Acta Medica Ruha E-ISSN: 2980-1184

International Journal of Medicine and Health Sciences

Original Research Article Volume: 1 Issue: 4 Year: 2023 DOI: 10.5281/zenodo.10198779

Surgical Treatment of Unstable Distal Radius Fractures With Articular Involvement In Adults

Eklem Tutulumu Olan İnstabil Distal Radius Kırıklarının Cerrahi Tedavisi

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Abstract

Objective: Radius distal end fractures are the most common type among whole-body bone fractures, constituting 8 – 15% of all fractures. Within the scope of this study, it was aimed to evaluate the results of anatomical plate fixation methods applied by volar intervention in the surgical treatment of distal radius fractures.
Method: In our study, 41 adult patients with distal radius fractures treated with open reduction and fixation of alternate volar plates with a mean follow-up of 20 months were evaluated retrospectively. Frykman and AO classification systems were used in the evaluation of fractures. Gartland – Werley clinical scoring method, DASH, and Stewart radiological evaluation scale were utilized by measuring the patients with a dynamometer and goniometer.
Results: According to the Gartland and Werley clinical evaluation criteria, 25 (61%) of 41 fractures had excellent, 9 (22%) good, 6 (14.6%) moderate, and 1 (2.4%) poor results. There was no statistical difference between the joint motion angles, grip strengths, and clinical evaluation results in the comparison of the operated patients with the unaffected hand. According to the results of the Stewart Radiological evaluation, 11 (26.8%) of the patients had excellent, 28 (68.3%) good, 1 (2.4%) moderate, and 1 (2.4%) poor results. There was no statistical difference compared to the healthy wrist.
Conclusion: Radius volar plates have provided successful results as they are an effective method in providing anatomical complete reduction and alignment in intra-articular and extra-articular unstable fractures, which are especially problematic in the lower end of the radius, and allow joint movements in the early period thanks to its high fixation strength. Volar intervention, on the other hand, allows reaching the lower end of the radius with minimal surgical trauma and allows a fixation more compatible with the surrounding tissues with low complication rates.

Keywords: Distal Radius Fractures, Locked Anatomical Plate, Unlocked Plate, İnternal Fixation.

Özet

Amaç: Radius distal uç kırıkları, tüm vücut kemik kırıkları arasında en sık görülen tiptir ve tüm kırıkların %8 – 15'ini oluşturur. Bu çalışma kapsamında radius distal uç kırıklarının cerrahi tedavisinde volar girişim ile uygulanan anatomik plak tespit yöntemlerinin sonuçlarının değerlendirmesi amaçlanmıştır.
Yöntem: Çalışmamıza radius distal uç kırığı nedeniyle açık redüksiyon ve değişik volar plak tespitiyle tedavi edilen ortalama takip süresi 20 ay olan erişkin 41 distal radius kırıklı hasta retrospektif olarak değerlendirildi. Çalışmaya dahil 41 hastanın kırıkların değerlendirmesinde Frykman ve AO sınıflandırma sistemleri kullanıldı. Hastalara dinamometre ve goniyometre ile ölçümler yapılarak, Gartland – Werley klinik skorlama yöntemi, DASH ve Stewart radyolojik değerlendirme skalası kullanıldı.
Bulgular: Gartland ve Werley klinik değerlendirme kriterlerine göre 41 kırığın 25 (%61)'inde mükemmel, 9 (%22)'nda iyi, 6 (%14.6)'sında orta ve 1 (%2.4)'inde kötü sonuç elde edildi. Opere edilen hastaların sağlam taraf el ile karşılaştırılmasında eklem hareket açıları kavrama güçleri ve klinik değerlendirme sonuçları arasın da istatistik olarak fark yoktu. Stewart Radyolojik değerlendirmesi sonucuna göre hastaların 11 (%26.8)'inde

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Received: 15.10.2023, Accepted: 29.11.2023, Published Online: 20.12.2023
Cite: Mertsoy Y. Surgical Treatment of Unstable Distal Radius Fractures With Articular Involvement In Adults. Acta Medica Ruha. 2023;1(4):573-582. https://doi.org/10.5281/zenodo.10198779

mükemmel, 28 (%68.3)'inde iyi, 1 (%2.4)'inde orta, 1 (%2.4)'inde kötü sonuç elde edildi. Sağlam taraf el bileğine göre istatistiki olarak fark yoktu.

