in a wide variety of daily activities. There is no conclusive evidence for which treatment method should be used in intra-articular comminuted distal radius fractures.[16] In the treatment of unstable intra-articular distal radius fractures, many different surgical techniques may be performed including arthroscopy-assisted surgery, fragment-specific fixation methods, external fixation, and locked or unlocked palmar plates.

The best treatment option for different types of fractures may be determined by comparing different methods. EF is multifunctional in managing intra-articular fractures with acceptable functional results. The advantages of external fixation are the relative ease of application, minimal surgical exposure, and reduced surgical trauma.[6–17] However, EF has some potential complications, such as pin tract infections, over-distraction, joint stiffness, restriction in finger movements, loss of grip strength, and superficial radial nerve injury. The advantages of open reduction and internal fixation include direct visualization and manipulation of the fracture fragments, stable fixation, and possibility of immediate post-operative motion. Despite its advantages, there are still fracture types where palmar locking plate cannot be applied. Especially in comminuted very distal fractures which do not allow screw application, external fixation application may give successful result (Fig. 1).

It is thought that VLP groups allow faster rehabilitation than EF. A prospective randomized trials have reported VLPs have certain advantages over EFs in the early postop period in terms of a faster return to the normal daily routine, better early ROM, and better patient tolerance of hardware.[18] However, Yu et al.[19] compared external fixation and VLP for treatment of type C2/C3 distal radius fractures and found no significant difference between the complications and the functional score based on DASH or Gartland–Werley scale at the final follow-up. Fu et al.[20] conducted a meta-analysis of nine published randomized controlled trials (RCTs) with 776 patients of distal radius fractures treated with either a VLP or external fixation and concluded that volar plating gives better clinical results in the early postop period with better DASH scores (3 and 6 months), grip strength (3 months), flexion, extension, and supination (3 months). Gouk et al.[21] compared external fixation with volar plating and found that disabilities of the arm, shoulder, and hand scores significantly favored VLPs, but only at 3 months was the difference clinically meaningful. Grip strength was better in the VLPs group in the early post-operative period, but was similar at 12 months.

Different types of fractures may occur due to the anatomy of the distal radius and the effect of forces in different directions. It is often not possible to have a successful outcome

Figure 1. (a and b) Pre-operative radiographs of a 48-year-old men with comminuted distal radius fracture. **(c and d)** Early post-operative radiographs following K-wire augmented external fixation. **(e and f)** Post-operative radiographs of the patient at 6 months. **(g and h)** Clinical picture of a patient treated with external fixation after 1 year follow-up.

using the same approach and materials for different types of fractures. While mechanical characteristics are important in fixator selection, the strategic placement of the selected materials may in fact be more important than the characteristics of these materials, particularly in intra-articular fractures. In one meta-analysis, the authors found, no difference in terms of functional results at least 1 year follow-up between EF and plate.[22] Internal and external fixation treatment methods can be applied for the distal radial fractures of types C. The outcomes of these treatment methods have been compared in this study and we found that these methods showed almost no difference of outcome in the long term between EF and VLP; however, VLP showed slightly better results in the earlier period. Considering fracture types, removal times of the EF in our study were similar to those reported in previous studies.[2–23] Mellstrand Navarro et al.[11] randomized 140 patients with a dorsally displaced distal radius fractures to VLPs or external fixation. They found no significant differences between the groups in terms of DASH and Patient-Rated Wrist Evaluation at 3 months and 1 year. However, in the present study the DASH score was better in VLP group at 6 month ($p<0.05$), but no difference was found at one year ($p=0.79$). Hammer et al.[10–24] compared the functional outcomes following fixation with a VLP with augmented external fixation (EF) of displaced, intra-articular distal radial fractures in patients 18–70 years of age. At 6 months, the patients in the VLP group had better functional results and reported significantly better mean Quick DASH score, ROM, and grip strength, which is in accordance with our findings. But there was no statistically significant difference in DASH score, ROM, and grip strength between EF group and VLP groups at one year in our study.