Sonuç: Radius volar plaklar, radius alt uç bölgesinde özellikle tedavisi sorunlu olan eklem içi ve dışı instabil kırıklarda anatomik tam redüksiyonun ve dizilimin sağlanmasında etkin olan yöntem olması ve yüksek tespit dayanıklılığı sayesinde eklem hareketlerine erken dönemde izin vermesi ile başarılı sonuçlar sağlamıştır. Volar girişim ise, radius alt ucuna minimal cerrahi travma ile ulaşmayı sağladığı gibi çevresel dokular ile daha uyumlu bir tespite izin verir. Yaşanan komplikasyon oranları düşüktür ve dikkat ve öğrenme eğrisi ile ilgilidir.

Anahtar Kelimeler: Radius Distal Uç Kırıkları, Kilitli Anatomik Plak, İnternal Tespit.

INTRODUCTION

Hand and wrist fractures occupy the emergency services and orthopedic clinics most frequently. Radius distal end fractures are the most common type among whole-body bone fractures, constituting 8 – 15% of all fractures (2). The incidence distribution shows two peaks. The first is in children between the ages of 6 – 10, and the second is in the elderly aged 60 – 69 (3). In addition, it is economically important in adulthood, especially after traffic and work accidents. As society ages and interest in sports activities increases, the incidence of lower radius fractures constantly increases. Diagnosis and treatment are important because it is common in every society, and the treatment results are closely related to the daily functional functions of the individual (4).

Along with the type of fracture in treatment planning, the patient's age, general condition, physical and cognitive capacity, comorbidities, treatment compliance, and expectations should be considered (5). The aim of treatment is to provide normal anatomy and to preserve the normal anatomy. However, complications such as joint stiffness and arthrosis can be avoided by allowing early joint movements. For many years, a wide variety of methods have been used to treat lower radius fractures. Of 75 – 80% of radius distal end fractures are stable extra-articular fractures treated conservatively in the emergency department (4).

Conservative methods are currently limited to low-energy, extra-articular and stable fractures. Multi-part, intra-articular and unstable fractures, formed with high energy, are the ones with problematic treatment. In this type of fracture, restoring the regularity of the articular surface and radius length cannot be achieved with closed methods most of the time. Various surgical methods and fixation materials are used (6).

In recent studies, understanding wrist anatomy, the necessity of recovery of functions, and increasing patient expectations have led to shifting the boundaries of treatment to surgery. In addition, developments in implant technology and surgical fixation methods offer new opportunities to surgeons (7).

The main problematic fractures in terms of treatment are high-energy, multi-component, extra-articular, and unstable fractures. Although a wide variety of surgical intervention methods and fixation have been described in the treatment of unstable fractures, a standard treatment method has yet to be established (5).

Today, open reduction and plate-screw fixations are widely used in the surgical treatment of radius lower-end intra-articular fractures (8). Whether the angulation of the fracture is dorsal or volar, there is no consensus on the choice of intervention to reach the lower end of the radius and the placement of the plate (9). However, the volar plating technique has come to the fore in all of these fractures, regardless of the displacement direction of the distal fracture fragments, due to complications related to the implant and the intervention route seen after dorsal plating.

In this study, patients with comminuted intra-articular radius distal end fractures were treated with the volar approach in our clinic; We aimed to evaluate the anatomical, radiological, and clinical outcomes and examined the effects of treatment outcomes on patients' daily work and social lives.

METHODS

In this study, 41 adult patients with a diagnosis of lower end of radius fracture, who underwent volar-local locking plate and had no other injuries on the contralateral wrist, and were followed up for at least 13 months in our institution were investigated. Anteroposterior and lateral wrist radiographs of the patients who presented to the emergency department and the outpatient clinic with a fracture of the distal radius of the radius were enrolled. Patients with additional life-threatening traumas or pathologies were excluded.

The extremity side of the distal radius fractures was determined. Frykman and AO classification systems were utilized in the evaluation of fractures. Open fractures were evaluated according to the Gustillo-Anderson classification, and pre-examination and treatment modalities were examined before the volar locking plate was placed. Except for the patients with open wounds and those unsuitable for reduction, closed reduction and circular plaster fixation were applied to the distal radius fractures of all patients, and control radiographs were taken. Radial height, radial inclination, palmar tilt, and articular incongruity were evaluated on pre-reduction and post-reduction radiographs. Considering the stability criteria determined by La Fontaine et al., volar angulation exceeding 20°/ dorsal angulation exceeding 10°, radial inclination angle falling below 15°, loss of radius more than 10 mm, intra-articular stepping more than 2 mm, Surgical indication was decided for patients with accompanying ulna fracture, excessive fragmentation of the radius dorsal cortex and loss of reduction while in plaster cast treatment (10).

Three patients with open fractures requiring soft tissue healing and unstable fractures underwent osteosynthesis with a plate and screw after 14 days of external fixation, making them suitable for operation. Locking plate systems with biomechanical advantages and anatomical adaptation, which preserve reduction and allow early movement, were preferred.

In the evaluation during surgery, a temporary (for 3 – 4 weeks) Kirschner (K) wire fixation was applied to 3 patients with alignment problems in the distal radioulnar joint (DRUE) and a total of 12 patients with 9 patients with multiple fractures. In addition, an external fixator was used to protect the fracture reduction in the operations of 2 patients.

Surgical Technique

The skin was opened with a longitudinal incision made over the flexor carpi radialis (FCR) tendon distally on the anterior surface of the wrist. The pronator quadratus muscle was exposed by excluding the radial artery on the radial side, the FCR tendon, and the distal part of the flexor pollicis longus (FPL) tendon and muscle on the ulnar side. The muscle was cut along the lateral edge of the radius, leaving enough tissue to be sutured close to the attachment site of this muscle to the radius, and the fracture site was reached by scraping the ulnar side subperiosteally. The soft tissues between the fracture ends were cleaned. The fracture was reduced openly, and the compatibility of the articular surface and reduction of the fractured fragments were controlled by fluoroscopy. After proper positioning, the fracture was temporarily fixed with K wires from the radial styloid. The distal part of the T plate, which was produced in accordance with the distal radial inclination, was placed on the anterior surface of the radius by bending in accordance with the anterior inclination of the radius. After controlling the placement of the plaque with fluoroscopy, the plaque was fixed to the radius with a screw from the proximal.

When it was determined that proper reduction was achieved in control, the metaphyseal part was fixed with 3.5 mm screws so that it would not pass the posterior cortex. The fixation was completed by placing the missing screws to hold the object proximally. In anatomical fixed-angle locking plates, the plate was placed in accordance with the distal volar surface of the radius and fixed with temporary K wires through the holes on the plate. Then, a non-locking screw was placed in the oval hole of the anatomical plate, and plate placement was checked with fluoroscopy. Locking screws in the distal row were placed so they did not cross the dorsal cortex. Then, the screws of the plate related to the radius body were placed.

The tourniquet was opened, and bleeding was controlled. The pronator quadratus muscle was sutured to cover the plate. The subcutaneous tissue was sutured with a 4/0 soluble thread. The skin was closed with a 4/0 non-melting thread. An elastic bandage was applied to patients with a locked plate, and a plaster splint was applied first. A short-arm circular cast was applied in the neutral position of the wrist in 3 patients thought not to preserve the stabilization. On the first postoperative day, finger range of motion exercises and forearm pronation-supination exercises were started as tolerated in all patients. At the end of the first week, wrist exercises were started for patients with locked plates.

Postoperative Evaluation

In evaluating the patients, radiological signs of the union on radiographs and the absence of pain on palpation at the fracture site were accepted as a clinical union. Exercises to increase joint range of motion and muscle strength were started after the radiological and clinical union was achieved.