The muscle function can be evaluated reliably by isokinetic testing.[24–26] Although it has been reported that some forearm rotation was affected,[27] isokinetic evaluation was not performed in the comparative trials evaluating distal radial fractures. Daumillare et al.[9] investigated the impact of an ulnar styloid process fracture on pronation and supination strength in isometric and isokinetic tests. They compared the ratio between the operated and contralateral sides for each patient and they reported that a decrease in pronation-supination strength in patients with ulnar styloid process fractures. In this study we found pronation muscle strength was better in VLP than EF after 6 month. However, after 1 year, muscle strength of forearm rotation was not affected. These

findings can be explained by the general rule as the methods allowing early mobilization leads to provide more ROM. In joint bridging EF treatment, wrist motion was blocked but forearm rotation was relatively free. The allowing of forearm rotation freely might play a role in the more muscle strength in the earlier period. However, the forearm rotation improves over time like other functional outcomes and after 1 year the forearm rotation showed no significant difference between the treatment methods.

One limitation of this study is the heterogeneity of the two groups and the other limitation is all procedures were performed in a single center.

Conclusion

In our study, we found that palmar locking plate and external fixation were reliable in the treatment of comminuted distal radial fractures. Objective and subjective functional assessments showed no significant superiority between EF and VLP in the long-term follow-up. The advantages of external fixation are the relative ease of application, minimal surgical exposure, and reduced surgical trauma. Therefore, we recommend external fixation ın comminuted and very distal fractures where palmar locking plate may not possible.

Ethics Committee Approval: This study was approved by the Ankara Numune Training and Research Hospital Clinical Research Ethics Committee (Date: 14.04.2014, Decision No: E-14-164).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Radius distal uç kırıklarının tedavisinde volar plak ve eksternal fiksatör tedavi sonuçlarının karşılaştırılması: İzokinetik çalışma

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AMAÇ: Bu çalışmada, eksternal fiksatör ve kilitli volar plak ile tedavi edilen distal radius kırıklı hastalarda klinik ve izokinetik sonuçları karşılaştırmayı amaçladık.
GEREÇ VE YÖNTEM: AO tip C1/C2/C3 olan 50 hasta çalışmaya alındı. Bunlardan 23 hastaya eksternal fiksatör, 27 hastaya volar kiliti plak uygulaması yapıldı. Kırık tipleri AO sınıflandırma sistemine göre sınıflandırıldı, hastalar eksternal fiksatör ve volar kilitli plak uygulamasına göre iki guruba ayrıldı. Tüm hastalar minimum 12 ay takip edildi ve ortalama takip süresi 13.5±1.02 (12–15) ay idi. Fonksiyonel sonuçlar eklem hareket açıklığı (ROM) ve kavrama gücü ile ölçüldü. Radyografik parametreler (radial inklinasyon, radial yükseklik, radial tilt) ve izokinetik değerlendirmeler ameliyattan altı ay ve bir yıl sonra ölçüldü. Elbilek skorları DASH puanlama sistemine göre yapıldı. Tüm verilerin analizi SPSS Windows 15.0 sistemi üzerinden yapıldı. Niteliksel verilerin analizi için ki-kare testi, eşleştirilmiş t-test kullanıldı ve anlamlılık $p<0.05$ düzeyinde değerlendirildi.
BULGULAR: Her iki gurup arasında DASH Skoru, palmarfleksiyon ve kavrama gücü gibi fonksiyonel parametrelerde altıncı ayda anlamlı fark bulunurken ($p<0.05$), birinci yıl sonunda fark bulunamadı ($p=0.79$). İzokinetik değerlendirmelerde volar plaklama yapılan hastalarda eksternal fiksatör yapılan hastalara göre altıncı ayda pik pronasyon tork ve total work daha iyiyken ($p<0.05$), birinci yıl sonunda fark bulunamadı ($p=0.11$).
TARTIŞMA: Sonuç olarak, eksternal fiksatör ve volar plaklama uyguladığımız bu ileriye yönelik çalışmada, volar plaklama yapılan hastalarda altıncı ayda eklem hareket açıklığı ve izokinetik değerlendirmeler daha iyi iken birinci yıl sonunda iki grup arasında anlamlı fark bulunamadı. Çalışmamızda birinci yıl sonunda bir gurubun diğerine üstünlüğü bulunamadı.
Anahtar sözcükler: Distal radius kırığı; eksternal fiksatör; izokinetik değerlendirme; volar plak.

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