Follow-up of the patients was done at the 2nd and 6th weeks in the early stage and then at the 3rd, 6th, and 12th months. Comparing the radiological controls with the healthy side, AP, lateral and true AP, and true lateral radiographs were taken. Radius tilt angle, radial inclination angle, and ulnar variance were measured and evaluated according to Stewart criteria (11).

While evaluating the functional status of the patients, the joint range of motion was measured with a standard goniometer and compared with the contralateral side. Grip strengths were measured with a dynamometer (Baseline Evaluation Ins, Hydraulic Hand Dynamometer) and compared with the healthy side. It was evaluated with the Quick DASH (Disabilities of the Arm, Shoulder, and Hand Questionnaire) questionnaire and the Gartland-Werley scoring system (12).

Statistical Analysis

SPSS 18.0.0 package program was used for the statistical analysis of the data. Categorical measurements were summarized as numbers and percentages, and continuous measurements as mean ± standard deviation or median. Chi-square test statistics were used to compare categorical measures between groups. The Mann-Whitney U test was used to analyze continuous variables that did not show normal distribution. A p-value of <0.05 was considered significant in all tests.

RESULTS

In this study, 32 (78%) of our patients were male, and 9 (22%) were female, with a mean age of 37 (range 19 – 72). The mean age of men was 36.01 (19 – 52), while the mean age of women was 43.44 (23 – 72), and the mean age was 37.65 (19 – 72). Of the distal radius fractures, 21 (51.2%) were seen in the right wrist and 20 (48.8%) in the left wrist. The fractures of 21 (51.2%) patients were on the dominant side. Among the patients with distal radius fractures, 14 (34.1%)

had fallen from a height, and 8 (19.5%) had in-vehicle traffic accidents. In addition, 8 (19.5%) patients had an open fracture (Gustillo-Anderson classification, type 2) and 1 (2.4%) had an open fracture (Gustillo-Anderson classification, type 3 C).

According to the Frykman classification, the fractures of the patients included in the study were; 12 fracture type 8 (29.3%), 8 fracture type 4 (19.5%), 7 fracture type 2 (17.1%), 5 fracture type 7 (12.2%), 5 fracture type 1 (12.2%), 3 fracture type 3 (7.3%) and 1 fracture was evaluated as type 5 (2.4%). According to AO classification, 13 fractures C3 (31.7%), 7 fractures A3 (17.1%), 7 fractures B3 (17.1%), 5 fractures B1 (12.2%), 3 fractures C1 (7.3%), 3 fractures C2 (7.3%), 2 fractures were evaluated as A2 (4.9%) and 1 fracture as B2 (2.4%).

The mean follow-up period of our patients was 20 months (6 – 50 months). As a result of the clinical examination performed at the last follow-up of the patients, the mean values of wrist and forearm rotation mean range of motion are shown in Table 1. Regarding motion angles, there was statistical significance for flexion and supination ($p<0.001$).

Table 1. Average Values Of Motion Angles According To Patients

Movements	Fractured Wrist (postoperative period)	Healthy Wrist
Flexion	68.29 (5 – 90)	79.22 (60 – 90)
Extension	63.27 (0 – 80)	70.73 (50 – 80)
Supination	79.93 (45 – 90)	85.22 (75 – 90)
Pronation	85.73 (45 – 90)	86.46 (75 – 90)
Radial deviation	24 (10 – 30)	22 (15 – 30)
Ulnar deviation	34 (5 – 45)	37 (30 – 45)

The hand grip strengths of the patients were measured comparatively with a dynamometer (Baseline hydraulic hand dynamometer, Irvington, NY, USA) with the elbow at 90°, forearm, and wrist in the neutral position. The mean grip strength in all patients was 85.3% (54.83 – 105.56) compared to the healthy side ($p<0.001$).

According to the Gartland and Werley clinical evaluation criteria, 25 (61%) of 41 fractures had excellent, 9 (22%) good, 6 (14.6%) moderate, and 1 (2.4%) poor results (Figure 1).

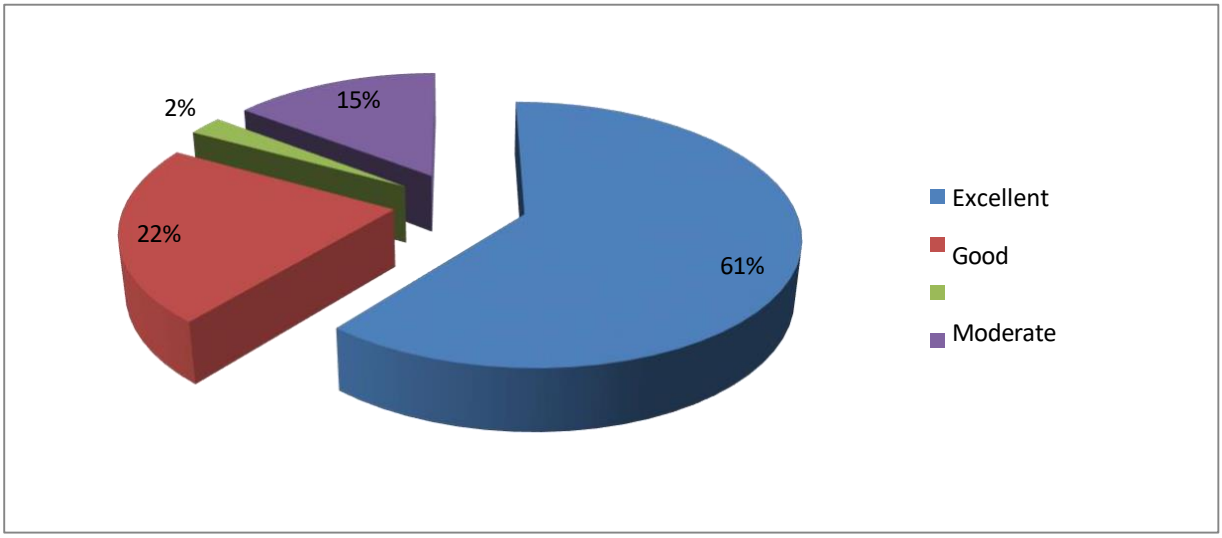

Figure 1. Gartland And Werley Clinical Evaluation Results According To Fracture Types

According to the results of the radiological evaluation, 11 (26.8%) of the patients had excellent, 28 (68.3%) had good, 1 (2.4%) had moderate, and 1 (2.4%) had poor results. When evaluated according to fracture types, excellent results were obtained in 63% of C1 fractures, 44% of C2 fractures, and 40% of C3 fractures.

In our study, patients with a mean follow-up period of 27 (range, 13 to 82) months had an uneventful union of fractures in a mean of 8 (range, 6 – 12) weeks. The mean value of the radiological evaluation was 1.26 (SD±1.37) points according to the Stewart criteria. The mean ulnar variance was 0.43mm (SD±1.48) at follow-up. The ulnar variance was equalized in 33 (80.4%) patients. An average of 2 mm (range, 1 – 5 mm) ulnar variance was detected in 9 (21.9%) patients, and compared with preoperative values, there was a significant difference ($p<0.0001$). No significant difference was found when the ulnar variance was compared with the intact wrist (mean:0.43; SD±0.23) ($p=0.099$).

In terms of radial inclination, the preoperative mean was 15.92˚ (SD ±8.62), and the postoperative mean was 20.53˚ (SD±4.26) ($p=0.809$).

While the mean absolute tilt loss was 19.750 (SD±6.28) before surgical treatment, it was 18.00 (SD±3.27) on average after surgery, and significant improvement was noted ($p=0.0001$). There was a significant improvement in tilt. In the postoperative period, the mean dorsal tilt was 12.31˚ (SD±5.85). In the intact wrist, the mean was 11.60 (SD ±1.44). When the patient's wrist was compared with the healthy wrist, there was a significant difference in dorsal tilt ($p=0.007$).

In our study, in the functional evaluation of the patients, the flexion movement was 68.2˚ (SD±20.54) on average, 89% of the healthy side; there was a statistically significant difference ($p=0.0001$). While the mean of the extension was 63.27˚ (SD±14.56), it was 93% of the intact side; there was a statistically significant difference ($p=0.0001$). The mean radial deviation movement was 24˚ (SD±4.13), 91% of the healthy side; there was a significant difference ($p=0.010$). The mean ulnar deviation was 34˚ (SD±4.54), and it was 88% of the healthy side; there was a significant difference ($p=0.016$). While the mean pronation movement was 83.73˚ (SD±8.11), it was 96% of the healthy side and there was a significant difference ($p=0.016$). While the mean supination movement was 79.93˚(SD±11.88), it was 94% of the healthy side, and there was a significant difference ($p=0.001$).

The grip strength obtained after surgery reached 88% of the healthy side, and there was a statistical difference ($p=0.019$). According to the Gartland and Werley clinical evaluation criteria, 25 (61%) of 41 fractures had excellent, 9 (22%) good, 6 (14.6%) moderate, and 1 (2.4%) poor results. was done. Patients with moderate and poor results were those with high energy, multi-trauma, and complications.

Our patients scored an average of 8.26 (range, 0 – 52) (SD±11.19) in the Quick-DASH patient-based subjective assessment questionnaire. 90% of our patients returned to their jobs in a short time without any problems. Complications were detected in 6 patients (14.6%) after surgery.

DISCUSSION

The incidence of radius distal end fracture is increasing due to the increase in the average age with the increase in social welfare, the increase in the need for human power, the increase in sports activities, the increase in the number of motor vehicles, and the widespread use of firearms. Young and active people are more frequently involved in wrist-related activities, and distal radius fracture is higher (8). Knirk et al. reported that 58% of the cases were the distal end fracture of the radius on the dominant side of the extremity (10). This may be due to the

fact that the patient reflexively uses his dominant extremity to protect himself during trauma. The rate of incidence in the dominant extremity in our study was determined as 52%, similar to the literature.

Although different authors define many classifications of inferior radius fractures, a consensus has been reached, and no classification method has been specified. Frykman and AO Classification systems are frequently used in publications. In our study, Frykman and AO classification was used to evaluate fractures. Mackenney et al. found a high incidence of early instability in minimally displaced fractures, especially in A3.2 and C3.2 fractures with metaphyseal fragmentation (13). There has yet to be a consensus among the authors on the concept of instability. Hove et al. followed 645 conservatively treated patients and found dorsal angulation, radial length loss, and patient age significant in malunion at first admission (14).

Another accepted instability criterion was published by Lafontaine et al. and utilized in our study (15). Thus, early surgery was indicated for unstable fractures, and the mean time before surgery was reduced. In our study, the mean time before surgery was 6 days. This period is unsuitable for the studies of gunshot wounds and falling from a height in the literature because of the expected time for the wound site to become suitable for the operation in patients who develop open fractures for various reasons and were placed with an external fixator before the plate. When the fracture patient is first seen in the emergency outpatient clinic, the reduction should be performed after classification and instability assessment. The criteria for an acceptable reduction in a radius distal end fracture are still unclear.

In clinical and laboratory studies conducted in recent years, researchers have tried to reveal which of these factors is more important in determining long-term results. In these studies, it was observed that radial shortness increased the radiocarpal contact area and pressure, caused adverse changes in the triangular fibrocartilage complex, and was the factor that caused the most deterioration in wrist kinematics (16).

While decreased radial inclination causes moderate changes, increased dorsal tilt led to dorso-ulnar migration of contact pressures, dorsal intercalar segment instability became evident, and wrist movements were restricted. In addition, changes in radial height, inclination, and dorsal angulation cause a shift in the center of rotation during pronation and supination. It has been understood that residual deformity affects the distal radioulnar joint, leading to persistent pain and loss of forearm rotations in some cases (17).

Although the radial heights of the patients in our study were equalized with the intact wrist, the dorsal tilt also came to normal limits. Catalano et al. focused on incompatibility in the joint and anatomical reduction of the joint must be controlled with computerized tomography to avoid arthrosis in the long term (18). In our study, 17 of our patients preoperatively had intra-articular stepping of more than 1 mm, while postoperative stepping was 1 mm in 4 patients and 2 mm in 1 patient. In the selection of treatment methods, as well as the type of fracture, the age of the patient,

Although most distal radius fractures can be treated conservatively, In the conservative treatment of complex, unstable fractures, especially seen in young people and caused by high-energy trauma, it is generally not possible to maintain this alignment until the fracture heals, even if the fracture is aligned with conservative methods (19). In the early studies of the Gartland and Werley series of 60 cases, 31% had inadequate functional and 60% inadequate anatomical results (20). They reported complications of posttraumatic arthritis and stiffness in the fingers at a rate of 30%. Previous studies showed a loss of motion with moderate and poor results in 21%, moderate or severe anatomical deformity in 37%, and inadequate cosmetic

appearance in 40%. The proportion of cases with poor outcomes with conservative treatment in unstable fractures (21). Various surgical intervention methods and fixation materials have been described in the literature, which vary periodically in the treatment of unstable fractures. While the studies on internal fixation continue, the issue of external fixation has come to the fore. In these periods, external fixation, beyond the use of pins alone or in combination with a cast, was recorded as a great improvement in the treatment of unstable lower end of the radius fractures. Common complications in external fixation include tightness of digital extensors, stiffness in the wrist joint capsule, osteopenia, sensory radial nerve problems, malunion, nonunion, pin infection, and regional pain syndrome. Despite these disadvantages, many studies have shown that external fixation is superior to closed reduction and casting (22).

In evaluating the cases with at least one-year follow-up, good and excellent results were obtained in 95% of the cases. On the other hand, the plates and screws had to be removed in 5 cases for technical reasons and in 8 cases due to extensor tendon problems. Finsen et al. reported that volar angulation developed afterward in 80% of the patients (23).

Special dorsal plating systems with low surface profiles have frequently resulted in extensor tendon irritation and rupture, despite changes in plate design and material properties. Stable internal fixation has traditionally been used for volar displaced fractures. Most surgeons have cautiously approached dorsal plates because of the frequent extensor complications. Despite the different designs of dorsal implants, they often require an extraction (24).

In our study, Henry's incision was performed to all of our patients. There was no complication in the median nerve or palmar cutaneous branch in any of the cases that did not have any preoperative median nerve complication and did not have median nerve neuropraxia. Therefore, carpal tunnel release was not performed in any case. Finger movements were started on the first day after surgery. Routine wrist passive movements were started in the third week. After the radiological and clinical union of the fracture was completed, exercises to increase the range of motion and muscle strength

Complications were generally the cases of volar plaque patients with simultaneous multi-trauma and rushed due to the patient's vital functions. We think these cases can be overcome by trying to act calmly and learning curve. Our complication rate of 14.6% was compatible with the literature. Our study did not find flexor pollicis longus tendinitis, although the plates we used in our cases were of the distal type. This may be due to the effective coverage of the pronator quadratus. We did not encounter the lunate facet collapse. We attribute this to the adequate reduction and bone stock supporting the facet and the proper delivery of our screws and stabilization.

As a result, we successfully operated on 41 patients with distal radius fractures using the volar plate and screw with the radius volar locking plates, which we have used extensively. Volar anatomical plates provided internal fixation, following the principles of AO, which is a very effective and safe method in the treatment of active adults with intra-articular distal radius fractures.

CONCLUSION

We concluded that it is an effective method in providing complete anatomical reduction and alignment and allows joint movements in the early period thanks to its high fixation strength. The complication rates experienced are low and are related to attention and learning curves. We believe that informing the patient in detail after the surgery as well as preoperatively and

explaining the physical therapy and sterilization in detail, will reduce the complications to be experienced.

Funding: There is no specific funding related to this research.

Competing Interests: The authors declare that they have no competing interests.

Ethical Declaration: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Ethics committee approval has been granted from our institution. As this was a retrospective research, no informed consent has been obtained from participants.

Author Contributions

Working Concept / Design	**:** YM, BYU
Data collecting	**:** YM, BYU
Data Analysis / Interpretation	**:** YM, BYU
Writing Draft	**:** YM, BYU
Technical Support / Material Support	**:** YM, BYU
Critical review of content	**:** YM, BYU
Literature Review	**:** YM, BYU

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